Modelling and Simulation of Ethiopian Leather Industry Supply Chain: A Discrete-Event Simulation Approach

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(INDUSTRIAL ENGINEERING STREAM)

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DEDICATION

This thesis is dedicated to my mother, **Zenebech Kebede**, who taught me with love and affection. I am really passionate of her, so that I go to success by recalling her effort and inspiration to educate me.

DECLARATION

I, the undersigned, hereby declare that the work which is being presented in this thesis entitled Modelling and Simulation of Ethiopian Leather Industry Supply Chain: A Discrete-Event Simulation Approach is original work of my own, has not been presented in any of other university and that all sources of material used for the thesis have been duly acknowledged.

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

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Place and Date of Submission**:** ***Addis Ababa University Institute of Technology (AAiT), September 2014***

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ABSTRACT

Supply chain system is a non-deterministic in nature so that it behaves in an uncertain manner which forms a complex net of physical and information flow at which decision made in one stage of the supply chain will usually have unpredictable impact on other stage of the chain. Having in mind all these and other behaviours of a supply chain that makes it challenging to manage, manufacturing industries are striving for the flow of their raw materials and goods to the right place, at the right time, with the right quantity with a reasonable price.

Due to the by-product nature of the raw material and lack of integrated supply chain, the Ethiopian leather industry particularly the tanning industries are suffering from the shortage of raw hide and skin, poor quality of supply and price hikes of the raw material which create a big challenge for the survival of some of the tanneries. Currently the tanneries are faced with two conflicting objectives, the need for collecting large amount of skin when available in the market to use it during scarce times and quality deterioration of the raw material if stored for more than fifteen days on average.

Different methodologies that are appropriate for supply chain modelling so as to improve its performance are reviewed. Modelling and simulation is found suitable and ARENA® simulation software is prioritized among the number of available commercial simulation software to analyze and propose solution for Ethiopian Leather Industry supply chain problems.

Thirty journal articles are reviewed based on content which use simulation and modelling methodology to overcome different supply chain management challenges. Gaps are identified regarding the performance measurement and other parameters that should be considered while modelling and simulation of a supply chain.

This study focuses on filling the gaps and develops a four echelon supply chain model with the help of Arena simulation software to investigate and improve the Ethiopian leather industry supply chain performance with a special focus on the upstream suppliers of hide and skin till it reaches to the tanneries. It concentrates on the way how to create balance between the conflicting objectives while keeping the operating performance of the tannery optimum and the inventory stored within a reasonable level.

Four scenarios on the inventory replenishment strategy for the tanning industries through varying the time between consecutive orders and the quantity of skin per unit order are developed. After running the trials a significant method to control the inventory level of the tanneries while keeping the operating performance in a reasonable level is achieved. The outputs are also analyzed to share inventory stock information in every

tier of the supply chain and help assigned personnel to make decisions based on facts rather than assumptions in such uncertain environment.

Due to the similarity of the Ethiopia leather industry supply chain, hence it is legally tied and proclamation supported, the research recommends the application of the developed model for all tanning industries with slight modification of the model and the input data provided. Finally three basic points for future research are identified and recommended.

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ACRONYMS

AA	–	Addis Ababa
COMESA	–	Common Market for Eastern and Southern Africa
DEDS	–	Discrete Event Dynamic Simulation
DHSPCC	–	Dire Hide and Skin Procurement and Collection Centre
DSS	–	Decision Support System
ELI	–	Ethiopian Leather Industry
ELIA	–	Ethiopian Leather Industry association
GQL	–	Good Quality Leather
GSCF	–	Global Supply Chain Forum
GTP	–	Growth and Transformation Plan
HS	–	Hide and Skin
ITC	–	International Trade Center
KPI	–	Key performance Indicators
LIDI	–	Leather Industry Development Institute
LLPI	–	Leather and Leather Products Industry
LMB	–	Livestock and Meat Board
LSCM	–	Logistics and Supply Chain Management
MoI	–	Ministry of Industry
MoT	–	Ministry of Trade
MRP	–	Material Requirement Planning
PASDEP	–	Plan for Accelerated and Sustained Development to End Poverty
PQL	–	Poor Quality Leather
RBS	–	Regional Big suppliers
RSS	–	Regional Small Suppliers
RSS	–	Regional Small Suppliers
SC	–	Supply Chain
SCM	–	Supply Chain Management
SCN	–	Supply Chain Network
SD	–	System Dynamics
SWOT	–	Strength-Weakness-Opportunity-Treat
UNISA	–	University of South Africa
USD	–	United States Dollar

CHAPTER ONE

PROBLEM AND ITS APPROACH

1.1. INTRODUCTION

No single organizational unit now is solely responsible for the competitiveness of its products and services in the eyes of the ultimate customer, but the supply chain as a whole. Supply chain networks of independent firms collaborating to serve a final market are becoming a normal business phenomenon. Yet at present it is not clear how such networks can achieve stability. There is no successful managerial guideline for individual companies operating in such networks regarding collaboration with the other firms involved [Henk Akkermans (2001)].

The term "supply chain" generally encompasses the web of interconnected relationships between the sales channel, distribution, warehousing, manufacturing, transportation, and suppliers. Each component of the supply chain is connected to other parts of the supply chain by the flow of materials in one direction, the flow of orders and money in the other direction, and the flow of information in both directions. Changes in any one of these components usually creates waves of influence that propagate throughout the supply chain. These waves of influence are reflected in prices (both for raw materials, labour, parts, and finished product), flow of materials and product (within a single facility or between facilities within the supply chain), and inventories (of parts, labour capacity, and finished product). How these influences propagate through the system determines the dynamic and the complex behaviour of the supply chain [GoldSim (2007)]. According to Viswanadham and Raghavan (2000) modelling and simulation analysis of such a complex system is crucial for performance evaluation and for comparing competing supply chains.

The use of analytical methods to model SCN is generally impractical because mathematical models for realistic cases are usually too complex to be solved. Obviously physical experimentation suffers from technical- and cost-related limitations. To study and investigate the structure of such complex systems like supply chain there is a strong demand for new decision support tools on strategic, tactical and operational levels of a manufacturing firm. In fact, a modelling and simulation approach is the only practical recourse for exploring performance of the large-scale situations that exist in reality. Furthermore, the modelling and simulation approach facilitates the design of the supply chain and, as well, the evaluation of its management prior to implementation [Thierry, Bel and Thomas (2010)].

According to Chang and Makatsoris (2003) discrete event simulation permits the evaluation of operating performance prior to the implementation of a supply chain system. 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. It models the relationships between elements in a system and help to understand how these relationships influence the behaviour of the system over time.

The simulation modelling methodology should accommodate the characteristics present in supply chain environments; namely stochastic, dynamic, and distributed environments, to allow supply chain decision makers to make informed decisions in a fast, sharable and easy to use format.

In this thesis a computer assisted discrete event simulation will be used to better understand supply chain dynamics, diagnose problems and evaluate possible solutions, optimize operations and make reliable and flexible supply chain decisions which can cope up with uncertain environment for Ethiopian leather industry.

1.2. THE LEATHER INDUSTRY

Leather and leather products are among the most widely traded and universally used commodities in the world. Already, the total value of annual trade is estimated at:

- 1.5 times the value of the meat trade;
- More than five times that of coffee; and
- More than eight times that of rice.

Global formal trade is calculated at over US$ 50 billion a year and the market is far from saturated. In the next decade, the demand for raw materials and finished products may exceed supply. The dynamism of the leather sector in some developing countries has resulted in a move up the value-added chain and stronger market positions. As a result, developing countries already hold a 45% share of world trade in leather manufactures [International Trade Centre (2004)].

Ethiopia possesses one of the largest populations of livestock in Africa and even 7th-9th in the world with 41million cattle, 25million sheep and 23million goats which is considered as a raw material base for leather industry. However, the resource is not fully utilized. Therefore, the leather industry has room to be developed further, optimizing the abundance of the resource. The Ethiopian government has also given due attention for the growth of the tanning industry in view of higher value addition in the Growth and Transformation Plan (GTP). From the leather industry in total the GTP has placed a target to earn 500 million dollars from export market per year which was close to 57 million USD worth of leather products at the beginning of the Growth and Transformation Plan (2009/10) [Umer (2012), Capital Magazine Thursday, 14 June 2012].

Like other industries the Ethiopian leather industries are operating today in a business environment characterized by unprecedented global competition and technological change. Although the government expected significant growth from the sector in the past decade, the sector has been adversely affected due to lack of a modern raw hide and skin marketing system. The demand and supply gap has also created unhealthy market competition between tanneries [Capital Magazine Thursday, 14 June 2012]. The leather industry is currently faced with problems like shortage of raw hide and skin, poor quality of the raw material arising from animal husbandry up to the recovery and transportation, as well as the uncontrollable price hikes of raw hide and skin. To avoid such problems the Ethiopian government has practiced various rules and regulations which are unsuccessful due to uncertainties those are available in the leather industry. According to International Trade Centre (ITC) African platform report (SWOT analysis of Ethiopian Leather) among the listed ten treats of the sector seven (70%) of it is directly related with lack of integrated and well managed supply chain of the sector. In order to alleviate such problem of being unable to be competent in market, the concept of supply chain management is important for the firms.

To study the structures of complex systems like such supply chain networks, the modelling and simulation approach has become a popular choice. Discrete event simulation is generally recognized as a valuable aid to the strategic and tactical decision making that is required in the evaluation stage of complex system of supply chain design and redesign processes. This research will use this approach to model and measure the performance of the Ethiopian leather industry supply chain network.

1.3. PROBLEM STATEMENT

Manufacturing supply chain networks (SCNs) are formed out of complex interconnections amongst various manufacturing companies and service providers such as raw material vendors, original equipment manufacturers, logistics operators, warehouses, distributors, retailers and customers. In this highly dynamic and competitive environment, customers demand short lead time, low-cost, high-quality, and diversified products. However, firms tend to have difficulties in managing the geographically dispersed supply chain network and in establishing the communication channels and service links between entities throughout the supply chain network in a seamless, timely, and cost-efficient manner. Also, firms are facing challenges in measuring the full performance of the whole supply chain network's attributes of collaboration, integration, cohesion, and ability to achieve unified business objectives, leading to continuous improvement [Viswanadham and Raghavan (2000)].

Currently the Ethiopian tanning industries are suffering from shortage of raw hide and skin, poor quality of the raw material arising from animal husbandry up to the recovery and transportation, as well as the uncontrollable price hikes of raw hide and skin.

To control the supply shortage and price hike, the government has taken three measures. The first one is banning new investors from entering in to the tanning industry, attempting to control price hikes and the chaos they can bring to the market by imposing a maximum price upon the raw materials which was not effective and recently the government has issued a duty free scheme to import raw hide and skins or semi processed leather products due to the supply shortage occurring in the country. All the three government measures have a negative effect on the country transformation plan, the country's liberalism policy (an economic theory advocating free competition and a self-regulating market) and the country's foreign currency deposit respectively. The reason for this shortage of the raw material is not only the scarcity of the resource but also the unpredictable, complex and dynamic system of the supply chain network so as the difficulty to manage it effectively.

The tanning industries have faced with two conflicting objectives while they are striving to overcome those problems in their own capacity. These are

- ✓ Due to the by-product nature of the raw material and the limited supply in the country (Hides and skins are available only when there is the need for meat) tanneries need to collect abundant amount of the hides and skins when it is available in the market to use it when there is scarcity.
- ✓ On the contrary tanneries are striving to avoid quality problems arising from transportation and storage problem. But the quality of wet salted hide and skin will deteriorate if it is stored for more than fifteen days on average.

It is virtually impossible for the human mind to fully comprehend and predict the dynamics of a complex nature supply chain system. Therefore to alleviate these problems and address all the above issues and design the dynamic nature of Ethiopian Leather Industry supply chain endeavour this research answered the following basic research questions.

a) What are the gaps in various researches published in any of international journals while modelling of supply chain network to overcome those SC management challenges with respect to the Ethiopian leather industry?

b) What is the performance of the overall leather industry supply chain network in terms of the sector key performance indicators?
c) What is the interaction of various components/variables of the supply chain system with one another?
d) What impact a change on the supply chain now will have in the future on the supply chain?

1.4. OBJECTIVES OF THE RESEARCH

1.4.1. GENERAL OBJECTIVE

The general objective of this study is to develop a computer assisted discrete event simulation model by filling literature gaps for Ethiopian Leather Industry to measure and improve the performance of the supply chain without disrupting the current process or spending lots of money and time on a trial system.

1.4.2. SPECIFIC OBJECTIVES

The specific research objectives that are going to be addressed in this study are:

a) Systematically identify the core problems of raw hide and skin supply for tanneries in Ethiopia with tangible justification. Bottle necks and uncertainties that brought shortage/poor quality of hide and skin on the local market are identified and analysed for better performance of the sector.
b) Extensively review journal articles which use different methodologies and approaches and then evaluate those articles which report the use of simulation modelling for supply chain analysis and performance measurement to identify gaps.
c) Develop a verified and valid simulation model of the raw hide and skin supply/trade with the help of simulation software so as to design an experiment and measure the performance of the supply chain.
d) Demonstrate and identify inputs (or factors) in the supply chain significantly affect outputs and the overall performance of the supply chain. Use simulation for causes and effects analysis of the supply chain performance.
e) With the help of discrete event simulation modelling sensitivity or a "what-if" analysis will be performed by designing scenarios with varying the inventory replenishment strategies and measure the supply chain performance in terms of capacity utilization and raw material inventory level of the tannery.

1.5. SIGNIFICANCE OF THE RESEARCH

If we are able to effectively manage the complex nature of this supply chain network, it will have a great benefit starting from an individual who is engaged in raw hide and skin trade up to the national economy. The leather industry is labour intensive and hence it is properly managed it will create more jobs for the citizens. Government bodies such as, Ministry of Trade (MOT), Ministry of Industry (MoI), Leather

Industry Development Institute (LIDI), and other interested organizations participating in the sector will get important concepts with justification on the overall supply chain behaviour of the leather industries for taking further action and decision on the policy of raw hide and skin trade. By taking advantage of this approach, firms can simply and effectively evaluate the performance of their supply chains, and thus take actions based on facts rather than assumptions to improve supply chain performance and derive better supply chain management solutions.

Ended these entire efforts combine together to make the local leather and leather product industries like tanneries, shoe factories and leather garment industries more profitable by creating a better competitive capacity in the international market by supplying a better amount of good quality products with competitive price which makes the country economy to grow significantly.

1.6. SCOPE OF THE RESEARCH

It is obvious that the supply chain of any leather industry starts from animal husbandry which includes the type of breed selection and the feeding style of the livestock for better achievement of the industry in terms of quality and price. Passing through a number of activities (livestock trade, slaughtering, flying, raw hide and skin trade, processing in modern tanneries, and converted in to end items in leather shoe and garment industries) various leather goods will be supplied for national and globally distributed ultimate customers. In many cases, the performance of a company will be highly dependent upon its upstream suppliers [Kim et al, (2004)]. Due to its large inherent nature of the supply chain network, this study considers only the following four reduced behaviours of the Ethiopian Leather Industry supply chain.

- The study focuses on upstream suppliers of the leather sector, which means it includes the tannery input and output buffer, regional and Addis Ababa big suppliers and their suppliers. The supply chain will have four echelons and two nodes in two of its echelons.
- The supply chain under study is a network of enterprises (without a focus on any particular enterprise within the supply chain). That means the external supply chain of the enterprise which includes the enterprise, the suppliers of the company and the suppliers' suppliers. In this case, supply chain management mainly focuses on integration of operation and cooperation between the enterprise and the other actors of the supply chain.
- Since the marketing structure of raw hides and skins is legally tied or proclamation supported, the supply chain network of all the tanneries is more or less similar. Therefore modelling and simulation of one of the tanneries supply chain will represent all. Due to this characteristic and to access relevant data of the sector one tannery (Dire Tannery) is selected for the case study.

- The case company is engaged in producing finished leather from sheep skin and hide with a ratio of 10:1. Based on Pareto principle the study focuses on the supply chain of only sheep skins.

1.7. RESEARCH METHODOLOGY

Literature Survey; A broad review of different literatures from different sources on the subject matter is used to do the research. Thirty articles published in internationally known journals on the subject matter will be intensively reviewed and available gaps are identified and analyzed based on the Ethiopian Leather Industry. Different books, journals and websites are used as a source of literature regarding Ethiopian leather industries and the dynamics of the supply chain in general.

Discussion and Interview; organized interview and a broad discussion is conducted to collect information about the raw material, the marketing system and the supply chain as a whole. It is held with tannery delegated personnel and Addis Ababa and regional suppliers for selected few tanneries, big collectors, medium traders and small collectors of raw hide and skin.

Gathering actual data and information from the stakeholders, different files, and recordings made on the subject. Peer discussion and personal observation are also used as a way of collecting data about the leather industry.

Model development: derived from the collected factual data a computer assisted simulation model is developed which is further executed and analysed with the help of simulation software. In this research a discrete-event simulation approach with the help of ARENA® (Rockwell software) is used to develop the simulation model, to measure SC performance and perform sensitivity and what if analysis.

Data Analysis and Synthesis; After the collection of the raw data (primary and secondary) on the existing conditions, it is analyzed and evaluated qualitatively and quantitatively with the help of discrete-event simulation software (Arena). The collected data is properly investigated and analyzed before interpretation to make it ready for management factual decision making process. The analyzed result has further been described and interpreted well in order to make it readily available for decision-making based on facts.

Diagrammatically the general methodology employed for the study of this thesis can be depicted as follows.

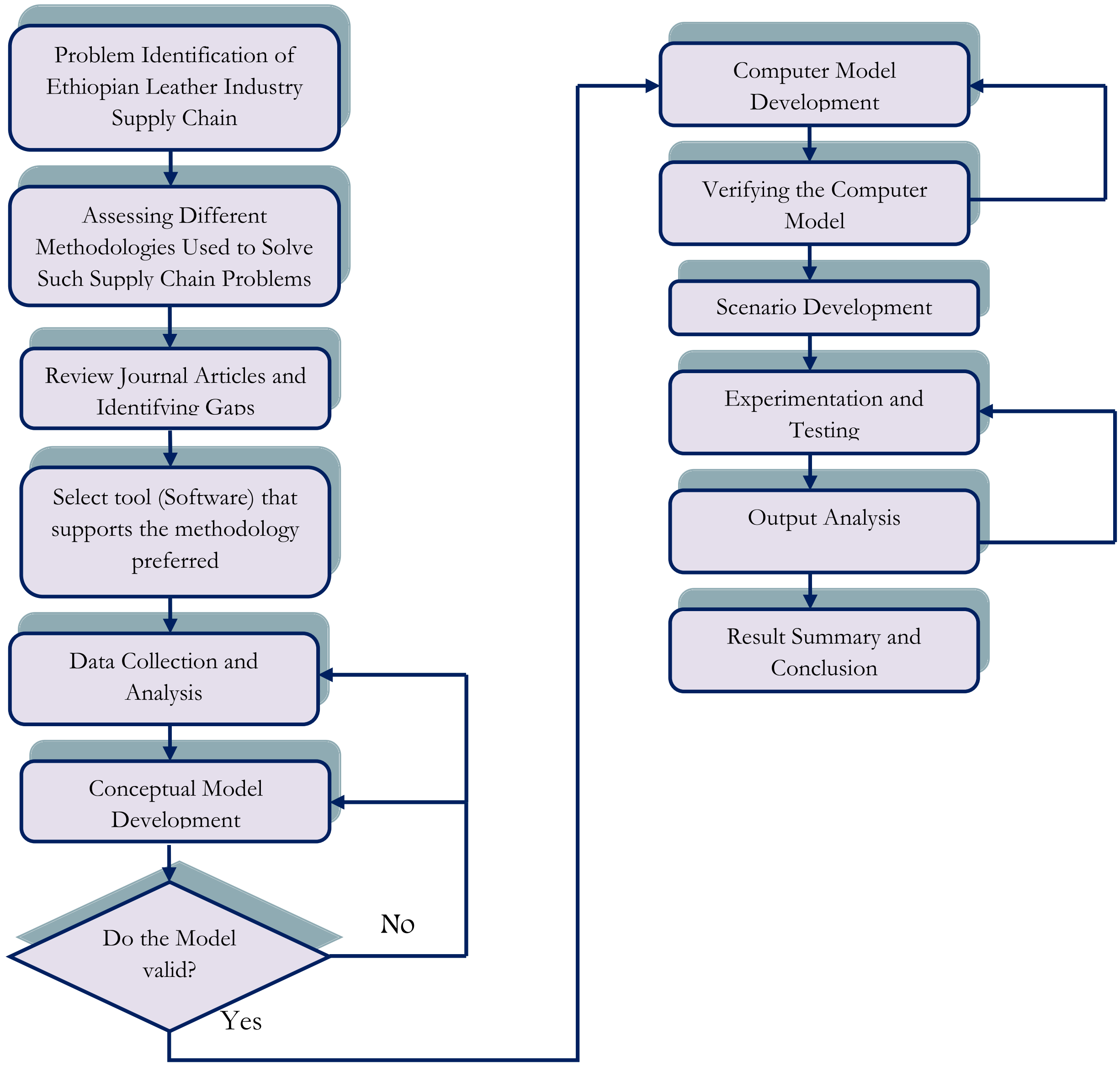


Figure 1.1 Methodology employed for the study

1.8. ORGANIZATION OF THE THESIS

The thesis is organized in seven chapters. The first chapter begins with an introduction and background of the study including problem statement and research objectives. Chapter two discusses the fundamental concepts of supply chain management. This chapter gives theoretical overview about supply chain management starting from its definition trough its components and behaviours up to its inherent management challenge.

Chapter three gives basic concepts regarding the Ethiopian Leather Industry and the major problems in the supply chain. It also includes the background of the case company.

Chapter four provides sufficient information regarding the different methodologies employed to solve various supply chain management challenges. In this chapter the appropriate methodology and tool (software) selected is presented with justification. At the same time the chapter contains 30 journal articles which are evaluated based on content and the research gaps identified.

The content of chapter five is mainly the Arena model developed for the Ethiopian Leather Industry supply chain with clear and step by step description. This chapter includes the data collected and the conceptual model developed latter which is converted in to computer model.

Chapter six mainly focuses on the design of simulation experiments and analysis of the simulation output with the execution of different scenarios developed. Chapter seven concludes the research result and provide genuine recommendations. Finally the thesis is winded with the provision of thee basic future research directions which can be used as an extension of this research.

CHAPTER TWO

SUPPLY CHAIN MANAGEMENT OVERVIEW

2.1. INTRODUCTION

Companies face an increasingly challenging marketplace with a growing field of competitors, higher customer expectations, and complex supplier relationships. Increased competition means that companies face the dual challenge of cutting costs while being more responsive to the market. The need to cut costs is driving companies to outsource business operations, minimize inventories, divest underutilized capital equipment and facilities, and in general run as close to the edge as possible. The need to be more responsive to the market drives companies to expand their product lines and increase options, minimize the time to bring new products to market, and quickly modify product delivery rates to match changes in demand [GoldSim, (2007)].

As competition and complexity has increased, supply chain management has emerged as an increasingly important issue for companies. The challenge of supply chain management is to identify and implement strategies that minimize costs while maximizing flexibility in an increasingly competitive and complex market. This paper briefly discuss and use dynamic simulation tool (Discrete Event Simulation) to understand supply chain dynamics, measure supply chain performance, perform what if analysis and test different scenarios, diagnose problems and evaluate possible solutions by considering Ethiopian leather industry as a case.

2.2. DEFINITION OF SUPPLY CHAIN & ITS MANAGEMENT

Many researchers and scholars define supply chain (SC) and supply chain management (SCM) in different ways. However, a broad conceptual consensus on the notion of supply chain and supply chain management is beyond anybody's reasonable doubt [Lu, (2011)]. To have a better understanding about the subject let us take a thorough investigation of supply chain and supply chain management separately by considering definitions of the terms by different authors who published their works in various international journals.

2.2.1. DEFINITION OF SUPPLY CHAIN

Turban, Rainer & Potter (2003) defined Supply chain as the flow of materials, information, payments, and services, from raw material suppliers, through factories and warehouses, to end customers. A supply chain also includes the organizations and processes that create and deliver products, information, and services to the end customers.

Dawei Lu (2011) define supply chain as a group of inter-connected participating companies that add value to a stream of transformed inputs from their source of origin to end products or services that are demanded by designated end customers. In this definition there are a number of key characteristics that have been used to portrait a supply chain. First, a supply chain is formed and can only be formed if there are more than one participating companies. Second, the participating companies within the supply chain normally don't belong to the same business ownership, and hence there is a legal independence in between. Third, those companies are interconnected on the comment commitment to add value to the steam of material flow that run through the supply chain.

According to Beamon (1998) a supply chain may also be defined as an integrated process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers.

For this research the definition of supply chain may not be diverted beyond those scholar definitions except the scope of the chain that might be narrower than the general definition provided. In this research when we say supply chain we mean the supply of raw/fresh hide and skin from the producers (small or big abattoir, export abattoir or person slaughtering animals for household consumption or engaged in providing slaughtering service and supplies raw hides and skins to the market) to the local tanneries (Ethiopian factories curing and tanning raw hides and skins to finished leather). It is recommended to see chapter four of this research for detail about supply chain of raw hide and skin in Ethiopian context.

2.2.2. DEFINITION OF SUPPLY CHAIN MANAGEMENT

Supply Chain management is aimed at examining and managing Supply Chain networks and it is the act of optimizing activities across the Supply Chain. Below are some of the definitions of supply chain management taken from different articles for better understanding of the subject.

Zhangs (2006) and Chang and Makatsoris (2003) defined Supply chain management (SCM) as a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements.

According to the Supply Chain Management Professionals' Council (2009) Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.

Global Supply Chain Forum (GSCF) defines SCM as: "Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders."

Even though the above definitions of supply chain management are satisfactory, for the purpose of this paper it is quite clear and preferable to use the definition by Cheng Zhang and Chenghong Zhang (2006) Effectively managing this process involves supervising connections with customers, suppliers and controlling inventory, forecasting demand and getting regular feedback on what is occurring at every connection in the chain. This definition is preferred because it clearly includes the objective in this research which focuses on those key performance indicators (KPI) stated in the definition (quality, quantity, time and cost) and evaluate different alternatives for optimal use of the resource available in the country.

2.3. HISTORY OF SUPPLY CHAIN MANAGEMENT

The term supply chain management was introduced in the early 1980s by Oliver and Webber [1982] where they discuss the potential benefits of integrating purchasing, manufacturing, sales and distribution [Kim, et al (2004)]. In the 1980s, companies discovered new manufacturing technologies and strategies that allowed them to reduce costs and better compete in different markets. Strategies such as just-in-time manufacturing, kanban, lean manufacturing, total quality management, and others became very popular, and vast amounts of resources were invested in implementing these strategies. In the last few years, however, it has become clear that many companies have reduced manufacturing costs as much as is practically possible. Many of these companies are discovering that effective supply chain management is the next step they need to take in order to increase profit and market share.

Pre-1990s (Paradigm shift) - Most firms were vertically oriented. The firm's employees performed all functions from product conceptualization thorough final sale and delivery. All manufacturing was done within the firm. The three traditional stages in the supply chain, which consist of procurement, production and distribution, have historically been managed independently [Rota, Thierry & Bel (2010)]. There was Central Control of all operations. In 1990s transportation costs dropped so that manufacturing could be performed anywhere in the world where the costs were appropriate. Outsourcing became a popular choice for manufacturing and assembly.

In Today's Paradigm firms outsource design/manufacturing wherever and whenever appropriate. The firms are concerned about the environmental and societal effects of the product manufacturing and the effect of outdated products.

According to supply chain brain online published in 2014, "major trends impacting supply chains for the next 3-5 years" indicates that supply chain management is becoming a higher priority and the job is becoming more challenging and complex. Until some time ago, the marketplace forced companies to compete against each other, individually. Nowadays, this is changing; companies still compete with each other, but more in terms of supply chain against supply chain [Vieira, (2004)].

2.4. COMPONENTS OF SUPPLY CHAINS

According to Min and Zhou (2002) supply chain synchronizes a series of inter-related business processes in order to: 1) acquire raw materials and parts, 2) transform these raw materials and parts in to finished products, 3) add value to these products, 4) distribute and promote these products to either retailers or customers, 5) facilitate information exchange among various business entities (e.g. suppliers, manufacturers, distributers, third party logistics providers and retailers). Its main objective is to enhance the operational efficiency, profitability and competitive position of a firm and its supply chain partners. It is commonly accepted that there are three main flows in the supply chain: material flow, information flow, and cash flow. The activities involved in the material flow are to deliver to the end-user via procurement of raw materials, manufacturing, distribution and customer service. All these activities must be managed using suitable information flows. It is characterized by a forward flow of goods, backward flow of finance and a flow of information in both directions as shown in figure 2.1 below.

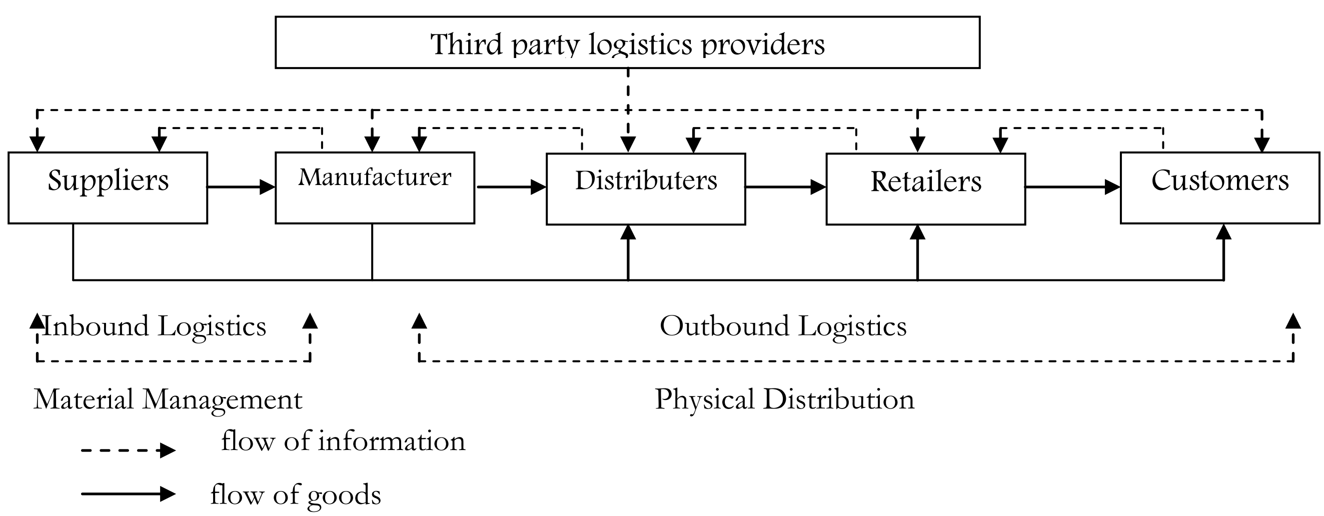


Figure 2.1: The supply chain process

The term supply chain comes from a picture of how partnering organizations in a specific supply chain are linked together. Generally a typical supply chain component can be classified in to three as the following.

1. Upstream supply chain-This part includes the organization's first-tier suppliers (which themselves can be manufacturers and/or assemblers) and their suppliers. Such a relationship can be extended, to the left, in several tiers, all the way to the origin of the material (e.g., mining ores, growing crops). Here the major activities are purchasing and shipping.

2. Internal supply chain-This part includes all the processes used by an organization in transforming the inputs shipped by the suppliers into outputs, from the time materials enter the organization to the time that the finished product goes to distribution, outside the organization. Activities here include materials handling, inventory management, manufacturing, and quality control.

3. Downstream supply chain-This part includes all the processes involved in distributing and delivering the products to final customers. Activities here include packaging, warehousing, and shipping. These activities may be done by using several tiers of distributors (e.g., wholesalers and retailers).

2.5. BEHAVIOURS OF A SUPPLY CHAIN

Supply chains do not always behave as expected or desired. Demand variability can be amplified as one move up the supply chain, and small changes downstream can result in large variations upstream. As a result, the whole supply chain can be distorted by very large demand swings; as each company within the supply chain tries to solve the problem within their own perspective. The consequences are significant; piles of stock, frequent stock-outs and unpredictable demands, and therefore bottlenecks in delivery. In addition to demand variability and information distortion, other main issues in supply chain management relate to the uncertainties within the supply chain system. Here below are some of the behaviours of a supply chain that creates the challenge for managing it effectively.

2.5.1. COMPLEXITY OF THE SUPPLY NETWORK

Systems such as a supply chain form a complex net of physical (material/products and capital) flows and non-physical flows (information). Decision made in one stage of the chain will usually have an unpredictable impact on other stages of the chain. The relationships among the stages (and their functions) are non-linear and the results of an action may not be estimated precisely beforehand. [Guilherme Ernani Vieira (2004)]. Complexity thus implies the capacity of a system to deliver surprises. A dictionary definition of the word "complex" is: "consisting of interconnected or interwoven parts."

This is something unavoidable, and that is the reason why companies have to learn how to manage it, how to live with it. The most important difficulty met because of complexity is prediction. In effect, today's systems are so complex that it becomes very difficult to make predictions about what will happen in the future, even though in a close future. Interactions between the parts that constitute the systems are innumerable and this is what makes them complex.

There is overwhelming agreement among academics and managers about the complexity of supply chains and its tremendous increase over the last few years. Most practitioners understand complexity at an intuitive level, but there has been a shortage of efforts towards developing a formal understanding of causes for this complexity [SimaFore, (2011)].

2.5.2. UNCERTAINTY AND RISK

Like any real world environment, supply chain environments are governed by uncertainty. However, uncertainty is extremely critical in a supply chain environment due to the integrated nature of supply chains. Since supply chains are composed of different elements (i.e. suppliers, supplier's supplier, customer, etc) integrated and interrelated, each element's uncertainty interacts with one another greatly affecting supply chain activities.

Global optimization is made even more difficult because supply chains need to be designed for, and operated in, uncertain environments, thus creating sometimes enormous risks to the organization. In addition to demand variability and information distortion, other main issues in supply chain management relate to the uncertainties within the supply chain system. There are many sources of uncertainties in a supply chain. Kim, et al (2004) identifies three sources of uncertainties:

a) Supplier uncertainty measured in terms of suppliers' on-time performance, average lateness and degree of inconsistency;
b) Manufacturing uncertainty that arises due to process performance, machine breakdown etc;
c) Demand or customer uncertainty arising from forecasting errors, irregular orders etc

They claim that one of the potential pitfalls in managing supply chains is failing to understand the likelihood and the magnitude of impact of these uncertainties. And they argue that the main objective of problem-solving methods in SCM is to reduce uncertainties.

Risk is an inherent feature of all operations. Supply chains are subject to disruption type of risks caused by natural or environmental disasters. Supply chain risk management has recently gained much greater attention as a result of natural disasters and terrorist attacks, as well as the greater complexity and globalization of supply chains.

2.5.3. DYNAMISM OF SUPPLY CHAIN

The dynamism in supply chains is encountered at different levels, which are the supply chain level, the enterprise level, or enterprises' elements level. The dynamic behaviour at the supply chain level is encountered when enterprises that constitute the supply chain change over time, e.g. enterprises leave the chain or new enterprises join the chain. Dynamism is encountered at the enterprise level when the elements in the enterprise are changing over time, e.g. new functional units such as a factory or a new information resource or enterprise application system may be added. The dynamism at the enterprise element level is encountered when the specification or the definition of the element changes over time, e.g. a change in the workflow, a change in the schema of an information resource, or a change in the semantics". Therefore, decision makers must count on a methodology that would allow for timely and efficient updating to reflect changes in the environment.

2.5.4. DISTRIBUTED ENVIRONMENT

Since supply chains are physically distributed, the information that makes up the supply chains is also distributed. The information in any supply chain is originated and owned by different entities, i.e. supply chain partners. Consequently, pieces of information are distributed along the Supply Chain in different systems and, therefore, in different formats. This has a great implication when decision makers attempt to make decisions regarding the supply chain as a unit. Often data is available but the knowledge required for decision-making is hard to come by since a great effort has to precede any analysis in order to obtain the data and format the available data into a common body of knowledge that is universal to all elements of the supply chain. This issue is further complicated when supply chain partners are hesitant to provide this data. According to Cope, et al (2007), Supply chain decisions are improved with access to global information. However, supply chain partners are frequently hesitant to provide full access to all the information within an enterprise. A mechanism to make decisions based on global information without complete access to that information is required for improved supply chain decision making.

2.5.5. BULLWHIP EFFECT

Demand variability can be amplified as one move up the supply chain, and small changes downstream can result in large variations upstream. As a result, the whole supply chain can be distorted by very large demand swings; as each company within the supply chain tries to solve the problem within their own perspective. This distortion is known as the Bullwhip and has been observed across most industries [Kim, et al (2004)]. The bullwhip effect will propagate to the entire supply chain areas producing backlogs, poor forecasts, unbalanced capacities, poor customer service, uncertain production plans, and high backlog costs. The consequences are significant; piles of stock, frequent stock-outs and unpredictable demands, and therefore bottlenecks in delivery. There are identified four major causes of the Bullwhip effect:

- Quality of the forecast and its update frequency
- Reorder frequency and the reorder batch size
- Price fluctuation
- Policy for expectation of shortage and level of safety stocks

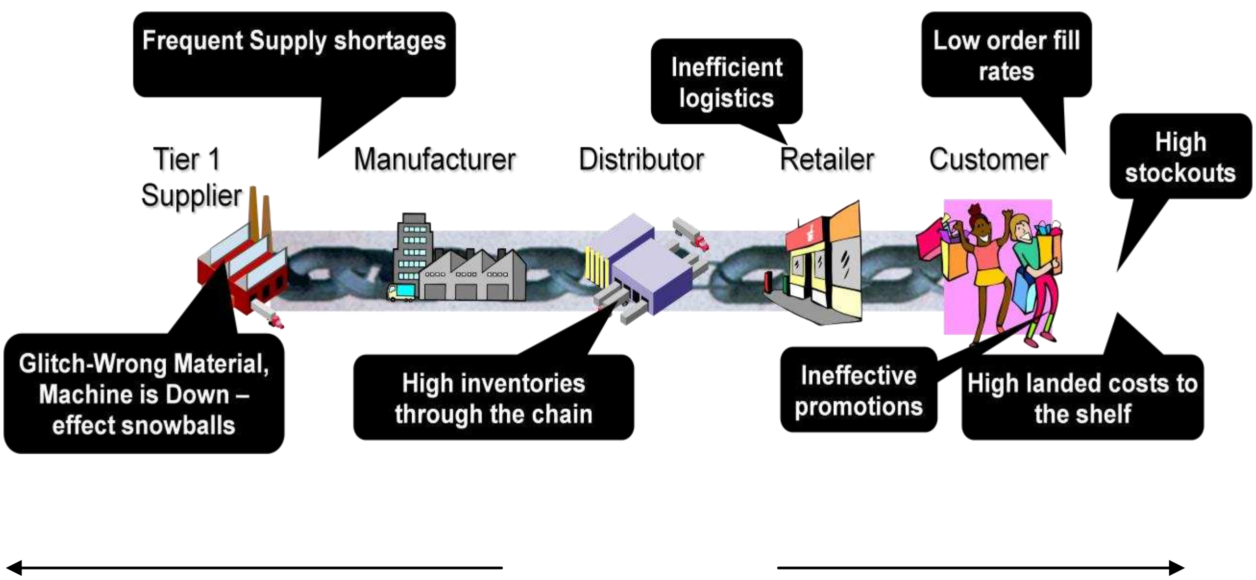
2.6. PROBLEMS ALONG THE SUPPLY CHAIN

According to Turban, Rainer & Potter (2003) the problems along the supply chain stem mainly from two sources:

(1) From uncertainties, and

(2) From the need to coordinate several activities, internal units, and business partners

A major symptom of ineffective supply chain management is poor customer service, which hinders people or businesses from getting products or services when and where needed, or gives them poor-quality products. Other symptoms are high inventory costs, loss of revenues, extra cost of expediting shipments, and more. One of the most persistent SCM problems is known as the bullwhip effect. The bullwhip effect refers to erratic shifts in orders along the supply chain.



Upstream Downstream

Figure 2.2 Supply chain management problems

Here below are some of the problems and challenges that are usually faced while managing a supply chain

- Supply chain strategies cannot be determined in isolation. They are directly affected by another chain that most organizations have, the development chain that includes the set of activities associated with new product introduction. At the same time, supply chain strategies also should be aligned with the specific goals of the organization, such as maximizing market share or increasing profit.
- It is challenging to design and operate a supply chain so that total system wide costs are minimized, and system wide service levels are maintained. Indeed, it is frequently difficult to operate a single facility so that costs are minimized and service level is maintained. The difficulty increases exponentially when an entire system is being considered.
- Uncertainty and risk are inherent in every supply chain; customer demand can never be forecast exactly, travel times will never be certain, and machines and vehicles will break down. Similarly, recent industry trends, including outsourcing, off shoring, and lean manufacturing that focus on reducing supply chain costs, significantly increase the level of risk in the supply chain. Thus, supply chains need to be designed and managed to eliminate as much uncertainty and risk as possible as well as deal effectively with the uncertainty and risk.
- ***Different facilities in the supply chain frequently have different, conflicting objectives***. For instance, suppliers typically want manufacturers to commit themselves to purchasing large quantities in stable volumes with flexible delivery dates. Unfortunately, although most manufacturers would like to implement long production runs, they need to be flexible to their customers' needs and changing demands. Thus, the suppliers' goals are in direct conflict with the manufacturers' desire for flexibility. Similarly, the manufacturers' objective of making large production batches typically conflict with the objectives of both warehouses and distribution centers to reduce inventory.
- The supply chain is a dynamic system that evolves over time. Indeed, not only do customer demand and supplier capabilities change over time, but supply chain relationships also evolve over time. For example, as customers' power increases, there is increased pressure placed on manufacturers and suppliers to produce an enormous variety of high-quality products and, ultimately, to produce customized products.
- System variations over time are also an important consideration. Even when demand is known precisely (e.g., because of contractual agreements), the planning process needs to account for demand and cost parameters varying over time due to the impact of seasonal fluctuations, trends, advertising and promotions, competitors' pricing strategies, and so forth. These time-varying demand and cost parameters make it difficult to determine the most effective supply chain strategy, the one that minimizes system wide costs and conforms to customer requirements.

2.7. BENEFITS OF A GOOD SUPPLY CHAIN MANAGEMENT

Supply chain management is concerned with the efficient integration of suppliers, factories, warehouses and stores so that merchandise is produced and distributed:

- In the right quantities
- To the right locations
- At the right time

In order to

- Minimize total system cost
- Satisfy customer service requirements

According to Chang & Makatsoris (2003) Expected benefits of supply chain management can be described as follows:

a) Throughput improvements: Better coordination of material and capacity prevents loss of utilization waiting for parts.
b) Cycle time reduction: By considering constraints as well as its alternatives in the supply chain, it helps to reduce cycle time
c) Inventory cost reductions: Demand and supply visibility lowers the requirement of inventory levels against uncertainty. Ability to know when to buy materials based on the customer demand, logistics, capacity and other materials needed to build together.
d) Optimized transportation: By optimizing logistics and vehicles loads.
e) Increase order fill rate: Real-time visibility across the supply chain (alternate routings, alternate capacity) enables to increase order fill rate.
f) Analysis of the supply chain management can help to predict propagation of disturbance to downstream.
g) Increase customer responsiveness: Understanding the capability to deliver based on availability of materials, capacity and logistics.

The goals of modern SCM are to reduce uncertainty and risks in the supply chain, thereby positively affecting inventory levels, cycle time, business processes, and customer service. All these benefits contribute to increased profitability and competitiveness. Successful supply chain management, then, coordinates and integrates all of these activities into a seamless process. It embraces and links all of the partners in the chain. In addition to the departments within the organization, these partners include vendors, carriers, third party companies, and information systems providers.

CHAPTER THREE

BACKGROUND OF ETHIOPIAN LEATHER INDUSTRY

3.1. HISTORY OF ETHIOPIAN LEATHER INDUSTRY

The Ethiopian leather industry is relatively an older industry with more than 80 years of involvement in processing leather and leather products. The first two tanneries were established and vertically linked to two shoe factories: Asco Tannery & Asco Shoe Factory (the present Addis Ababa Tannery and Tikur Abbay Shoe Factory) and Darmar Tannery & Shoe Factory (the present Awash Tannery and Anbessa Shoe Factory). In the subsequent years, several local tanneries, such as Dire, Modjo and Combolcha were set up. Yet hides and skins trading systems remained largely traditional and inefficient, with quality and quantity ramifications on the raw materials supplied to these tanneries. Recognizing these problems, the government set up the Livestock and Meat Board (LMB) in 1964 by proclamation No.212/64 to improve the collection, preservation and trading of hides and skins [Abebe & Schaefer (2013)]. The LMB attempted to enhance the quality of raw hides and skins through technical assistance to skins and hides collectors including the preparation of manuals on hides and skins preservation and dispatching of trainers to different parts of the country where hides and skins is collected in large quantities.

Government intervention also involved the introduction of hides and skins regulations and differential price systems whereby properly preserved hides and skins would command higher prices with the intent of driving out low quality skins and hides from the market. LMB was also involved in setting up market centres in different provinces as well in appraising and monitoring the erection of slaughter houses.

Before 1991 the number of tanneries in the country was only seven and after 1991 twenty two new tanneries were established by the private investors and the number of tanneries has now increased to twenty nine.

The Ethiopian leather and leather products industry (LLPI) comprises three major industrial sub-sectors or components: the tanneries processing and producing the leather, the footwear manufacturers (shoe producing), and the leather goods and garments manufacturers. They are medium and large enterprises operating in the formal sector, whereas the micro enterprises particularly in footwear manufacturing area operate in the informal sector. The current status (LIDI 2013 report) of the Ethiopian leather and leather products industry can be classified and presented as follows:

1. Tanning Industry: There are 29 tanneries converting hides and skins into different types of finished leather. The sector is successfully moved to the production & export of higher value-added (fully processed) finished leather. There is a possibility of producing up to 500 million square feet of finished leather per year. This industry relatively, having a better position due to mature in its age and huge investment. .

2. Footwear Industry: It is a stage of development in the country in which there were only two factories before 1991 but currently there are 16 medium and large scale footwear manufacturers. The production capacity of these shoe factories is rise up to 15 million pairs of footwear per annum. The shoe industry is emerging and promising industries.

3. Leather goods and garment industries: There are 15 garments and goods factories, three gloves factories, garments, bags & different kinds of leather articles. This industry is also an emerging segment & appears to be more promising.

4. Micro and Small Scale enterprises: There are 368 Micro and small scale enterprises producing leather products with small capital ranging from 2000 ETB to 220,000 ETB in different regions of the country.

3.2. COMPARATIVE ADVANTAGES OF ETHIOPIAN LEATHER INDUSTRY

The leather industry bases itself on the country's livestock resources. Indeed Ethiopia possesses one of the world largest livestock populations of which is 52 million Cattle population that makes the country ranking 1st in Africa and 6th in the world, 27 million Sheep population which makes 3rd in Africa and 10th in the world and 23 million Goat population which makes 3rd in Africa and 8th in the world. The off-take rate for cow hides 13.87%, Goat skins 27.34% and Sheep skins 40.29%. The hides and skins supplied to the tanneries are reached 1.4 million cow hides, 6.7 million Goat skins and 13.2 million Sheep skins [LIDI, 2013].

With a population over 90 million, Ethiopia has abundant, hard-working, inexpensive and easily trainable labour force. Because of its high quality, the Ethiopian leather, particularly sheepskin and goatskin leather can easily be marketed in the major leather importing countries. Moreover, there is also a high domestic market potential of finished leather for the growing local leather products manufacturing industries. Cheep cost of electricity, land and various government incentives can be considered as a comparative advantage for leather industry in Ethiopia. The Government encourages that all new investments in the tanning industry be capable of processing hides and skins up to finished leathers stages. So, investments in rehabilitation and expansion of existing tanneries as well as in new ventures in the leather sector are areas that Ethiopia has better comparative advantages and the government has given due attention.

3.3. UNIQUE FEATURES OF ETHIOPIAN HIDES AND SKINS

Ethiopian hides and skins have good reputations in the international leather market for their unique natural substance of fitness, cleanness, and compactness of texture, thickness, flexibility and strength. The cattle population of Ethiopia consists of "Zebu" type species and small number of exotic breeds The cattle hides, identified as "Zebu type", are popular for their fine grain pattern and fibre structure that are well suited for the production of quality upper leather.. The sheep are mainly of the hairy type producing skins highly valued in the world markets for high tensile strength and compact fibre structure. They are very suitable for the production of high quality leather, dress-gowns, sport gloves and garments and are in great demand in the world market. The high fibre structure of the highland sheepskins and goatskins of the Country has given these products a very high acceptability on the world leather market and as the result "Bati genuine" goatskin and "Salalie sheepskin" which have got their names from Bati town and Salalie area of Ethiopia, respectively, valued at premium price. Goatskin and sheepskin from other sources that are similar to these products are referred to as "Bati type" and "Salalie type", respectively, and given the best price. Selalie type sheep skins are excellent raw material for high quality leather for dresses, gloves, sports gloves and other garments.

This unique feature of the Ethiopian sheepskins enables them to fetch higher prices in the. The particular characteristics of Ethiopian bati-genuine goatskins are their thicker, highly flexible and clean inner surface and are known world-wide for being excellent raw material for producing high quality suede leather. Hence Ethiopia is known in the international leather market for its sovereign qualities of sheep skins that acknowledged being the best in the world, most of leather glove manufactures prefer to have these categories of raw materials.

3.4. GOVERNMENT POSITION FOR THE LEATHER SECTOR

The Ethiopian government's industrial development strategy states that ensuring accelerated and sustained industrial development is a fundamental policy direction. To implement this policy, the sector's development strategy focuses mainly on industries that are labour intensive, have broad linkages with the rest of the economy, use agricultural products as inputs, are export oriented and import substituting, and contribute to rapid technological transfer. To carry forward the important strategic directions pursued in the Plan for Accelerated and Sustained Development to End Poverty (PASDEP), the government has formulated the five year Growth and Transformation Plan (GTP) in which the leather sector is expected to generate 500 million USD at the end of planning period which was about 57 million on the beginning of GTP.

The government considers that the leather industry, being the largest manufacturing industry has the potential to contribute significantly to the export earnings of the country on one hand and the employment opportunities on the other. So, to enhance this, the government has designed different policies and strategies in order to catalyze the growth of the leather industry through policy interventions and intensive technology up gradation programs. Accordingly, leather as the priority sector of the economy is given due attention by the government to maximize the efficiency and effectiveness of the companies of leather and leather products as well as increasing the overall performance of selected value chain through benchmarking program which strengthen the international competitiveness.

3.5. MARKETING OF HIDES AND SKINS IN ETHIOPIA

The marketing of HS starts at the producer/consumer level and passes through a chain of middlemen until it reaches the tanneries (Fig.3.1 below). The market chain for raw HS consists of the primary producers/consumers, who are the initial sources (individual meat consumers, rural slaughter slabs, municipal slaughter houses, abattoirs, meat processing plants), agents of traders, collectors, local tanners, regional medium/small traders, regional/Addis Ababa big traders and tanneries. The individual consumers who kill animals in their backyard sell the HS either to agents, collectors, or directly to regional small/medium traders. After preservation by air-drying or wet salting, the HS are passed on to big traders and then to the tanneries. The tanneries can be supplied directly from the slaughter premises, regional big traders or Addis Ababa big traders as well. The tanneries process the HS received from their suppliers either in the green (fresh), air dried or wet salted states to semi-finished or finished stages for both local and export markets. The current operational market structure for raw HS is illustrated in Figure below.

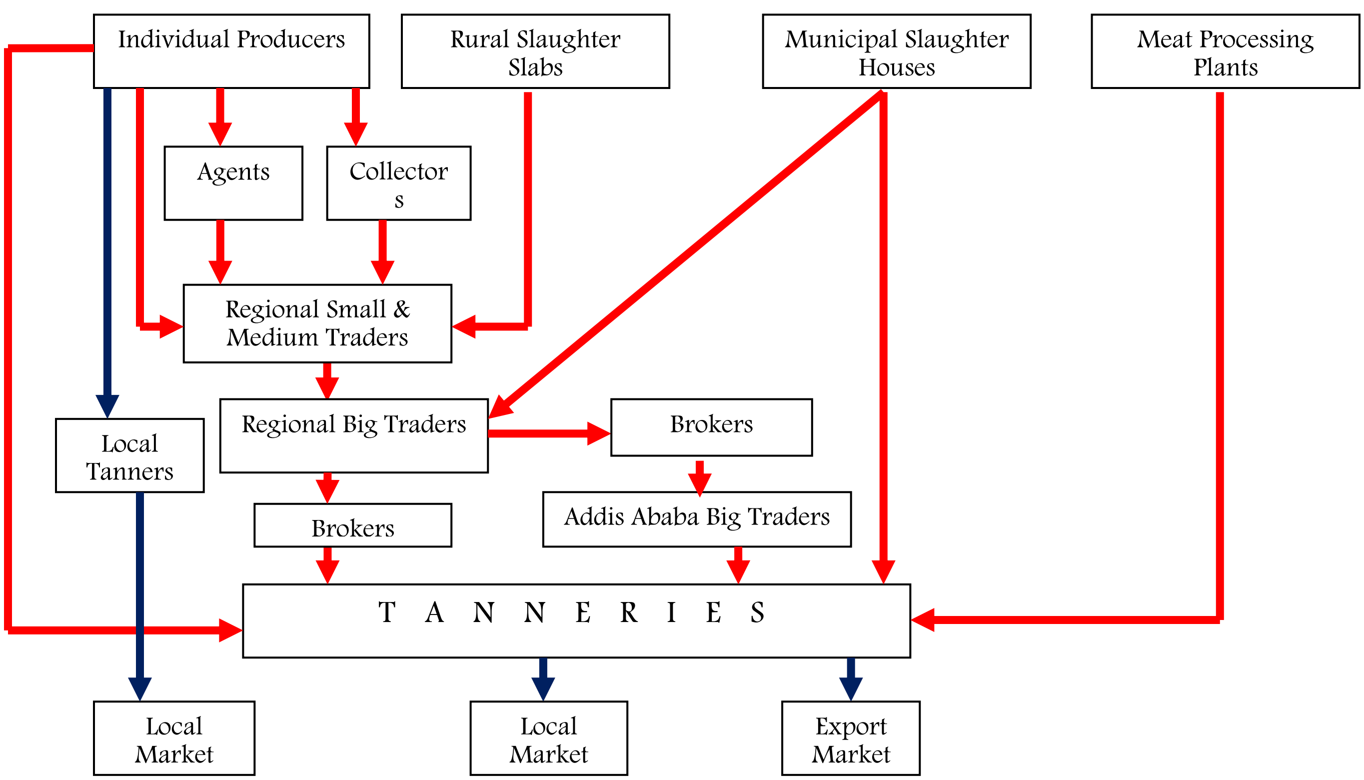


Figure 3.1 Existing Hide and Skin marketing structure

Many varieties of traders are involved from the point of skins and hides collection to the point of delivery to tanneries, with implications for both quality and quantity of supplies. The major sources of hides and skins in Ethiopia can be categorized into four distinct types. The first is individual producers in rural and urban areas that include slaughtering in urban and rural areas for personal consumption (particularly on the holidays) and for the hospitality business. Agents and micro-traders go door-to-door to collect hides and skins produced from individual producers, which then supply to small regional traders. The second sources are rural slaughtering slabs which mainly supply to small and midsized regional traders. Municipal slaughtering houses are the third sources of raw hides and skins that directly supply to tanneries in addition to large regional traders. Direct supply of raw hides and skins to tanneries also takes place through a fourth source, namely meat processing plants. According to information from ELIA, nearly 80% of raw hides and skins transacted in the formal market are derived from rural areas, and only 20% is collected from abattoirs and slaughter houses in large cities and towns. The importance of big traders has increased over time as tanneries seem to prefer to deal with big collectors than small traders. Because of economies of scale, this should have helped shorten the supply chain and improve the amount and quality of raw hides and skins that reach tanneries.

Even though the Ethiopian government through its parliament has been implementing raw hide and skin proclamation under proclamation number 457/2005 for the last eleven years ; the existing proclamation/old one/ could not work effectively due to poor market structure, no price differentiation based on quality, lack of transparent marketing system, poor and limited regulatory framework etc. So it becomes paramount to improve the existing proclamation with the new one. With this in mind the Ethiopian House of Peoples' Representative Passed the revised Raw Hides and Skins Marketing proclamation on December 19/2013. Three major points have been incorporated in the new raw hide and skin proclamation number 814/2013.

a) Primary and secondary marketing centers will be created and legally bind everybody to purchase and sell their products only in this market centers.

In the first level of raw hide and skins market centers, which shall only be fresh or air-dried, and should only be conducted between individual producers and suppliers; individual producers and traditional tanners; small abattoirs and suppliers. In the second level marketing of raw hides and skins marketing should be conducted between: suppliers and tanneries; big abattoirs and tanneries; or export abattoirs and tanneries.

b) Purchasing and selling should be based on quality of hide and skin and sales contracts to be concluded between market actors should correctly state detail information stipulated by directives issued and delivery of marketed raw hides and skins should be effected at suppliers processing and storage warehouse or at tanneries.

c) Detailed penalties have been clearly stated.

The following figure depicts the newly approved marketing structure of raw hide and skin based on proclamation number 814/2014.

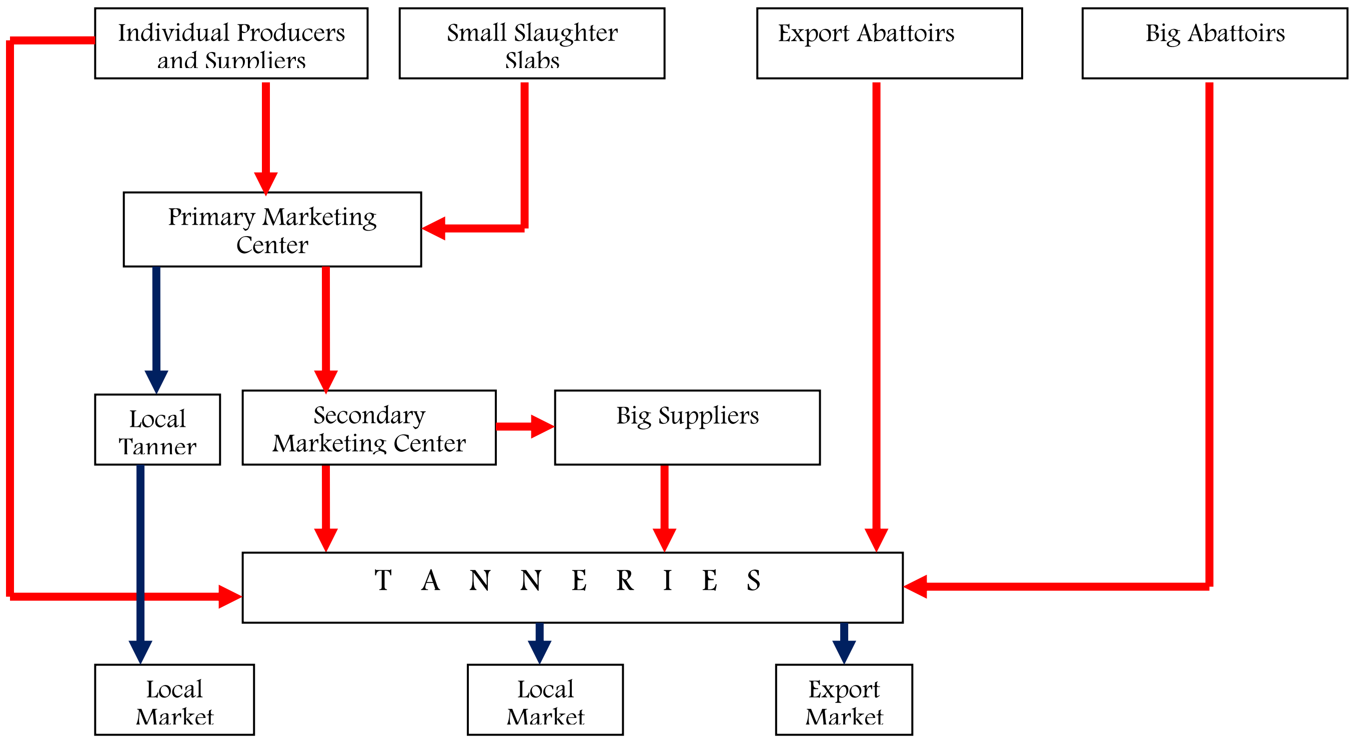


Figure 3.2 The newly approved raw hide and skin marketing structure.

3.6. CURRENT PERFORMANCE OF THE ETHIOPIAN LEATHER SECTOR

In many cases, the performance of a company will be highly dependent upon its upstream suppliers [Kim, et al (2004)]. They also argued that real competition in the marketplace now exists between supply chains, not between companies. This implies that an organization can no longer act as an isolated and independent entity in competition, but the fully-integrated supply chain can provide competitive advantages in the market. Hence the following drawbacks (Constraints of Hides and Skins Marketing) face the Ethiopian leather supply chains that impede the supply chain performance.

3.6.1. SHORTAGE OF RAW MATERIAL

Acute shortage and quality of hides and skins is a major problem faced by tanners in Ethiopia (CoMESA, 2012). This is considered to be one of the reasons for the tanneries' low capacity utilization. There has been a move to overcome the problem by importing duty free hides and skins from abroad. This however is not a lasting solution since those countries currently exporting hides and skins will soon develop their own capacity and process the same. Such move also defeats the purpose of establishing a competitive industry using the country's rich resource endowment (CoMESA, 2010). According to Yakob Hailu (2013) among the 22 tanneries operating in the country with annual tanning capacity of 2.2 million hides, 25.9 million sheep skins and 13.7 million goat skins, but the annual potential of purchase is 1.7 million hides, 7.7 million sheep skins and 8 million goat skins. This illustrates that the tanneries are utilizing only 77.3%, 29.7% and 58.4% of their tanning potential respectively due to the shortage of raw material. Skin diseases such as mange which damages the skin seriously can be observed on skins by farmers and skin and hide traders. Hence such skin will not enter the market leading scarcity of supply to the tanneries.

According to Bisrat Gebremichael (2013) there are about 27 tanneries operating in the country and have an average capacity of 4000 pieces of hides and 30,000 pieces of skins per day. However they are working under capacity even if the country has a potential to supply around 20 million pieces of hides and skins per annum. The potential supply of hides and skins depend of the scale of meat production, not on the size of livestock population. Thus the product i.e. hides and skins, become available when meet is needed, not when it is appropriate for leather processing and so it is not primary agricultural commodity.

The expansion of artisans (local tanners) and the utilization of hide and skin for traditional household items, the existence of cross border illicit trade and misuse of the raw material due to lack of awareness, result in a low recovery rate and ultimately shortages of raw H & S in the central market.

3.6.2. PRICE HIKE

The increasing number of tanneries has increased raw material demand far beyond the existing potential supply. This leads to unhealthy competition among tanneries and an escalation of price in the domestic market

3.6.3. QUALITY DETERIORATION

The limited number of slaughter facilities, inadequacies in preservation techniques, and other man-made and natural defects inflicted on the raw hides and skins downgrade quality. The number of slaughterhouses in the country is very limited. Thus, the majority of cattle, sheep and goat slaughter are carried out in the backyard that results in poor quality raw hide and skin.

According to Yakob Hailu (2013) In Ethiopia, as many as one-quarter to one third of all skins processed at tanneries have various defects and are unsuitable for export purposes. Up to 65% of these defects occur in the pre-slaughter stage of production while the animals are alive while considerably large portions of these pre-slaughter defects are directly related to parasitic and /or to secondary self-inflicted damages. Post-slaughter defects related to poor management and treatments of skins after slaughter are also among important problems. The various affecting factors and causes include: Age, Sex and Breed of the Animal, Climate and Feeding, Diseases Mechanical Causes (Damages), Small Size, Incorrect Shape, Preservation and Storage Defects.

According to Yakob Hailu (2013) Ethiopian tanneries reported that 35%of sheep skin and 56% of goats' skin are rejected due to external parasites and out of the reject groups of the processed skin about 80-90% defects were believed to be due to external parasites.

3.7. BACKGROUND OF THE CASE COMPANY

Dire Tannery is one of the 29 operating tanneries in Ethiopia. It is a private company established in 1973 G.C. The company is located in North West of Addis Ababa around Wingat. It is a member and one of the sister company of Dire Industries Plc. It has a maximum soaking capacity of 6000pcs of skin and 600pcs of hide per day. Currently the company is not processing goat skin rather it is done in its sister company Modjo Tannery. The factory works for 24hrs/day for five days a week and operate half a day on the weekends (Saturday and Sunday). It releases some harmful waste material to the environment, although there is an effluent treatment plant for the waste materials; it discharges drying bed (which is out of the chrome precipitation tank) to a nearby river. The solid waste is transported to municipal disposal site.

Much of the raw materials excluding raw hide and skin and non iodized salt are brought from abroad. These include differing chemicals necessary for tanning purpose which are stated in the previous chapter. Regarding to the process sections (core and support), it has all the necessary departments like Administration, Maintenance, production, quality control, R&D and general service and property. The company has more than 425 permanent and contract employees. Currently the company is engaged in the production of finished leather for local and foreign market due to the discouraging tax policy of exporting raw and semi processed leather of the country. It produces different grade and purpose finished leather of which 20% is for local market and 80% for export market which particularly targeted on Italy, Korea, India and china markets. Dire tannery is an ISO 9001:2008 certified company and operates under its documented procedures.

CHAPTER FOUR

LITERATURE REVIEW

4.1. INTRODUCTION

The term "supply chain" generally encompasses the web of interconnected relationships between the sales channel, distribution, warehousing, manufacturing, transportation, and suppliers. Each component of the supply chain is connected to other parts of the supply chain by the flow of materials in one direction, the flow of orders and money in the other direction, and the flow of information in both directions. Changes in any one of these components usually creates waves of influence that propagate throughout the supply chain. These waves of influence are reflected in prices (both for raw materials, labour, parts, and finished product), flow of materials and product (within a single facility or between facilities within the supply chain), and inventories (of parts, labour capacity, and finished product).

It has been observed in many cases that supply chain dynamics demonstrate cyclical fluctuations and instability [Goldsim, (2007)]. These fluctuations are typically a result of information delays (e.g., orders may be based on inventory data that is several week old) and inertia (e.g., once an order is placed it may be weeks or months before the production rate can be changed). These fluctuations can result in much undesirable and/or costly inefficiency, including stock outs, obsolete inventories, unfulfilled customer demand, or idled factories. The objective of dynamic supply chain simulation is to understand the dynamics of the system and ultimately to identify and evaluate strategies to minimize inefficiencies in the system.

The challenge of supply chain management is to identify and implement strategies that minimize costs while maximizing flexibility in an increasingly competitive and complex market. This chapter addresses the overall methodologies used for modelling supply chain to overcome the different supply chain management challenges and review journal articles and identify gaps.

4.2. SUPPLY CHAIN MODELLING METHODOLOGIES

There are a number of supply chain modelling methods that have been proposed. Beamon [1998] classified multi-stage models for supply chain design analysis into four categories by analytical and mathematical approaches. The classifications are:

1) Deterministic analytical models, in which the variables are known and specified
2) Stochastic analytical models, where at least one of the variables is unknown, and is assumed to follow a particular probability distribution,
3) Economic models, and

4) Simulation models.

A fundamental problem in SCM is performance evaluation. Thierry, Bel and Thomas (2010) identified three approaches to evaluate supply chain management performance:

a) Analytical methods, such as queuing theory,
b) Physical experimentations, such as lab platforms or industrial pilot implementations
c) Monte-Carlo methods, such as simulation

The use of analytical methods is generally impractical because mathematical models for realistic cases are usually too complex to be solved. Obviously physical experimentation suffers from technical- and cost-related limitations. In fact, a modelling and simulation approach is the only practical recourse for exploring performance of the large-scale situations that exist in reality [Thierry, Bel and Thomas (2010)]. Furthermore, the modelling and simulation approach facilitates the design of the supply chain and, as well, the evaluation of its management prior to implementation. The ability to carry out "what-if" analysis that lead to a "best" configuration further strengthens the case for the approach. Moreover it is important to stress that simulation focuses primarily on the dynamics of the physical and decision processes in the supply chain.

Kim, et al (2004) presented four techniques which are commonly used to model the supply chain for problem-solving. These are linear programming, integer/mixed-integer programming, network models and simulation modelling.

Linear programming- Linear programming can be used to model various situations, and identifies optimal problem solutions using linear mathematical equations. There are no qualitative aspects, but only quantitative ones, which mean that only problems that can be expressed mathematically can be solved.

Mixed-integer programming- Integer programming is similar to the linear programming, but all the variables must be integers.

Network models- The network is represented with nodes and connections. Nodes generally represent plants, distribution centres, suppliers or customers, while connection represents transportation lanes. The network can be translated into mathematical representations such as linear, integer and mixed-integer programming. A typical example is to find a solution to minimise the transportation costs from factories to distribution centres with certain production output from each factory.

Simulation modelling- The main problem with most analytical models is that numerous additional issues and constraints have to be considered before the results can be applied in practice. Many analytical models are highly simplified, and consider only a few variables, such as inventory and the cost of running out of stock, ignoring other costs such as order processing and transportation. In short, mathematical approaches often require too many simplifications to model realistic supply chain problems, although they may be valuable for gaining an understanding of general supply chain principles and effects. Simulation is the process of designing and creating a model of a real or proposed system, using abstract objects in an effort to replicate the behaviour of their real-world equivalents.

4.3. SIMULATION MODELING

GoldSim (2004) defined simulation as the process of creating a computer model to represent existing or proposed system (in this case, a supply chain) in order to identify and understand the factors that control the system. Any system that can be quantitatively described using equations and/or rules can be simulated.

In a dynamic simulation, the system changes and evolves with time and the objective in modelling such a system is to understand the way in which it is likely to evolve, predict the future behaviour of the system, and determine how to influence that future behaviour.

Simulation does not provide a definitive solution, but that experiments must be carried out with a variety of different input values to obtain corresponding outputs. Further statistical analysis is then frequently required to evaluate the results obtained. The simulation model may take many forms, depending on the simulation technique used. Simulation models can represent real systems in their "as-is" state, or proposed changes to the system - "what if" scenarios.

Simulation is considered as one of the most powerful techniques to apply within a supply chain environment [Terzi and Cavalieri, 2004].

4.3.1. TYPES OF SIMULATION FOR SUPPLY CHAIN MANAGEMENT

There are many different types of simulation tool available, from domain specific, event-based discrete simulations, through continuous simulation, to general-purpose mathematical tools and simulation languages. Although every specific model has its own unique characteristics, Kim, et al (2004) classify different models according to the following three factors.

- ✓ ***Static or Dynamic***: In static models the fundamental conditions do not change with time, whereas in dynamic models there may be various changes over time.
- ✓ ***Discrete or Continuous:*** In a continuous model the changes that take place can be considered as happening gradually and continuously over time (and hence could be plotted as smooth curves). In contrast, a discrete model considers changes which happen discontinuously at points in time.
- ✓ ***Deterministic or stochastic:*** Deterministic models have no random inputs: all the conditions and parameters are considered to be known with certainly. Stochastic models take account of the fact that in reality there are frequently factors that are uncertain and variable (such as the arrival of

customer orders, the occurrence of machine breakdowns). Such factors are modelled using random sampling from appropriate probability distributions.

Jack P.C. Kleijnen (2004) identified four simulation types for SCM:

i. **Spreadsheet Simulation-** Spreadsheets have been used to implement manufacturing resource planning (MRP), which is an important subsystem of SCM. However, this type of simulation is often too simple and unrealistic.

ii. **System Dynamics (SD)-** SD models have no randomness, and yet their behaviour remains counter-intuitive because of the non-linear feedback loops.

iii. **Discrete-Event Dynamic Systems (DEDS) Simulation-** A DEDS simulation is more detailed than the preceding two simulation types. DEDS simulation has the following two characteristics:

   a) It represents individual events (for example, the arrival of an individual customer order), whereas SD has a much more aggregated view including flows.

   b) It incorporates uncertainties (for example, customer orders arrive at random points in time; machines break down at random points of time, and require random repair times). The other three types of simulation models remain relevant—even when eliminating randomness.

iv. **Business Games-**It is relatively easy to simulate technological and economic processes, but it is much more difficult to model human behaviour. A solution is to let managers themselves operate within the simulated 'world', which may consist of a supply chain and its environment.

DES models systems as a network of queues and activities where state changes occur at discrete points of time, whereas SD models represent a system as a set of stocks and flows where the state changes occur continuously over time. In DES entities (objects, people) are represented individually. Specific attributes are assigned to each entity, which determine what happens to them throughout the simulation. On the other hand, in SD individual entities are not specifically modelled, but instead they are represented as a continuous quantity in a stock. DES models are generally stochastic in nature, where randomness is generated through the use of statistical distributions. SD models are generally deterministic and variables usually represent average values. In DES state changes occur at irregular discrete time steps, while in SD State changes are continuous, approximated by small discrete steps of equal length.

The type of simulation applied in SCM depends on the problem to be solved. For example, Spreadsheets may be part of production control software; SD aims at qualitative insight (not exact forecasts). DEDS simulation can quantify fill rates, which are random variables. Business games may educate and train users since the players are active participants in the simulated world. Example is the use of games to study the confidence that managers have in their decisions.

By definition, a *simulation* model has the following four characteristics [Jack P.C. Kleijnen (2004)]:

- ✓ It is a quantitative, mathematical, computer model.
- ✓ It is a dynamic model; i.e., it has at least one equation with at least one variable that refers to at least two different points in time.
- ✓ This model is not solved by mathematical analysis; instead, the time paths of the dependent variables (outputs) are computed—given the initial state of the simulated system, and given the values of the exogenous (input) variables.
- ✓ Simulation does not give a 'closed form' solution. Instead, the simulation analysts experiment with different input values and model structures, to see what happens to the output—so-called *sensitivity analysis*. Next the analysts may perform Validation & Verification, optimisation, and robustness analyses.

The simulation modelling methodology should accommodate the characteristics present in supply chain environments; namely stochastic, dynamic, and distributed environments; to allow supply chain decision makers to make informed decisions in a fast, sharable and easy to use format.

Our system in this study is a discrete one since tiers' supply chain activities, such as order fulfilment, inventory replenishment and product delivery, are either triggered by customers' orders or arrival shipments from suppliers at points of time. In the case of most applications of simulation in manufacturing and operations management so as in this research the appropriate models are dynamic, discrete and stochastic simulation model.

4.3.2. ROLE OF SIMULATION AND MODELLING IN SUPPLY CHAIN

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

As SCM has drawn much attention in industrial and academic fields, various techniques are developed to model, analyze, and solve complex decision problems in supply chains. Simulation is one of the techniques, which allows the researcher to capture and experiment with the rules in real or proposed systems [Cheng Zhang, Chenghong Zhang (2006)]. Oftentimes, there are some situations in which a problem cannot meet the assumptions set by analytical modelling methods, especially when a problem exhibits significant uncertainty and is quite difficult to be dealt with analytically. With simulation, it is possible for decision makers to examine the changes in the part of the chain and following consequences with less expense than field experiment which is usually difficult to be carried out.

Simulation modelling provides the flexibility to model processes and events to the desired level of complexity, in a risk free, dynamic and stochastic environment [Cope, Fayez, Mollaghasemi and Kaylani (2007)]. It provides the essential level of realism and utility required to model supply chain environments accurately. In addition, simulation models provide flexibility to allow for the dynamism and distributed nature of supply chain environments.

The use of a model of a system, rather than the system itself, has a number of important advantages [Kim, et al (2004)]: among these some of them are speed, cost Safety and convenience and prospective investigation.

Therefore, the model should be able to capture the complexities of the supply chain and facilitate supply chain integration. Kim, et al (2004) summarised the main motivations for supply chain modelling:

- Capturing supply chain complexities by better understanding and uniform representation of the supply chain
- Designing the supply chain management process to manage supply chain interdependencies
- Establishing the vision to be shared by supply chain partners, and provide the basis for internet-enabled supply chain coordination and integration
- Reducing supply chain dynamics at supply chain design phases

According to GoldSim Technology Group LLC (2007) white paper the process of building a dynamic supply chain simulation model provides valuable insights and understanding regarding the behaviour and characteristics of a supply chain. Beyond this expanded knowledge, however, most models are developed to address particular issues. Types of issues that can be addressed using dynamic simulation generally fall into the categories *optimization, decision analysis, diagnostic evaluation, risk management and project planning.*

4.3.3. STEPS IN MODELLING AND SIMULATION OF SUPPLY CHAINS

Supply chain management has three sub-system components; i.e., a physical system, an information system and a control system. Building a simulation model requires the development of an appropriate model of one or more of these three sub-systems which is implemented on a computer.

The process of building and developing a model, and hence also the processes of validation and verification, involves an incremental, iterative procedure. It is very unlikely that the correct model, and a correct computer version of the model, will be produced first time. Instead there is commonly a process of gradual development and improvement of the model, with validation and verification required at each stage [Kim, Tannock, Byrne, Farr, Cao and Er (2004)]. The development of a simulation model should follow a logical, systematic process; that is, a series of steps should be followed. Those researchers explain the steps in a successful simulation study as follows:

- ✓ Formulating the problem and planning the study
- ✓ Collecting the data and defining the model
- ✓ Validation
- ✓ Constructing a computer model
- ✓ Verification
- ✓ Determining run parameters of the simulation
- ✓ Performing simulation experiments
- ✓ Analysing output data

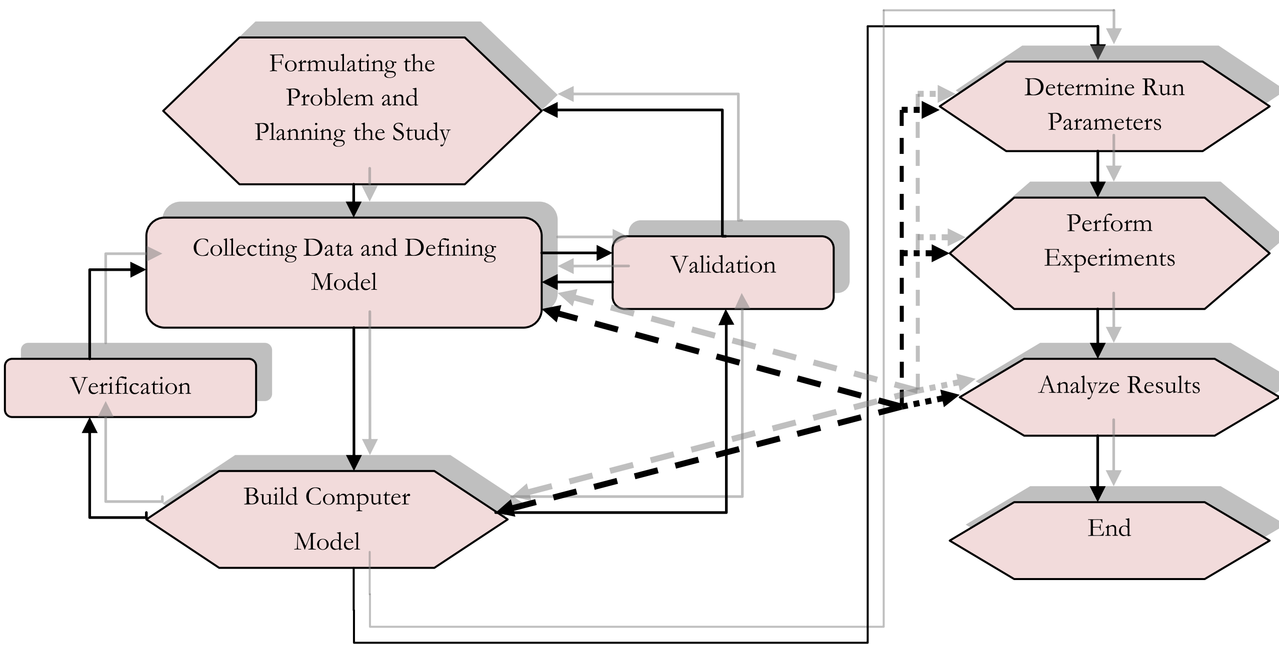


Fig. 4.1 Procedure for model development [source Kim, et al (2004)]

Fredrik Persson and Jan Olhager (2002) formulated simulation steps more or less similar with the above steps except giving more emphasis on validation which they recommend it should be performed twice before computer model development and after computer representation of the model. Persson and Olhager also state sensitivity analysis as one step next to validation of the computer representation of the real system. Yoon Chang and Harris Makatsoris (2003) also identifies seven steps in different expressions, it might be included under the steps stated formerly. As reported in [Antonio Cimino, Francesco Longo and Giovanni Mirabelli (2010) a simulation study requires a number of different steps; it starts with problem formulation and passes through different and iterative steps: conceptual model definition, data collection, simulation model implementation, verification, validation and accreditation, simulation experiments, simulation results analysis, documentation and reports.

Even though all the steps in all the research papers would be performed, for clear description of the simulation process and the more commonly accepted steps identified by Kim, et al (2004) shall be adopted for this research.

4.4. DISCRETE EVENT SIMULATION AND SOFTWARE SELECTION

Nowadays there is a large availability of discrete event simulation software that can be easily used in different domains: from industry to supply chain, from healthcare to business management, from training to complex systems design. Simulation engines of commercial discrete event simulation software use specific rules and logics for simulation time and events management [Cimino, Longo and Mirabelli (2010)].

As described in Cimino, Longo and Mirabelli (2010), discrete-event simulation software selection could be an exceeding difficult task especially for inexpert users. According to GoldSim Technology Group report (2007) numerous vendors and consultants claim to provide packaged or custom simulation software suitable for supply chain modelling. Although many of these simulation software packages are suitable for modelling simple supply chain systems, some of these packages lack critical features necessary to address real-world problems. When selecting simulation software, key features to look for include the following [Goldsim (2007)]:

- ➢ Capability to explicitly incorporate variability and uncertainty into the analysis
- ➢ Capability to explicitly represent discrete events
- ➢ Top-down hierarchical model structure
- ➢ Capability to dynamically link to external data repositories

Kim, et al (2004) identified 48 commercial softwares available for supply chain management and they overlooked them in a specific characteristic, listed out 10 of them and do a detail evaluation and compare the short-listed software as below. They identified nine criteria to evaluate the software with respect to supply chain management modelling and simulation.

- ✓ **Vendor**: includes vendor pedigree, maintenance support, and documentation
- ✓ **Model development and input**: includes the model building and coding aspect, batch processing, library of reusable modules, conditional routing, statistical distributions, queue policy, input modes,

automatic documentation, batch input modes, random number generator, standard commands, model packaging

- ✓ **Execution**: includes multiple run, automatic batch run, reset capability, start in nonempty state, interaction with user and unit conversions
- ✓ **Simulation and optimization engines**
- ✓ **Animation**: includes icon and animation development, screen layout and animation running
- ✓ **Testing and efficiency**: includes validation and verification tools, display features, tracing, step functions, breakpoints, model size and model speed
- ✓ **Output**: includes report, integration with external packages and business graphics
- ✓ **User:** required experience and cost of package
- ✓ **Experimental design** use of tools that can help to model correctly.

Table 4.1 Simulation packages simulation scores [source: Kim, et al (2004)]

Criteria	Weight	Anylogic	Arena	Automod	Enterprise Dynamics	Extend	Flexsim	Promodel	Quest	Simul8	witness
Vendor	5.6	1	3	2.5	2	2.67	2	2	3	2.33	3
Model Dev't & input	9.5	3	2.71	2.3	2.57	2.71	2.7	2	3	2.43	2.5
Simulation & opt. engine	8	2.5	2.5	2.7	2.6	2.5	2.5	2.7	2.5	2.5	2.5
Execution	7.6	2	2	2	2.33	2.33	2	2	2.5	2	2
Animation	6.3	2.5	2.67	3	2.33	1.33	3	2.67	3	1	3
Testing & efficiency	7.6	2	2.38	2.5	2.38	2.5	1.5	2	2.5	1.75	2
Output	6.6	2.5	2.33	2	1.67	2.33	2.7	2	2	2.67	2
Experimental Design	5.9	2	3	2	2	2	2	3	2	2	2
User	5.6	1	2	2	1.5	2.5	1.5	2	1	3	2.5
Total		**124.2**	**156.9**	**138.8**	**138.1**	**147.0**	**140.4**	**141.1**	**152.8**	**137.2**	**148.9**
Rank		**10**	**1**	**7**	**8**	**4**	**6**	**5**	**2**	**9**	**3**

Antonio Cimino, Francesco Longo and Giovanni Mirabelli (2010) has also conducted a survey regarding commercially available software to select the best software which can help to model and simulate complex systems like supply chain. The following table summarises the evaluation of commercial simulation software by Cimino, Longo and Mirabelli (2010).

Table 4.2: Survey on most widely used Simulation software [source Antonio Cimino, Francesco Longo and Giovanni Mirabelli (2010)]

Criteria	Anylogic	Arena	Automod	Emplant	Promodel	Flexsim	Witness
Logistics	6.5	7.5	7	7.2	6.5	7	7.5
Manufacturing	6.6	7.5	6.5	7.5	6.7	6.7	7.5
3D virtual reality	6.6	6.9	7.3	6.8	6.7	7.2	7
Simulation engine	7	8	7.5	8	7	7.5	8
User ability	7	8	6	7	9	7.5	8
User community	6.2	9	6.7	6.5	7.5	6.6	8.5
Simulation language	6.8	7	6.25	6.5	6.5	6.7	6.5
Run time	7.5	7	6.5	6.5	7.5	6	7
Analysis tools	6.5	8	6.9	7.1	7.7	6	7.8
Internal programming	7.2	7	6	7	6.2	7	6.5
Modular construction	6.1	7	6	6.5	7.5	7	7
Price	7	6	5.6	5.8	7	5.7	6
Total	**81**	**88.9**	**78.25**	**82.4**	**85.8**	**80.9**	**87.3**
Rank	**5**	**1**	**7**	**4**	**3**	**6**	**2**

According to Kim, et at (2004) and Cimino, Longo and Mirabelli (2010) evaluation of commercially available software for modelling and simulation of supply chain Arena of Rockwell Automation is the best and preferred one so as it is used in this research for modelling and simulation of Ethiopian leather industry supply chain.

Arena is simulation software by Rockwell Corporation and it is used in different application domains: from manufacturing to supply chain (including logistics, warehousing and distribution) from customers' service and strategies to internal business processes. Arena provides the user with objects libraries for systems modelling and with a domain- specific simulation language, SIMAN. Simulation optimizations are carried out by using OptQuest. Arena includes three modules called Arena Input Analyzer (for distributions fitting), Arena Output Analyzer (for simulation output analysis) and Arena Process Analyzer (for simulation experiments design). Moreover Arena also provides the users animation at run time as well as it allows to import CAD drawings to enhance animation capabilities.

4.5. DIFFICULTIES WHILE SIMULATING SUPPLY CHAINS

Within a simulation model of a SCM system, the number of "objects" and the number of events can become very large. As a result, the duration of a simulation experiment can become unacceptably long. Steps therefore have to be taken to either restrict the size of the supply chain being studied or reduce model size. Various approaches exist for reducing the size of a supply chain model [Thierry, Bel and Thomas (2010)]:

a) Abstraction, which is a "method for reducing the complexity of a simulation model while maintaining the validity of the simulation results with respect to the question that the simulation is being used to address"
b) Aggregation which is a "form of abstraction by which a set of data or variables with common characteristics can replaced by an aggregated data or variable"
c) Reduction of the number of events which consists of replacing "part of a discrete event model by a variable or a formula"

The two main difficulties are highlighted, and then the different types of models for SCM simulation are quickly presented.

1) Size of the system

One characteristic of supply chain simulation is the huge number of "objects" to be modelled. A supply chain is composed of a set of companies, a set of factories and warehouses, a set of production resources and stocks. Between all these production resources circulate a set of components, parts, assembled parts, sub-assemblies and final products. Thus, the number of "objects" of the model can be very large.

2) Complexity of the production management system

To simulate a system it is necessary to simulate the behaviour of the "physical" system and the behaviour of the "control" system. For a supply chain this implicates that it is necessary to model the behaviour of the supply chain management system of each company and the relationship between these production management systems (cooperation).

4.6. ARTICLE REVIEW

The aim of this study is to explore the use of simulation modelling for logistics and supply chain management (LSCM) and looking specifically in to the nature and level of issues modelled so as to identify untouched/less focused areas and implement the methodology in to Ethiopian leather industry supply chain. In order to achieve this objective the literature analysis is based on the frequency of different performance indicators and other parameters those should be considered for a valid and more realistic modelling of supply chain in any of the simulation approached which can be applied in supply chain management. Most scholars believe that the big challenge in supply chain management is to measure the performance of the supply chain network either the existing or the newly designed ones. Hence, most of the articles regarding supply chain with the help of simulation and modelling mainly focuses on the measurement of performance criteria in a specified supply chain network so as to choose the best design by performing "sensitivity" and "what-if" analysis.

The study is based on review of journal articles that describe the application and implementation of simulation and modelling in logistics and supply chain management particularly on those articles which are engaged in measuring and evaluating key performance indicators (KPI) of supply chain network so as strives for the design of the best supply chain network and make strategic decisions based on facts.

This research addresses the following two research questions on this literature survey part of the paper.

1) What are the mostly considered/selected performance indicators of supply chain network?
2) What are the gaps while modelling and simulating of supply chain network with respect to key performance indicators and other parameters of the Ethiopian leather industry supply chain network?

The literature review undertaken follows three stages, identification of journal articles which use simulation and modelling for supply chain as a methodology and identification of performance criteria and the simulation approach adopted and finally identification of gap and performing analysis on different aspects of supply chain with respect to Ethiopian leather industry context.

4.6.1. IDENTIFICATION OF JOURNAL ARTICLES FOR REVISION

Thirty journal articles that report simulation modelling relevant to decision support system (DSS) for logistics and supply chain management were selected based on a key word search using the web of knowledge citation database, particularly I used the web of University of South Africa (UNISA) library, Addis Ababa University (AAU) library e-resource, and other sources which may allow their articles to access for free. Some of the journal databases which are used as a source of selected articles for review are:

- ✓ Emerald Group Publishing Ltd
- ✓ JOSTOR Archive Collection
- ✓ IEEE/IET Electronic Library
- ✓ Science Direct Engineering and Technology
- ✓ Springer link Fully Access Journals and
- ✓ Tailor and Francis Online

Journals from those databases which are selected as a source of article include International Journal of Production Research, journal of Simulation Modelling Practice and Theory, journal of Computers & Industrial Engineering, European journal of operations Research, journal of Production Planning & Control, International Journal of Production Research and International journal of Simulation and Process Modelling.

This provides a multidisciplinary collection of literatures including subjects such as science and engineering, logistics and supply chain management and operations research. The key words used to search the articles were "Supply chain", "modelling and simulation", "performance measurement", "discrete-event simulation" and a combination of Supply chain with other keywords. According to this search there are a number of articles but only thirty are selected which are considered relevant for this research.

I tried to review more recent articles on the subject. Only one article is selected beyond a 10 years period publication. Fifteen of the reviewed articles are published five years onward, which is quit commendable in surveying journal articles. In general all the articles are published in between 2001 to 2013.

4.6.2. CREATION OF A SCHEMA FOR CLASSIFYING PAPERS

If the performance of a system cannot be measured, it cannot be efficiently managed. Unfortunately, it is difficult to select appropriate supply chain performance metrics because of the complexity of the supply chain and ever-changing business environments. Beamon (1998) noted that the establishment of appropriate performance measures is an important element of supply chain design and analysis. He classified performance metrics into two categories; qualitative metrics for which there is no single direct numerical measurement, and quantitative metrics that may be directly described numerically. Qualitative measures include customer satisfaction, flexibility, information and material flow integration, effective risk management and supplier performance. Quantitative measures include measures based on cost and measures based on customer responsiveness etc.

The first classification scheme for the surveyed articles is the performance measurement criteria that the paper is focusing on while modelling and simulation of supply chain networks. The performance criteria are mainly depends on the supply chain network structure, its complexity and the product/service type that is flowing in the chain. For example Mahdi Mobini , Taraneh Sowlati , Shahab Sokhansanj (2013) in their simulation model for the design and analysis of wood pallet supply chain selects cost, energy consumption and carbon dioxide emission as the key performance indicators for the design of wood pallet supply chain network. Jansen, Weert, Beulens and Huirne (2001) identified satisfaction of customer and lead time in their catering supply chain simulation model. Klimov & Merkuryev (2010) considers the resilience and reliability of the supply chain network when there is something that interrupts the chain. Datta & Christopher (2010) design a simulation model to manage uncertainty in supply chains.

For the purpose of this research I have identified eight performance indicators of supply chain network with related to the Ethiopian context so as to evaluate and classify the articles in terms of those criteria. The identified supply chain performance evaluation criteria are

- Quality
- Lead time
- Cost
- Risk mitigation strategy
- Flexibility to survive uncertain environments
- Access to the required Quantity
- Service level
- Inventory level

Other scheme to classify and evaluate the number of sources of raw material or sub assembly, variety of goods, number of echelons, resource constraint (whether the model is developed with limited or unlimited resource) and the type of simulation software used to model the supply chain. The reason why I add these classification criteria is that most of the developed models neglect the basic characteristics of supply chain in order to simplify the model and for the ease of the analysis part. For example Wan, Pekny, & Reklaitis (2005) assumes there is only one source of input (number of nodes in each echelon is assumed to be one) to the firm and Janson,Weert,Beauienes& Huirne (2010), Nikolopoulov & Ierapetritov (2012) and Zhang & Chenghong (2006) assumes the number of sources for raw material or sub assembly for the mother company is two. These assumptions are mostly unpractical in the global world in which companies extend their supply up thousands of sources to survive in the market by mitigating risk factors and uncertainties in the supply. The number of the variety of inputs also significantly affects the performance of the chain. Most of the articles took the variety of inputs as one or two which is also rare in real world. A supply chain also should have to react for limited resources which cannot be found when needed like hide and skin. The number of echelon/tiers is also directly related with the performance of supply chains. Table 4.3 shows list of selected papers categorized by selected evaluation schema.

Table 4.3. List of selected papers categorised by selected evaluation

Articles	Performance measurement criteria								Number of nodes in each echelon				Variety of input			Supply		Number of echelon			Software used
	Quality	Cost	Quantity	Lead time	Risk	Uncertainty	Service level	Inventory level	1	2	3	>=4	1	2	>2	Limited	Unlimited	2	3	>=4	
Helen Cavario Barroso Machdo Avedo (2011)		X		X	X									X			X		X		Arena
Datta, & Christopher (2010)						X							X				X		X		Stat Fit
Umeda & Zhang (2001)				X		X	X	X					X				X			X	Extend
Janson,weert,Beauienes& huirne (2010)		X		X			X	X		X					X		X			X	
Nikolopoulov & Ierapetritov (2012)		X						X		X						X			X		ABS
Cigolini, Pero,Rossi, Sianesi (2013)		X	X	X								X	X				X		X		Arena
Wan, Pekny, &Reklaitis (2005)						X		X	X					X	X				X		
Mobini, Sowlati & Sokhansanj (2013)		X		X		X							X			X				X	Extend Sim
Zhang & Chenghong (2006)						X	X			X							X		X		GPSS
Li, Sheng, & Liu (2010)		X				X					X						X				
Klimov & Merkuryev (2010)					X	X															Promodel
Vandam,Luksz&Srinivasan (2009)					X	X															ABS
Noche & Elhasia (2013)		X				X														X	Arena
Zhang,Johnson & Johnson (2012)		X																			Arena
Wan, Penky & Reklaitis (2004)						X		X											X		LSSVM
Mishra & C Han (2011)				X			X								X					X	Arena
Byrne &Heavey (2004)			X	X		X															
Chan & Prakasha (2011)		X						X												X	Arena
Ho &Spears (2006)		X		X															X		ERP
Bottani & Montan21ari (2009)		X																		X	Simul8
Cannella & Ciancimino (2005)						X	X	X													Vensim
Lau, Xie, & Zhao (2005)		X					X	X										X			SAS
Mishra& Chan (2009)		X		X	X		X	X				X			X					X	Arena
Aramyan, Vorest & Lans (2009)	X	X		X		X														X	
Memari, Anjomshoae, Galankashi and Rahim (2010)		X		X		X	X		X						X		X		X		Arena
Zhao Cong (2009)			X	X		X		X	X				X				X		X		Arena
Patil, Jin & Li (2011)			X					X	X										X		Arena
Persson, Olhager (2002)	X	X		X				X	X				X				X	X	X	X	Taylor II
Al-Aomar, Al-Refaei, Diabat, Faisal, and Alawneh (2014)		X		X			X				X										Witness
Agarwal and Shankar (2005)		X		X		X	X														Ithink

4.6.3. GAP IDENTIFICATION AND SURVEY ANALYSIS

As seen in the above survey table only Aramyan , Meuwissen , Lansink (2009) considers quality of good/service the remaining researchers neglect the criteria or assumes as there is no quality problem in the supply chain which definitely violets cases like the Ethiopian leather industry which is suffering from the poor quality of raw hide and skin and significantly affects the performance of leather industry. Hence the model that is going to be developed here will include quality criteria as a performance measurement by quantifying it.

Even though all the eight key performance indicators of the supply chain are necessary to measure the performance of Ethiopian leather industry, according to a survey conducted in the industry quantity, quality, cost and lead time and tanneries capacity utilization are identified in the order of seriousness by keeping in mind the uncertain environment in different scenarios. So as this paper will use these evaluation criteria to measure the performance of the Ethiopian leather industry.

The source of raw materials is not limited in this study. There are millions of hide and skin producers, thousands of small collectors and hundreds of hide and skin traders which supply the material to tanneries. Therefore a compressed and aggregated data is collected which can belong all these from the case tannery and its few big suppliers located in Addis Ababa and Region. In this research the variety of input is assumed to be one, raw hide and skin.

The other basic concept in supply chain management is the availability of the required raw material/resource in sufficient. Even though resources are limited in real world only two of the research articles [Nikolopoulov & Ierapetritov (2012), Mobini, Sowlati, & Sokhansanj (2013)] assume there is limitation of resources in the supply chain network. For the case of Ethiopian leather tanneries will never find fresh hide end skin when needed in sufficient amount. Raw hide and skin is available when meat is needed due to it's by product nature. This supply some time has a seasonal behaviour. There will be abandon hide and skin during New Year, Christmas and Easter. Therefore the assumption of supplying unlimited resource will never do for the case of Ethiopian leather so as the simulation modelling in this study will consider the resource constraint of hide and skin.

One can note that works on SC simulation usually lack detailed description on what the SC models considered, stages, functions, interactions among the companies, production and logistics rules adopted (as, for instance, minimum truck load, production or safety stock levels, order processing times, bullwhip effect). Lots of simplifications are made, like, single product, no bill-of-material; a product is made of only one component or raw material, one or two SC stages", or "no order, transportation and/or production lot sizes, demand is constant or well known, etc. The supply chain simulation models overcome these (and other) simplifications.

In fact, usually the literature on SC simulation shows very little detail on how to simulate the intricacies inherent of supply chains. Authors mention results, but lack detailed explanations on how they have built the supply chain simulation structure.

According to Guilherme Ernani Vieira (2004) to make it trustworthy, a supply chain simulation model has to consider, at least four SC stages: Customers, Retailers (wholesalers or distributors), Manufactures and Suppliers.

- ✓ Different customer demand behaviours;
- ✓ Different product types;
- ✓ For each product type, different bill-of-materials (each product is manufactured from different raw materials and/or components;
- ✓ Minimum production lot sizes;
- ✓ Safety inventory levels;
- ✓ Several retailers and suppliers;
- ✓ Information and material (components or products) flows:
- ✓ Distribution (delivery) lead-times; and
- ✓ Minimum order and delivery quantities.

This research will adopt those recommendations in the development of simulation model so as in the experiment design regardless of the scope of the study.

None of the reviewed articles try to create balance between the supply quantity and the inventory level for perishable goods. For the case of Ethiopian leather industry supply chain the either the fresh or salted hides or skins are considered as a perishable product. Meaning unsalted fresh hides and skins should never been stored for more than a day and fifteen days on average after salt is applied. If stored for more the quality of the raw material will be degraded or deteriorated. To overcome these and other challenges there should be a balance between the amount of on hand inventory and the quantity of the raw material received per unit time by considering the daily demand of the tanneries while keeping the limitation of the resource (not found in the required quantity when required) under consideration.

This research is basically focuses on handling this situation by developing a validated simulation model with the help of Arena software and testing different scenarios/experiments to see the operating performance of the tanneries with a reasonable amount of raw hides and skins in their stocks. This is done by developing four scenarios by varying the time between consecutive orders and the quantity of shipment per unit order.

Based on these facts which are generated in the output report of the simulation decision makers in every echelon of the supply chain to analyze and predict their future fate. It is quit helpful to make decision based on facts rather than assumptions even for long term strategic planning.

CHAPTER FIVE

DEVELOPMENT OF SIMULATION MODEL FOR THE LEATHER INDUSTRY

5.1. INTRODUCTION

It is obvious the leather industry supply chain starts from animal husbandry to the ultimate customers of leather and leather products located worldwide. In the context of Ethiopian leather industry supply chain, various problems regarding the sector mainly focus on the supply of raw hide and skin. As described earlier the Ethiopian tanning industry is suffering from shortage of raw hide and skin, poor quality of the raw material arising from animal husbandry up to the recovery and transportation, as well as the uncontrollable price hikes of raw hide and skin. According to International Trade Centre (ITC) African platform report (SWOT analysis of Ethiopian Leather) among the listed ten treats of the sector seven (70%) of it is directly related with lack of integrated and well managed supply chain of the sector. It is worthwhile to elaborate and analyze the behaviour of the leather supply chain under study. Most scholars also conclude that to improve the supply chain performance it is best to start from upstream so that this paper focuses on.

Building a simulation model requires the development of an appropriate model of one or more of the three sub-systems (physical, information and control) which is implemented on a computer. As illustrated in chapter four of this research the development of a simulation model should follow a logical, systematic process. This study adopted Kim, et al (2004) recommendation while developing a simulation model. Here below the eight basic steps which are implemented to develop Arena simulation model for Ethiopian leather industry for the case of Dire tannery.

5.2. FORMULATING THE PROBLEM & PLANNING THE STUDY

Due to the limited resource of Hide and skin in the country, unlike other manufacturing industries which are engaged for production if they have enough market for their products, the driving force to get the tanneries operational is the availability of the major raw material in their warehouse (input buffer). According to the information from Dire tannery they have never been failed to operate due to market problem rather shortage of raw hide and skin. Therefore the first assumption for this model is to take finished leather demand unlimited so as there won't be excess finished leather inventory in the tannery output buffer.

This study specifically focuses on a four echelon supply chain with two nodes in two of the echelons which include Addis Ababa and regional small traders of hides and skins, Dire Hide and Skin Procurement and Collection Centre (DHSPCC), regional big suppliers and the company (Dire Tannery) itself. The general framework of the supply chain under study is depicted in the figure below.

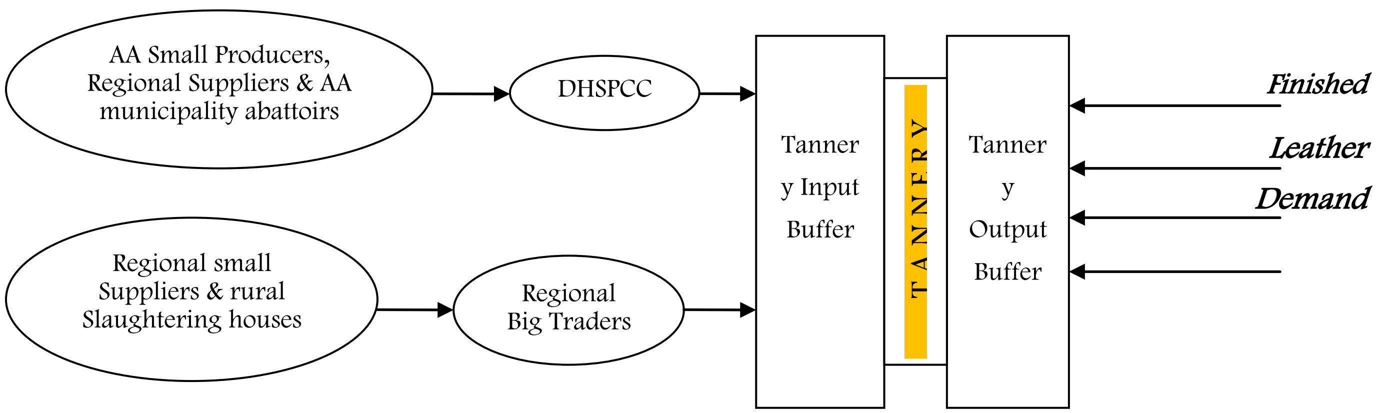


Figure 5.1: General framework of the supply chain under study

Those individual producers located in Addis Ababa and some other regional small traders of hide and skin would supply the raw material for big traders of located in Addis Ababa. After collecting some amount hide and skin those Addis Ababa suppliers forward to Dire Hide and Skin Procurement and Collection Center (DHSPCC) which is located in Tekilehaimanot, Addis Ababa after receiving order from the downstream ones. DHSPCC also collects fresh hide and skin on daily basis from Addis Ababa municipality abattoir by participating on a bid which is held monthly. DHSPCC then send shipment to the tannery after receiving an order from tannery through phone with minimum amount of order quantity set by the tannery which is 1000 sheep skins on average (full load tannery truck).

The Regional Big Suppliers (RBS) of Dire tannery are a lot which are distributed all over the country. Some of the suppliers come from sellalie, Jima, Gojam and Wollo. These regional big traders will receive collected skins and hides from the small ones and rural slaughtering houses on daily basis without quantity restriction. Those regional big suppliers of hide and skin will ship a full truck load of 4000 sheep skins on average after receiving order from the tannery. If the inventory level of the RBS is less than the economic order quantity (EOQ) of the tannery the order will wait until the stock is replenished.

The tannery should have to strive to fulfil the daily demand of raw hide and skin to produce with its full installed capacity. If there is any gap in the supply chain the tannery would be forced to operate under capacity or may be starved at all. Keeping in mind these processes there are a number of activities performed from hide and skin collection to tannery supply figure 5.2 (Conceptual model) depicts the detail processes and activates of the supply chain until it reaches to the tannery.

5.3. CONCEPTUAL MODEL DEVELOPMENT

First step in each simulation modelling is building conceptual model. In fact, modeller should identify and gather all the details and formulations that are necessary for the model in mind map and then convert all of them into simulation software. Here is the detail description of the conceptual model derived from the general frame work of the supply chain which is shown above in figure 5.1. The conceptual model is also depicted in figure 5.2 below so that it is converted to computer simulation model with the help of arena simulation software. The objective is to capture the system logic and data necessary for the simulation modelling activity.

Those big traders of hide and skin which are located in Addis Ababa and also confirmed as a supplier for DHSPCC collects hide and skins from AA small suppliers of Addis Ababa and region. Even though these suppliers are a lot in number for the case of this research they are considered as a single supplier to DHSPCC and the data is collected as an aggregate value. Not only Addis Ababa traders DHSPCC also collects fresh hide and skins daily from Addis Ababa municipality abattoir by participating on bid available monthly. Most of the time the AA suppliers didn't wait order from DHSPCC so DHSPCC didn't send order to them, rather the suppliers send shipment to DHSPCC daily for what they have on hand. Order may be sent to upstream suppliers if and only if there is a gap and delay. The same is true for regional suppliers which collect fresh and salted hides and skins from regional small suppliers, individual producers and rural slaughtering houses. When skins are transported to DHSPCC from Addis Ababa suppliers and abattoir there is a delay time for loading, unloading transporting and grading the skins in terms of quality. The average and aggregated delay time for all the system is tabulated in the next data collection part of the thesis.

Skins are graded as grade I-III if the status of the skins are good and considered as good quality skins and grade IV for those skins with different defects and considered as poor quality skins which are subjected to further price negotiation but not rejected at all. In the DHSPCC these skins are salted and separately palletized for the ease of shipping it to the tannery when needed. When order is arrived to DHSPCC from tannery it will ship the required amount but not less than economic order quantity which is 1000 sheep skins which is assigned to use full truck load. If there is high scarcity of the raw material in the tannery shipment may be less than the specified amount of sheep skin. If inventory level of DHSPCC is less than the economic order quantity (EOQ) of the tannery the demand may be lost and wait until the inventory is replenished.

When regional big suppliers receive order from the tannery they automatically send shipment ship if and only if their stock status is greater or equal to EOQ of the tannery from region. If there is no enough stock the demand is backordered and wait for inventory replenishment. The average and aggregated delay time for loading, unloading, transporting and inspecting for quality is tabulated below with some assumptions.

The tannery has its own warehouse for stocking the raw hides and skins from both directions (DHSPCC and Regional Suppliers). To be safe the tannery has willing to have a stock level of skins for three or four days of production. It should not also have to stock of skins more than fifteen days of production since the quality of salted skins will deteriorate after fifteen days of stock. This value may vary due to the weather condition. If the climate is cold the skins may wait more than fifteen days with good position. Those skins assigned as poor quality (Grade IV) are allowed to dry with sun/air and stocked separately in the tannery warehouse so that it will be subjected to production when there is scarcity of the resource.

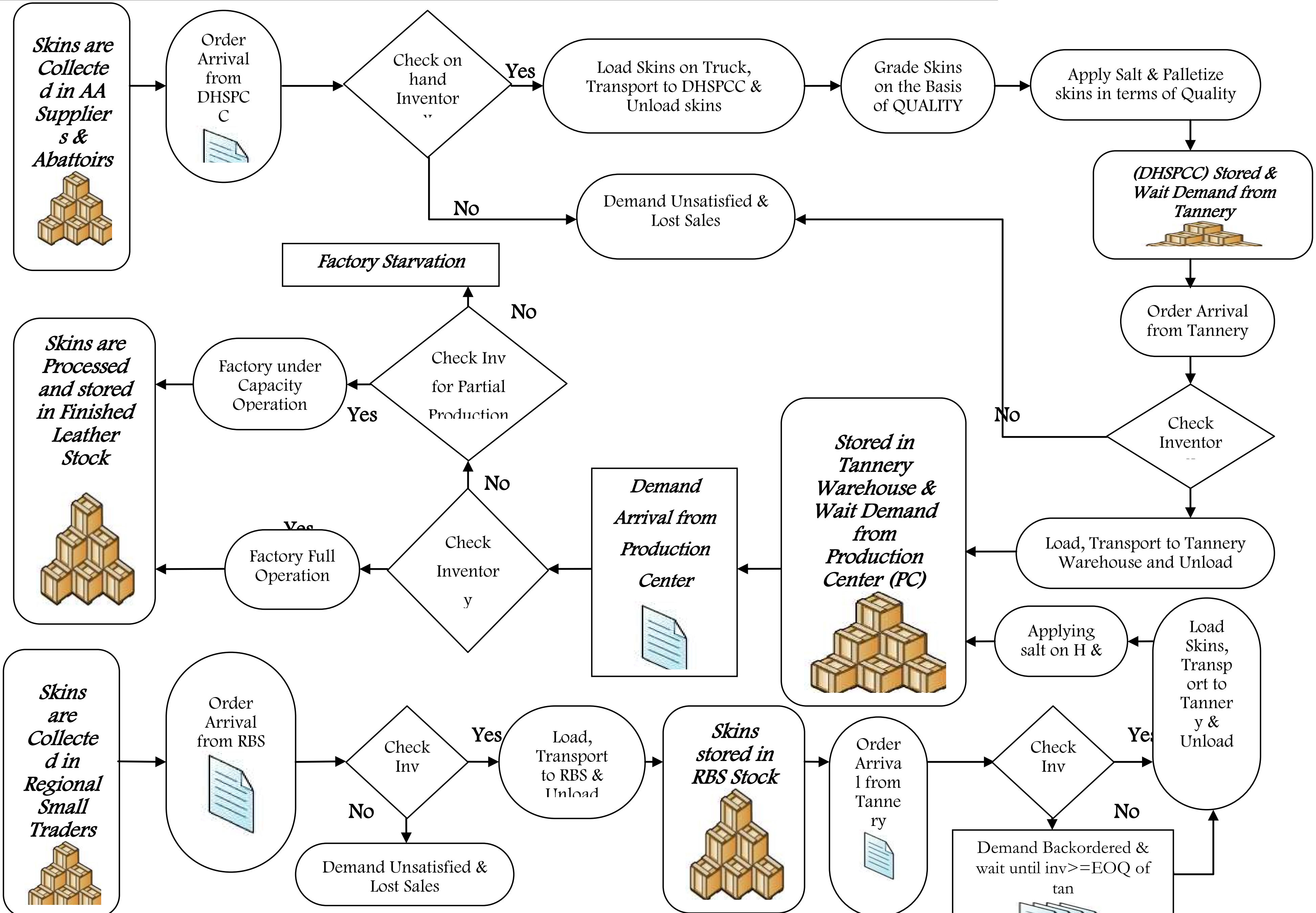


Figure 5.2 Conceptual model of the supply chain

With this in mind the tannery has to get average 6000 skins daily to continue the factory full capacity operation. If the factory lacks to access this amount of raw skins it will be forced to operate under capacity with average 3000 skins by neglecting one of the socking drums. Again if the tannery has no a daily stock for under capacity operation i.e. less than 3000 skins on average the tannery will be starved at all and forced to go for other operations rather than socking which is the first process for production of finished leather.

5.4. OBJECTIVES OF THE MODEL

The tannery is facing with two conflicting objectives. These are

a) Collecting bulk amount of skins from all over the country and avoiding factory under capacity operation and starvation.

b) The tannery raw skin stock should not exceed quantity for fifteen days of production because of quality deterioration of skin if stored more than fifteen days since wet skins are considered as a perishable good.

Therefore the tannery should have to balance these two objectives. To do this it is obvious to create variation in the quantity of skins order from upstream suppliers and the time at which the order is placed and check for the average daily inventory level of the tannery and its operation performance in terms of capacity utilization (full operation, partial operation or starvation). Four scenarios with different values each are designed and tested which can help decision makers to select the best inventory replenishment strategy that can balance the two conflicting objectives. The current tannery strategy of inventory replenishment is also tested and analysed. Keeping all this in mind the objective of this model is to measure the performance of the tannery in terms of capacity utilization and inventory level in each tier by considering the quality of skins and the lead time at which the skins are able to reach in the tannery.

While developing the model the limitation of the resource, the uncertain behaviour of raw material availability, transportation and other delays (loading and unloading delays, pelletizing delay, salting delay) and the cost in terms of order quantity are under consideration to measure the tannery operating performance in terms of capacity utilization and inventory level. The purchasing price is neglected because of the government has posed a maximum price for a unit skin that the tanneries should have to purchase, i.e. 65 Birr.

5.5. COLLECTING THE DATA & DEFINING THE MODEL

One of the challenging tasks in modelling and simulation is collecting data that is relevant or simulation. Most of the input data required for arena model is not raw data rather it is in the form of probability distribution. This can be achieved with the help of input analyzer which is the part of the software. To do so there should be at least twenty observations to get a relevant and valid distribution in order to develop the mathematical and logical relationships in the model. The necessary data is collected from the tannery and the suppliers of the tannery through document revision and discussion with the experts of the tannery as well as the suppliers. But with some extent there is data which is inaccessible from the case company. Therefore this research takes some assumptions with the help of logic by discussing and interview with the delegated experts in the supply chain of the hide and skin. The major data required for running the simulation and get relevant output based on the objective of the research is

a) The daily skin collection capacity of those suppliers of DHSPCC which are located in Addis Ababa
b) The daily skin collection Capacity of regional small suppliers which supply for the regional big traders
c) The daily skin demand of the tannery required for processing for partial and full production (tannery daily raw material consumption)
d) The percentage of raw skins which are graded as good quality skins (Grade I-III) and poor quality skins (Grade IV) which is collected from each source.
e) The total lead time to supply the skins from AA suppliers to DHSPCC and from regional small suppliers to the big ones.
f) Time taken to forward raw material from DHSPCC to tannery and from RBS to tannery and
g) The existing inventory replenishment policy of the tannery and the middlemen suppliers.

The first four data is collected from the tannery and the suppliers' record and the remaining are taken as an assumption with interview and discussion from the delegated personnel with convincing justifications due to lack of recorded data.

The first step to collect data is to determine the number of observations that the data should include. To decide this in Ethiopian leather industry context it is very important to understand the behaviour of the production of the raw hide and skins all over the country. For this matter as most scholars and those business men who are engaged on raw hide and skin marketing agreed, due to its by-product nature of the skins it is available when meet is needed. This by-product nature of skins makes them available in the market with seasonal behaviour. In general skins are available in bulk when there is religious and national holiday festivities in the country like New Year, Christmas, Easter etc. Therefore to collect a representative data it is mandatory to have at least twelve months of observation so as implemented in this research. Here below is tabulated data for skin collection capacity of Addis Ababa and regional suppliers by taking an assumption that there will not be a waste of skins in the middlemen (all collected skins are forwarded to the immediate receiver of the skins) collected from DHSPCC and tannery documentation. Hence a 365 days collected skin from AA suppliers and reached to DHSPCC is tabulated below. Nine months or 270 days of collected skin from regional suppliers is found recorded and the monthly data is distributed for the remaining 3 months or 90 days are based on the other month's distribution.

Table 5.1. Dire tannery Addis Ababa raw hide and skin collection centre suppliers collection report (2006 E.C)

Date	September		October		November		December		January		February	
	Accepted	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*
1	1423	3	278	0	851	3	281	0	788	11	1091	8
2	2309	3	314	0	1394	3	275	0	697	6	795	6
3	1172	8	339	0	1006	9	301	0	1142	11	671	5
4	1846	9	293	0	650	2	312	0	784	6	495	6
5	1329	3	734	0	685	0	243	0	1034	9	549	3
6	894	5	608	0	968	15	420	0	739	12	1122	15
7	1079	7	423	0	1264	13	367	0	657	4	729	1
8	703	0	373	0	915	4	308	0	907	23	1166	11
9	1123	19	323	0	974	9	296	0	599	3	809	6
10	956	7	406	0	907	6	305	0	632	5	1032	4
11	1068	13	365	0	612	1	326	0	1086	17	983	4
12	993	8	371	0	1110	3	384	0	971	10	605	1
13	769	10	305	0	888	1	194	0	798	3	1138	3
14	1085	8	361	0	873	14	396	0	560	3	800	2
15	751	6	261	0	896	7	325	0	860	5	1038	12
16	1061	14	383	0	732	6	295	0	600	9	722	3
17	1102	3	528	0	568	2	287	0	1008	11	631	6
18	1277	18	293	0	616	5	296	0	738	4	555	2
19	1043	8	217	0	796	10	294	0	796	4	599	3
20	976	8	437	0	536	3	466	0	532	8	566	16
21	851	11	338	0	888	6	252	0	610	0	607	4
22	715	0	338	0	698	4	218	0	949	14	587	8
23	863	13	615	0	751	15	270	0	650	2	433	3
24	590	4	618	0	756	17	2599	0	893	10	446	6
25	857	4	346	0	537	1	299	0	707	7	534	5
26	784	7	605	0	809	28	233	0	828	15	470	4
27	815	4	293	0	566	8	303	0	945	7	568	6
28	838	4	317	0	522	14	199	0	564	1	504	1
29	577	4	407	0	687	12	297	0	977	17	559	4
30	862	16	713	0	782	12	517	0	613	6	458	2

Date	March		April		May		June		July		August		Pagume	
	Accepted	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Accepted*	*Rejected*	*Acc*	*Rej*
1	507	5	502	2	966	3	838	5	624	9	573	4	1219	11
2	535	3	506	3	1441	3	828	5	439	3	453	2	664	6
3	500	1	540	4	608	4	798	3	820	7	458	2	932	1
4	619	8	556	3	866	6	567	0	472	4	324	0	1068	2
5	508	4	443	1	866	2	883	8	1174	15	474	4	769	1
6	562	6	485	6	839	3	590	1	1752	2	457	2		
7	440	5	479	2	849	6	882	12	879	10	411	2		
8	552	5	505	0	678	4	643	0	885	0	524	2		
9	524	9	672	7	881	11	824	13	499	0	488	2		
10	554	3	514	3	557	3	729	4	1053	11	596	4		
11	543	0	871	5	747	5	533	2	361	3	386	0		
12	577	3	2843	5	714	8	772	10	715	13	449	0		
13	568	13	392	2	764	6	624	1	622	3	487	4		
14	479	2	394	0	902	11	892	15	715	8	432	1		
15	538	1	695	1	849	5	583	2	771	6	595	5		
16	532	2	824	5	982	2	780	6	388	0	540	1		
17	475	3	847	5	782	4	807	6	827	12	2028	11		
18	586	2	904	5	911	7	558	1	449	7	803	4		
19	509	5	1032	10	914	7	823	3	628	18	606	0		
20	518	10	954	3	752	4	594	5	792	0	1005	10		
21	471	1	828	7	1028	4	976	12	936	6	573	0		
22	457	5	786	1	703	5	834	5	595	0	939	12		
23	491	3	954	3	1129	9	843	7	283	2	633	0		
24	499	2	918	3	768	2	648	3	792	6	1065	10		
25	524	6	944	4	806	8	286	0	392	0	859	1		
26	553	6	831	3	699	11	650	9	876	0	790	4		
27	670	2	803	6	692	5	440	5	662	4	835	6		
28	491	2	823	1	650	18	747	8	878	7	569	1		
29	610	6	708	4	885	7	578	7	849	4	872	14		
30	554	5	1000	7	1169	13	761	5	484	2	611	1		

As discussed earlier the goat skins are not processed in the case company rather collected and shipped to its sister company Modjo tannery. At the same time amount of hides collected is too small with relative to sheep skins so as the company focus. Due to this reason the model will consider only the supply of sheep skins in the supply chain system of the case company, Dire tannery. Below is a picture taken by a snipping tool from the Arena input analyzer software for determining the daily skin collection distribution of those suppliers of DHSPCC located in Addis Ababa. This is because of in simulation modelling, it is essential to determine which statistical distribution fits to the data. Here we should have to remember it is the aggregate value of all suppliers beyond DHSPCC. As we see in the figure 5.3 the skin collection capacity of Addis Ababa suppliers can be represented by a normal distribution with expression NORM(706, 322).

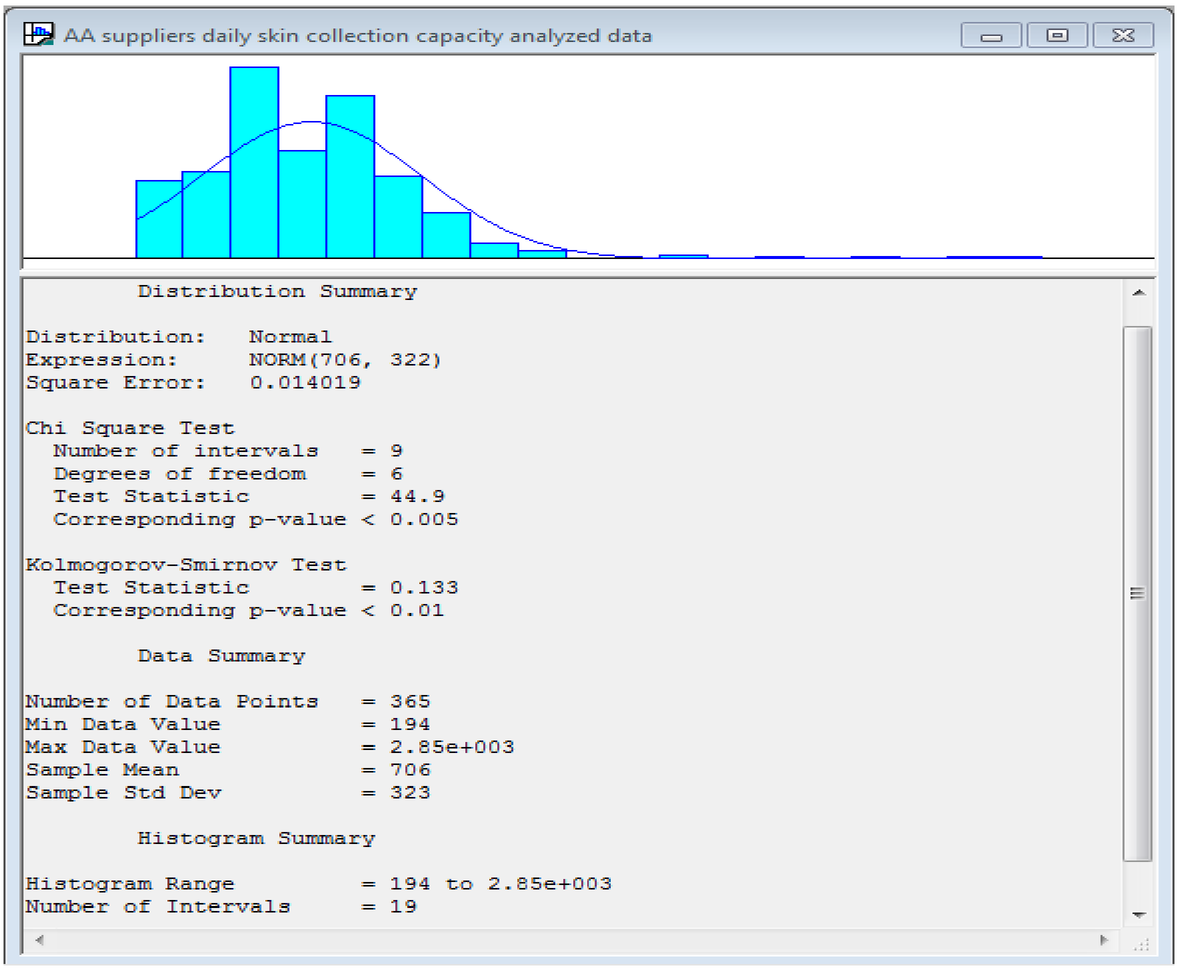


Figure 5.3 Probability Distribution of skin collection capacity of AA DHSPCC suppliers

To check the summery of all distributions Arena input analyzer has an option which compares the distributions in terms of the mean squire error which selects normal distribution a better match. Here below indicates the summary taken from the software.

AA suppliers daily skin collection capacity analyzed data - Fit All Summary

```
=================================================================
Fit All Summary
Data File: C:\Users\Toshiba\Desktop\Arena input  Analyzer\New DHSPCC.txt


Function        Sq Error
-----------------------
Normal          0.014
Weibull         0.0144
Beta            0.0154
Gamma           0.0178
Erlang          0.0196
Lognormal       0.0396
Exponential     0.0554
Triangular      0.0621
Uniform         0.103
```

Figure 5.4 Summary of AA DHSPCC Suppliers Skin collection capacity probability distribution

The percentage of rejects can be taken as a constant value of the average percentage of all the defective skins in the twelve months which is 0.674%.

The following table indicates the amount of sheep skins collected from regional suppliers including the amount of rejects on monthly basis.

Table 5.2 Dire Tannery regional suppliers' skin collection and supply capacity

Date	September		Total	October		Total	November		Total	December		Total	January		Total	February		Total
	Accepted	*Rejected*		*Accepted*	*Rejected*		*Accepted*	*Rejected*		*Accepted*	*Rejected*		*Accepted*	*Rejected*		*Accepted*	*Rejected*	
1	0	0	0	3255	1305	4560	0	0	0	2818	180	2998	0	0	0	458	29	487
2	869	35	904	0	0	0	0	0	0	4275	274	4549	2400	154	2554	5030	322	5352
3	0	0	0	0	0	0	30158	0	30158	3014	193	3207	0	0	0	0	0	0
4	496	20	516	590	0	590	11385	776	12161	7912	506	8418	1309	84	1393	1309	84	1393
5	0	0	0	0	0	0	297	32	329	14569	932	15501	561	36	597	5677	363	6040
6	0	0	0	706	331	1037	2072	0	2072	8147	521	8668	0	0	0	0	0	0
7	0	0	0	1190	34	1224	3754	1253	5007	7367	471	7838	16143	1033	17176	16143	1033	17176
8	26897	3883	30780	1950	0	1950	0	0	0	3082	197	3279	10396	665	11061	5396	345	5741
9	14000	204	14204	0	0	0	6065	422	6487	0	3	3	0	45	45	0	0	0
10	1497	454	1951	0	0	0	0	0	0	9305	596	9901	0	0	0	2541	163	2704
11	2474	0	2474	0	0	0	297	128	425	1326	85	1411	13169	843	14012	13169	843	14012
12	0	0	0	5451	13	5464	8884	1383	10267	8384	537	8921	3476	222	3698	3476	222	3698
13	3772	98	3870	15797	2833	18630	2012	113	2125	0	0	0	16643	1065	17708	6643	425	7068
14	29137	269	29406	657	51	708	3467	816	4283	396	25	421	8147	521	8668	8147	521	8668
15	3400	404	3804	2318	1006	3324	0	0	0	325	21	346	15913	1018	16931	15913	1018	16931
16	5739	837	6576	1873	611	2484	940	105	1045	13057	836	13893	2000	128	2128	2000	128	2128
17	0	0	0	0	0	0	4805	309	5114	945	60	1005	0	0	0	0	789	789
18	0	0	0	1915	176	2091	27082	3421	30503	296	19	315	8553	547	9100	8553	547	9100
19	0	0	0	1425	80	1505	386	66	452	789	50	839	11492	735	12227	11492	735	12227
20	9060	359	9419	0	0	0	3857	196	4053	466	30	496	7142	457	7599	7142	457	7599
21	6468	1767	8235	0	0	0	11653	143	11796	10256	656	10912	2911	186	3097	2911	186	3097
22	41493	130	41623	6218	210	6428	0	0	0	0	0	0	18300	1171	19471	18300	1171	19471
23	0	0	0	14822	1709	16531	8978	1093	10071	270	17	287	6611	423	7034	7611	487	8098
24	0	0	0	0	0	0	0	0	0	12599	806	13405	1091	70	1161	1091	70	1161
25	3694	120	3814	677	314	991	0	0	0	999	64	1063	3890	249	4139	3890	249	4139
26	0	0	0	2857	227	3084	886	51	937	1837	118	1955	1204	77	1281	1204	77	1281
27	3052	0	3052	110	27	137	17158	1582	18740	14568	932	15500	3152	202	3354	3152	202	3354
28	1094	25	1119	13871	123	13994	0	0	0	1969	126	2095	5039	322	5361	295	19	314
29	6865	1785	8650	13450	93	13543	7892	467	8359	9977	639	10616	0	0	0	8943	572	9515
30	13670	1473	15143	0	0	0	10820	1670	12490	5170	331	5501	1943	124	2067	0	478	0

Date	March		Total	April		Total	May		Total	June		Total	July		Total	August		Total
	Accepted	*Rejected*	**Total**	*Accepted*	*Rejected*	**Total**	*Accepted*	*Rejected*	**Total**	*Accepted*	*Rejected*	**Total**	*Accepted*	*Rejected*	**Total**	*Accepted*	*Rejected*	**Total**
1	2228	118	2346	0	0	0	0	0	0	1508	175	1683	987	59	1046	1105	500	1605
2	12548	15	12563	4396	335	4731	26030	631	26661	0	0	0	2450	147	2597	2744	165	2909
3	158	10	168	1642	76	1718	0	0	0	0	0	0	25456	45	25501	25546	1533	27079
4	4589	0	4589	0	0	0	1309	12	1321	32674	850	33524	11385	683	12068	12751	765	13516
5	789	50	839	0	0	0	5677	36	5713	961	34	995	297	18	315	333	20	353
6	4478	287	4765	5036	26	5062	0	0	0	2347	598	2945	2072	124	2196	2321	139	2460
7	3658	98	3756	6939	1081	8020	16143	690	16833	0	0	0	3754	225	3979	4204	252	4457
8	20789	145	20934	1616	0	1616	20396	1055	21451	0	0	0	0	0	0	0	0	0
9	5789	78	5867	13041	552	13593	0	0	0	4250	302	4552	6065	364	6429	6793	408	7200
10	89	6	95	0	0	0	0	0	0	52828	1364	54192	0	0	0	0	1879	1879
11	787	50	837	361	0	361	13169	396	13565	0	0	0	297	18	315	333	20	353
12	10594	678	11272	0	0	0	3476	113	3589	10343	260	10603	8884	533	9417	9950	597	10547
13	9875	632	10507	0	0	0	16643	354	16997	9725	0	9725	2012	121	2133	2253	135	2389
14	5786	370	6156	0	0	0	8147	49	8196	3454	178	3632	3467	208	3675	3883	233	4116
15	2581	417	2998	0	0	0	21913	1462	23375	0	0	0	0	0	0	0	7894	7894
16	2674	417	3091	0	0	0	2000	126	2126	3843	1190	5033	940	56	996	1053	63	1116
17	19414	100	19514	2039	0	2039	0	0	0	3530	180	3710	4805	288	5093	5382	323	5704
18	3861	492	4353	0	0	0	8553	230	8783	3919	143	4062	22082	689	22771	23460	1408	24868
19	0	0	0	0	0	0	11492	221	11713	17869	338	18207	386	23	409	432	26	458
20	3206	329	3535	6295	251	6546	7142	347	7489	7513	355	7868	3857	231	4088	4320	259	4579
21	0	0	0	11662	0	11662	2911	153	3064	0	0	0	11653	87	11740	11827	710	12537
22	12121	287	12408	7856	139	7995	18300	1642	19942	0	0	0	0	0	0	0	0	0
23	5400	479	5879	0	0	0	24611	143	24754	114	1	115	8978	54	9032	9086	545	9631
24	3559	306	3865	24511	134	24645	1091	0	1091	1861	53	1914	0	2	2	12589	755	13344
25	0	0	0	0	0	0	3890	15	3905	0	0	0	0	4	4	9785	587	10372
26	3931	458	4389	0	0	0	1204	92	1296	912	94	1006	886	53	939	992	60	1052
27	909	56	965	0	0	0	3152	177	3329	11094	87	11181	17158	29	17187	19785	1187	20972
28	0	0	0	6678	193	6871	295	312	607	23148	1278	24426	0	0	0	0	3489	3489
29	3587	406	3993	2182	190	2372	8943	122	9065	0	0	0	7892	474	8366	8839	530	9369
30	4100	360	4460	19732	608	20340	0	0	0	0	0	0	6820	0	6820	9004	540	9544

With the same fashion as above the daily collection capacity of regional small suppliers can be represented by a probability distribution with the help of input analyzer, Arena software.

The aggregated and daily skin collection capacity of regional suppliers can be represented by a Beta distribution with expression -0.001 + 5.42e+004 * BETA(0.395, 3.4) and mean Square Error: of 0.006574.

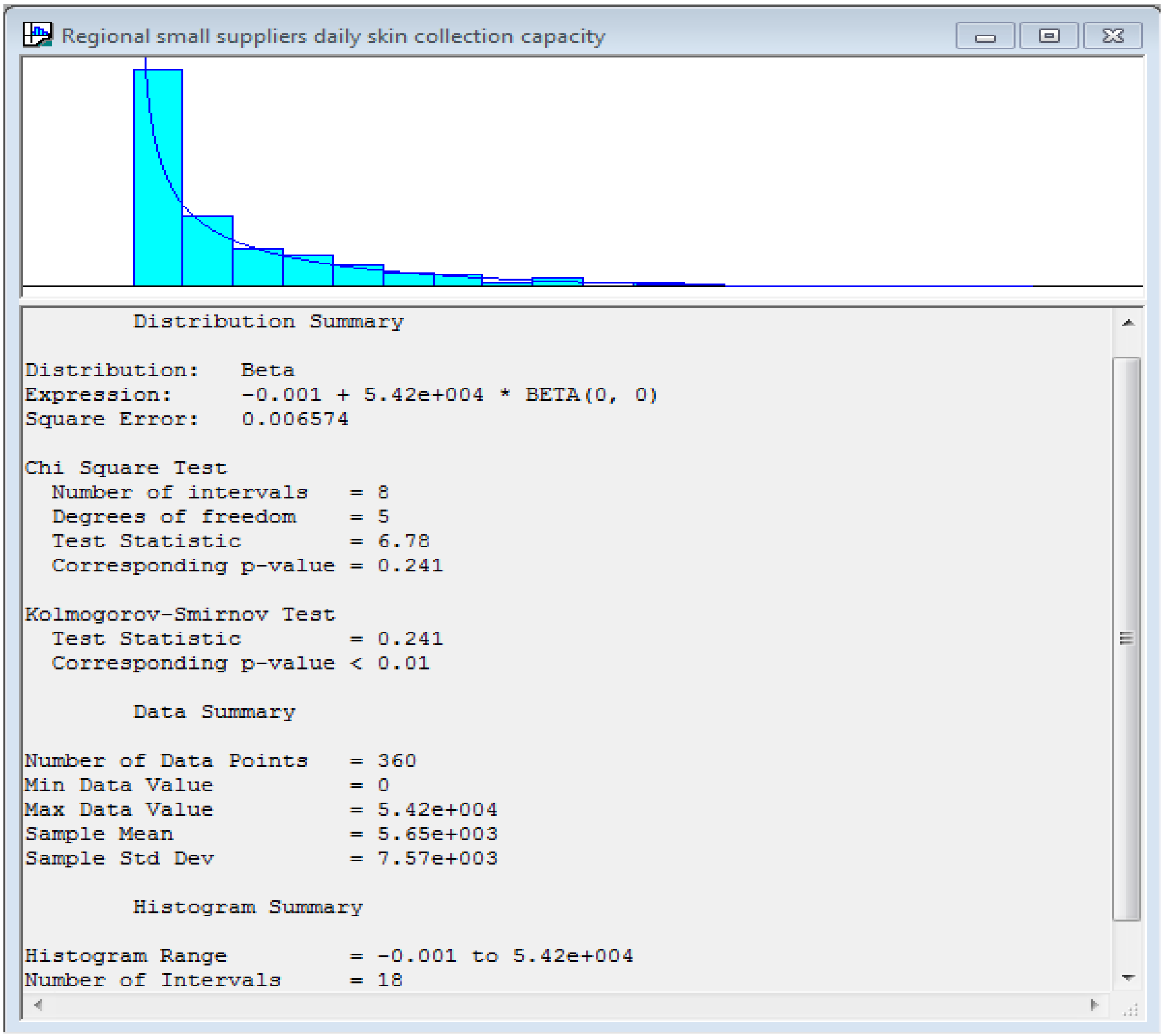


Figure 5.5 Probability distribution of RSS skin collection capacity

Even though the installed socking capacity of the case company is considered to be 6000 skins per day, it is not always the same even if there is enough stock. The skins are weighted before inserted in to the socking drum so that it should not exceed the maximum loading capacity of the drum. The following table indicates daily sheep skin demand of the tannery for production in the month of June 2006.

When there is limitation of the raw material the tannery offs one of the socking drums and keeps operating with one by reducing the socking capacity exactly by half.

Table 5.3 The daily sheep skin demand of Dire Tannery

Date (June)	Tannery Demand on Due Date	Remark
1	6000	
2	5000	
3	5000	
4	5000	
5	5000	
6	5500	
7	6000	
8	5500	
9	5500	
10	6000	
11	6400	Reject skin
12	5400	
13	6000	
14	5000	
15	5000	
16	6000	
17	5300	
18	5500	
19	6000	
20	5000	

The production center demand can also be represented by a probabilistic distribution by following the methods applied earlier with the help of input analyzer of Arena software. Therefore the full production batch size distribution is exponential with expression: 5e+003 + EXPO (505) and mean Square Error: 0.076645 and with the same fashion the partial production batch size follows exponential distribution with expression 2.5e+003 + EXPO(253).

5.6. MODEL ASSUMPTIONS

According to Persson, Olhager (2002) in all simulation studies it is relevant to specifically point out the model assumptions made in order to get the simulation model to operate. In this study we will take some general model assumptions and other data related issues which are inaccessible in any of the sources with justifiable reasons. Here below are some of the assumptions considered in simulating and modelling of the Ethiopian leather industry.

- All the collected data at the upstream suppliers will be forwarded to the immediate downstream receiver of the goods without any wastage and reduction of the quantity of skins.
- Grading criteria of skins for quality is considered all the same in any of echelons in the supply chain.
- The manufacturer working time is 24 hours per day and 7 days per week.
- The demand for finished leather that is produced in the tannery is unlimited. That means there will never be market problem for finished leather so as the production process will not stop production due to marketing problem.
- The transhipment lead times are assumed to be normally distributed.
- The tannery is assumed using a continuous review inventory policy.
- At all echelons, orders are received in the order they were placed (no overtaking takes place). In fact, an order shipment is launched only after the previous one is received at its destination.
- If the full order is not available as per EOQ of the tannery, there is no shipping of partial orders. In brief order shipment will be deferred until the full order becomes available.
- The production process experiences no technical failures. Meaning no down time of socking drum.
- The suppliers are assumed to be loyal for the Mother Company /tannery.

Here below are some of other assumptions included in the simulation modelling with justifications due to lack of recorded data in any of the supply chain shareholders.

Table 5.4 Assumed data for the model with justification

S.No.	Data Type	Description	Quantity
1	Minimum Reorder Level of Tannery Warehouse	Skin remaining for 3 to 4 days of Production	16000
2	Minimum Order Quantity of Tannery from regional suppliers	One truck full skin (big truck)	4000
	Minimum Order Quantity of Tannery from DHSPCC	One truck full skin (medium truck)	1000
3	Common transhipment delay if order is from DHSPCC	Loading, Unloading, transportation	Uniformly Distributed 3-6 Hours
4	Common transhipment delay if order is from Rural Suppliers	Loading, Unloading, transportation and inspecting for Quality	Uniformly Distributed 0.25-1.25 Days
5	Shipment of order from AA suppliers and abattoirs to DHSPCC	All what they collect at each day	Daily
	Shipment of order from regional small suppliers and slaughtering houses to Regional Big Suppliers	All what they collect at each day	Daily
6	Target stock of the tannery	15 Days of Production to keep quality of salted skins	UNIF 75000-90000

5.7. MODEL VALIDATION

Validation is part of the total model development process and is itself a process. The most important issue arises from the fact that simulation involves experimentation on a model, and not on the real system of interest. If the results of a simulation are to be of any value to obtain insight into the real system it is vital to ensure that the model is a sufficiently good representation of reality. Because a model is (by definition) different in some respects from the real system it represents it is vital that the model is built such that the model's behaviour reflects that of the real system sufficiently well for the specific purpose. Validation is an attempt to answer the question: "does this model (whether in its verbal, diagrammatic or computer form) adequately represent the real system of interest for the specific purposes of the study?"

To answer this and other model validity question the only way is to consult tannery and supplier experts on the subject. I just have discussed those experts who have been working for more than ten years in the raw hide and skin section of Dire tannery. At the same time I spent days in DHSPCC and tannery ware house to discuss and share information about the supply chain network of the raw material. All of them agree and approve that the current diagrammatic representation of the supply chain on figure 5.2 could represent their activity in the business so that they approved the validity of the model. Kim, et al (2004) argued it is not feasible to determine that a model is absolutely valid over the complete domain of its intended application. Instead, a sufficient degree of confidence is enough for validation of the model. But this study model couldn't face any validity challenge from the concerned bodies.

5.8. CONSTRUCTING A COMPUTER SIMULATION MODEL

In a simulation study computer modelling of the system is an inevitable task of model development and solution procedure. This can be done with either general-purpose programming languages or simulation packages. In the system under study Arena software (Rockwell's Automation Software) is used to develop a computer simulation model so as to run and test experiments on the supply chain system under study. Even though the preliminary model is developed with academic version of Arena the final model is developed with cracked Arena master development version.

The system under study is too complex than modelling manufacturing systems (Inventory and production management) because the Arena model of the study is composed of seven segments or sub-models, each associated with an inventory-holding buffer in a system echelon. Each sub model is subjected to the following events: order arrival, inventory updating, replenishment order triggering, and order shipment. Figure 5.6 displays all the variables of the developed Arena model. Random initial values for some variables are provided to activate the model at the start up period.

Variable - Basic Process

	Name	Rows	Columns	Data Type	Clear Option	Initial Values
1	Socking Ship Skins or Production			Real	System	0 rows
2	Good Quality Warehouse Inventory			Real	System	1 rows
3	EOQ of the Warehouse from DHSPCC			Real	System	1 rows
4	EOQ of the Warehouse from Regional Big Suppliers			Real	System	1 rows
5	Good Quality Inventory Position of DHSPCC			Real	System	1 rows
6	Good Quality Inventory Position of Regional Big Suppliers			Real	System	1 rows
7	Place Order to DHSPCC			Real	System	0 rows
8	Place Order to Regional Big Suppliers			Real	System	0 rows
9	Minimum Reorder point of Warehouse			Real	System	1 rows
10	Minimum Reorder point of DHSPCC			Real	System	1 rows
11	Minimum Reorder point of Regional Big Suppliers			Real	System	1 rows
12	Target Stock of the Warehouse			Real	System	1 rows
13	Target Stock of DHSPCC			Real	System	1 rows
14	Target Stock of Regional Big Suppliers			Real	System	1 rows
15	Place Order to AA DHSPCC Suppliers			Real	System	0 rows
16	Place Order to Regional Small Suppliers			Real	System	0 rows
17	Finished Leather Inventory			Real	System	1 rows
18	Inventory Position of Finished Leather			Real	System	1 rows
19	Finished Leather Inventory Target Stock			Real	System	1 rows
20	Minimum Reorder level of Finished leather			Real	System	1 rows
21	Grade IV Quality Skins Collected from Regional Small Suppliers			Real	System	1 rows
22	Regional Big Suppliers Good Quality Skins Inventory			Real	System	1 rows
23	Regional Big Suppliers Poor Quality Skins Inventory			Real	System	1 rows
24	Grade IV Quality Skins Collected from AA Suppliers			Real	System	1 rows
25	Good Quality DHSPCC Inventory			Real	System	1 rows
26	Poor Quality DHSPCC Inventory			Real	System	1 rows
27	Poor Quality Warehouse Inventory			Real	System	1 rows
28	Poor Quality Inventory Position of Regional Big Suppliers			Real	System	1 rows
29	Good Quality Warehouse Inventory position			Real	System	1 rows
30	Poor Quality Warehouse Inventory position			Real	System	1 rows
31	Poor Quality Inventory Position of DHSPCC			Real	System	1 rows
32	Backorder of Warehouse from Regional Big Suppliers			Real	System	1 rows
33	Collected Skin at Regional Small Suppliers			Real	System	1 rows
34	Partial Production Batch Size			Real	System	0 rows
35	Full Production Batch Size			Real	System	0 rows
36	Poor Quality Finished leather Production			Real	System	1 rows
37	Good Quality Finished Leather Production			Real	System	1 rows
38	Collected Skin at AA Suppliers			Real	System	1 rows
39	Demand for Finished Leather			Real	System	1 rows
40	Good Quality Skins Collected from Regional Small Suppliers			Real	System	1 rows
41	Good Quality Skins Collected from AA Suppliers			Real	System	1 rows
42	Skin Collection Capacity of Regional Small Suppliers			Real	System	0 rows
43	Poor Quality Skins Collected from Regional Small Suppliers			Real	System	0 rows
44	Skin Collection Capacity of AA Suppliers			Real	System	0 rows
45	Poor Quality Skins Collected from AA Suppliers			Real	System	0 rows

Figure 5.6 Dialog spreadsheet of the Variable module for the Arena model of the Ethiopian leather industry supply chain

Even though the sub-models are not directly wired each other, they are logically interrelated with the help of global variables. Next, I have described each model segment in some detail, starting with the extreme upstream echelon and moving downstream the supply chain.

5.8.1. INVENTORY MANAGEMENT SUB-MODEL FOR REGIONAL SMALL SUPPLIERS

The Regional Small suppliers are those suppliers of hide and skins to Regional Big suppliers by collecting hides and skins from home to home or other small suppliers. They are assumed to forward all the hides and skins collected to the bigger ones on daily basis. In general this sub-model or segment collects raw hides and skins from the surrounding, generates Regional Big Suppliers order, handles demand fulfilment of the Regional Big Suppliers (RBS), sends shipments from the regional Small suppliers to Regional Big Suppliers of the tannery and updates the RBS inventory level.

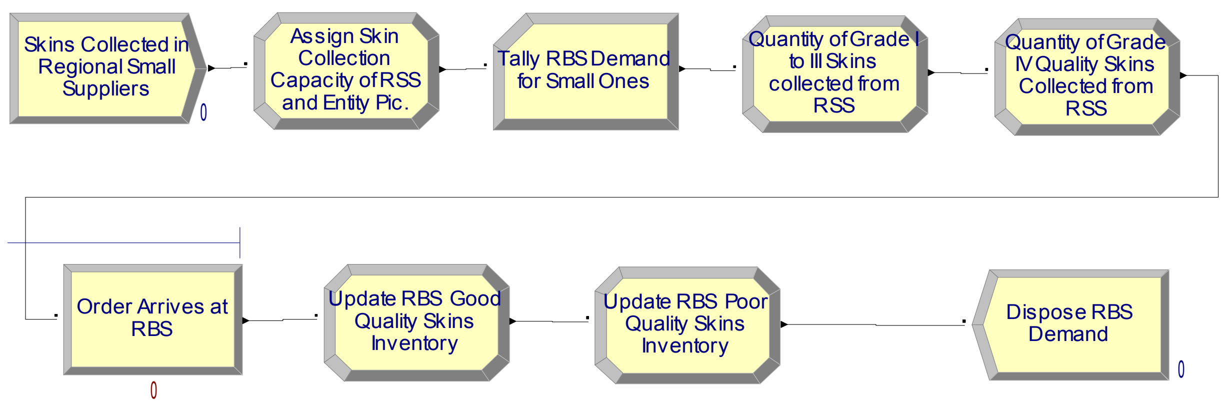
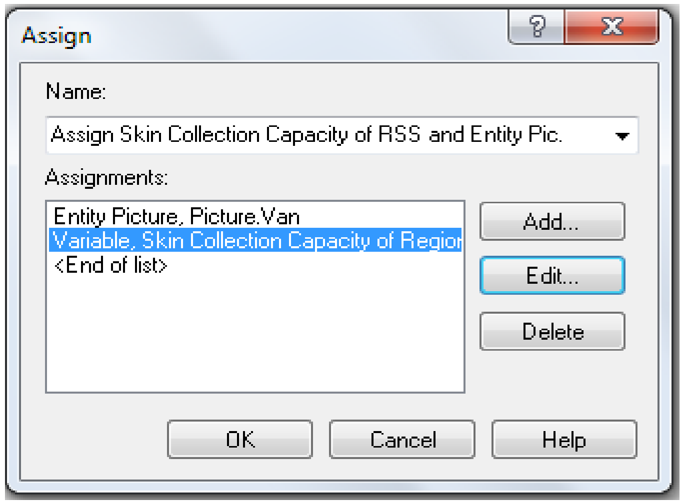


Figure 5.7 Arena model of Inventory Management segment for Regional Small Suppliers

As shown in the sub-model entities are created on the *Create* module called *Skins Collected in Regional Small Suppliers* on a daily constant manner and activates the *assign* module which is used to assign an entity picture and the skin collection capacity of the Regional Small Suppliers (RSS). As analyzed in the data collection part of this study the skin collection capacity of the Regional small suppliers follows a Beta distribution with expression -0.001 + 5.42e+004 * BETA(0.395, 3.4) and filled in the assign module as shown in the figure below.



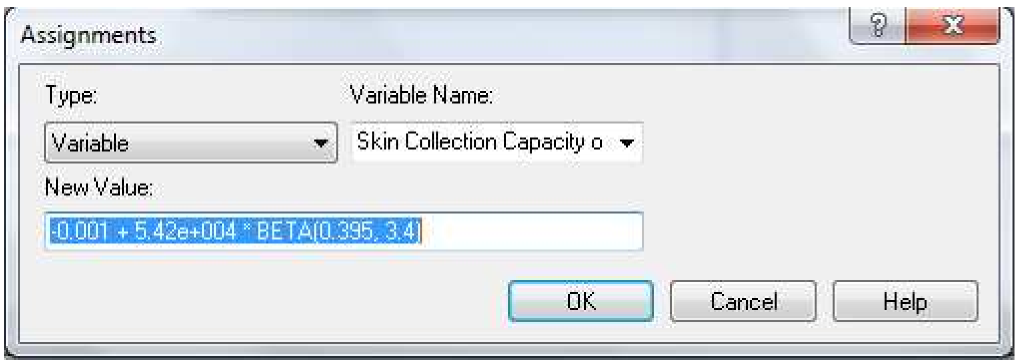


Figure 5.8 Dialog boxes of assign module "assign skin collection capacity of RSS and entity picture

The control entity next proceeds to the *Record* module *tally RBS demand for small ones* for the purpose of recording and collecting data regarding the number of orders that RBS places to RSS. Next RSS are subjected to give grade for the collected skins assigning in the assign module as either grade I-III or grade IV for those good quality and poor quality skins respectively. As described in the data collection part the ratio of poor quality skins and good quality skins to the total amount of skin collected from region is 0.064 and 0.936 respectively. Therefore the two consecutive *Assign* modules calculate the quantity of good and poor quality skins and forward it to the *Process* module *Order Arrives at RBS* which performs shipment and transportation to the RBS stock. As discussed and justified in the assumptions held earlier transportation to destination in RBS will take a uniform value of between 3-8 hours (UNIF (3, 8)). Then the control entity automatically proceeds to updating inventory of both types of skins (good and poor quality) available in Regional Big Suppliers stock in the two consecutive *Assign* modules. Finally the control entity will be disposed and the sub model will wait the creation of entity in the *Create* module next day and repeats all these processes until the end of the simulation time.

5.8.2. INVENTORY MANAGEMENT SUB-MODEL FOR AA DHSPCC SUPPLIERS

The basic modelling concept in this sub-model is similar with the previous one except the data input. The Addis Ababa DHSPCC suppliers are those suppliers of hide and skins which are located in Addis Ababa including Addis Ababa municipality abattoir and other individuals engaged in supplying the raw material to Dire Hide and Skin Procurement and Collection Center (DHSPCC). They are also assumed to forward all the hides and skins collected to DHSPCC on daily basis. In general this sub-model or segment collects raw hides and skins from the Addis Ababa and rural small suppliers, generates DHSPCC order, handles demand fulfilment of DHSPCC, sends shipments to DHSPCC and updates the DHSPCC inventory level. As described earlier the skin collection capacity of the Addis Ababa suppliers can be represented by a normal distribution with expression NORM(706, 322). The average percentage of good and poor quality skins collected in Addis Ababa suppliers is 0.99326 and 0.00674 respectively. Figure 5.9 below indicates the Arena sub-model of AA suppliers.

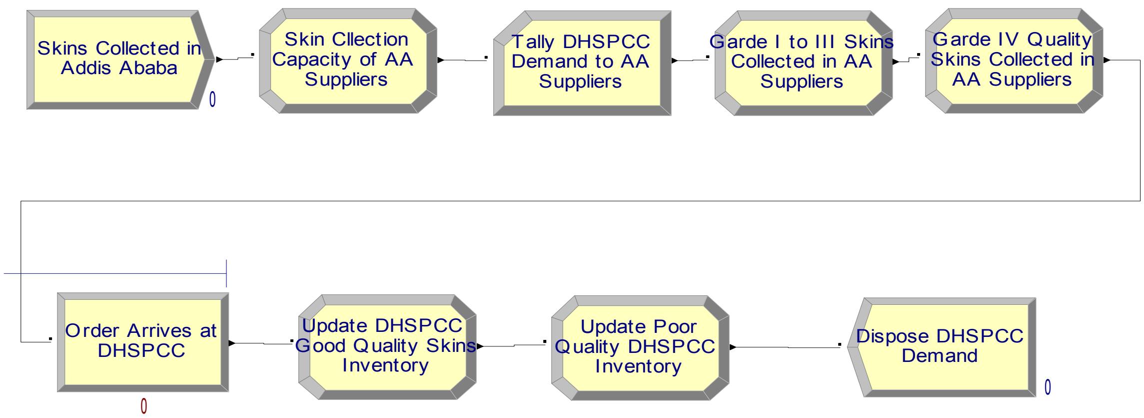


Figure 5.9 Arena model of Inventory Management segment for Addis Ababa DHSPCC Suppliers

5.8.3. INVENTORY MANAGEMENT SEGMENT/SUB-MODEL FOR REGIONAL BIG SUPPLIERS OF HIDE AND SKIN FOR THE TANNERY

As shown in Figure 5.10 Arena model of the Inventory Management segment/Sub-model for Regional Big suppliers of hide and skin only one entity is created at the *Create* module with a maximum of one entity. This is because this single entity will be duplicated with *Separate* module when Order to RBS is released. To make it brief the created control entity is assigned by a picture truck in the *Assign* module *Assign truck picture*. Then the entity goes to the *Hold module shall RBS Release Tannery Order?* to scan the condition *Place order to RBS* in the *Assign* module at inventory replenishment strategy control of tannery sub-model in figure 5.14. Once order is released to RBS from tannery it must be terminated and again wait to scan the same condition whether order to RBS is placed or not. The original order entity is proceed to the *Record* module to tally the amount of orders to RBS while the duplicate order entity is returned back to the *Hold* module to san the condition *Place order to RBS==1*.

After the Record module the order entity precedes to a *Decide* module *Check RBS on hand inventory* to check whether the total amount of good and poor quality skins in RBS stock is greater or equal to the Economic Order Quantity (EOQ) of the tannery to RBS which is initially set to 4000 skins. If *Regional Big Suppliers Good Quality Skins Inventory + Regional Big Suppliers Poor Quality Skins Inventory >= EOQ of the Warehouse from Regional Big Suppliers* the *Decide* module takes the true exit the order entity next enters in to the two consecutive *Assign* modules to reduce both types of inventory in RBS and update the tannery warehouse inventory after shipment with in the *Process* module *Order arrives at the tannery from RBS* which has a uniform transportation delay of 0.25 to 1.25 days. These activities are done as per the ratio of good and poor skins collected from Regional small suppliers.

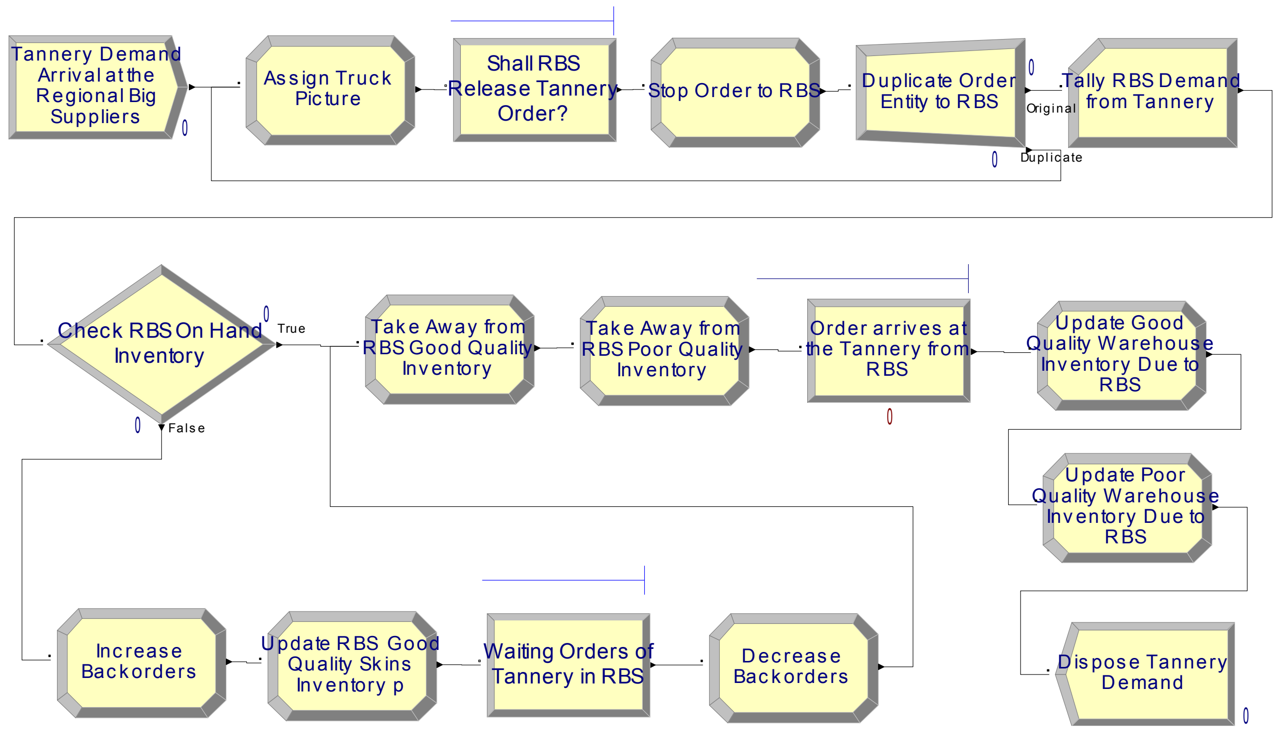


Figure 5.10 Arena model of the Inventory Management segment/Sub-model for Regional Big suppliers of hide and skin

If the *Decide* module *check RBS on hand inventory* takes the false exit, meaning there is insufficient amount of skins in stock, the order will be taken as a back order by updating its inventory shipped from the RSS and detained in *Hold* module *Waiting orders of tannery from RBS* till the minimum inventory level is reached for shipment (the condition is true and satisfied). When RBS inventory reaches to minimum EOQ level the *Hold* module will release the entity and the back order is deducted in the *Assign* module *decrease backorders*. After the *Hold* module releases the order entity the number of back order will be reduced by one and go for shipment process in the *Process* module *Order arrives at the Tannery from RBS* which is a seize, delay, release type with uniform delay time between 0.25 and 1.25 days then entity proceeds to updating tannery warehouse inventory. After performing these all activities finally the circulating order entity has completed its sojourn through the system and would normally be disposed of in the *Dispose* module *Dispose tannery demand* so as wait the next order entity.

Figure 5.11 and Figure 5.13 demonstrates a samples *Assign* modules *take away from RBS good quality inventory* and the Assignment dialog box as well as the *Assign* module *Update poor quality warehouse inventory due to RBS*. Inventories are reduced and increased as per the ratio of good and poor quality skins data taken from the case company.

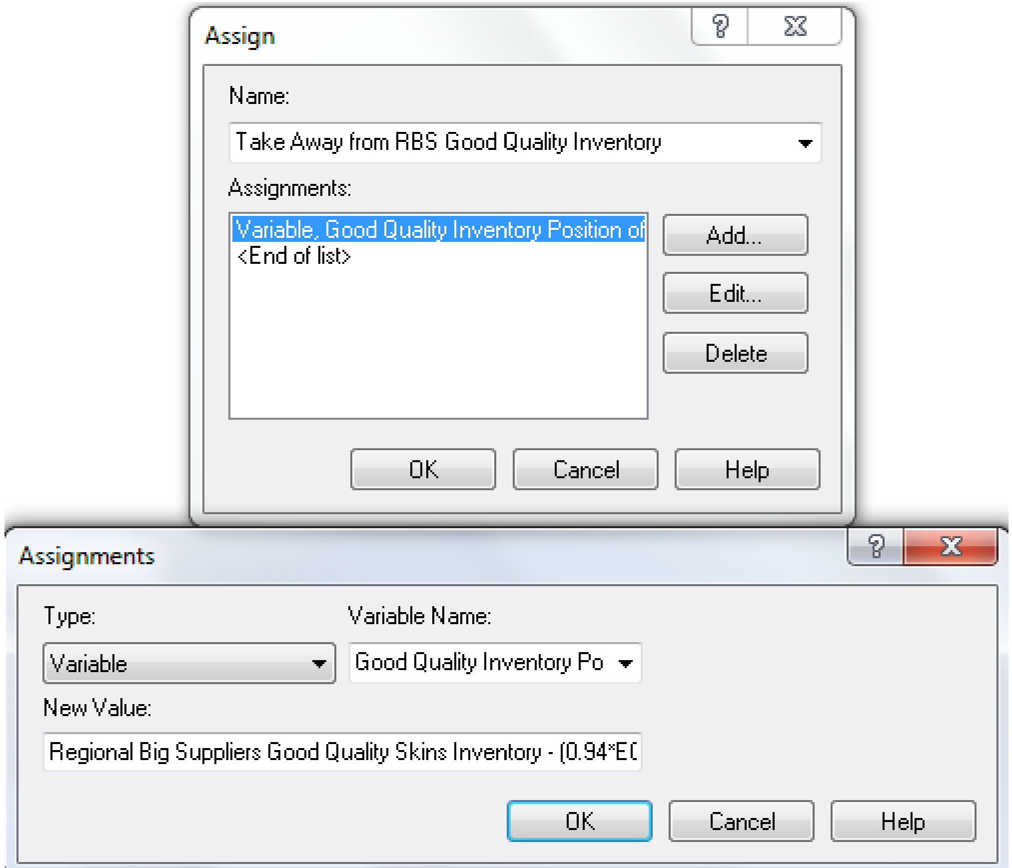


Figure 5.11 Dialog box of Assign module Take Away from RBS Good Quality Inventory

Below is the dialog box figure for *Hold* Module *waiting orders of Tannery in RBS* and the Process module next to it.

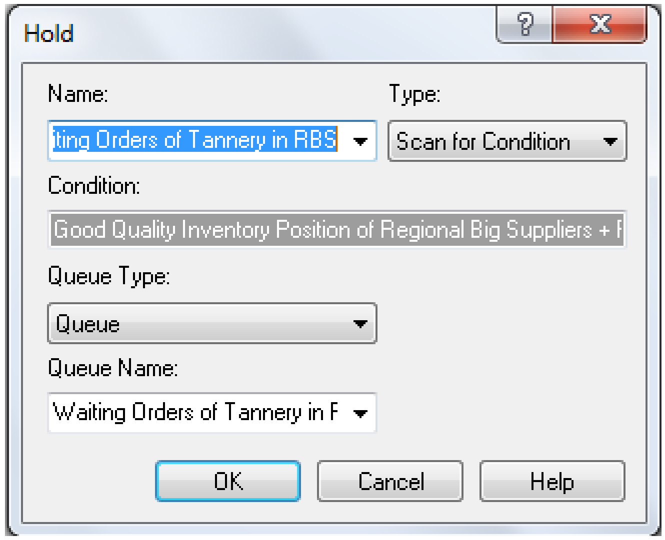


Figure 5.12 Dialog box for Hold Module waiting orders of Tannery in RBS.

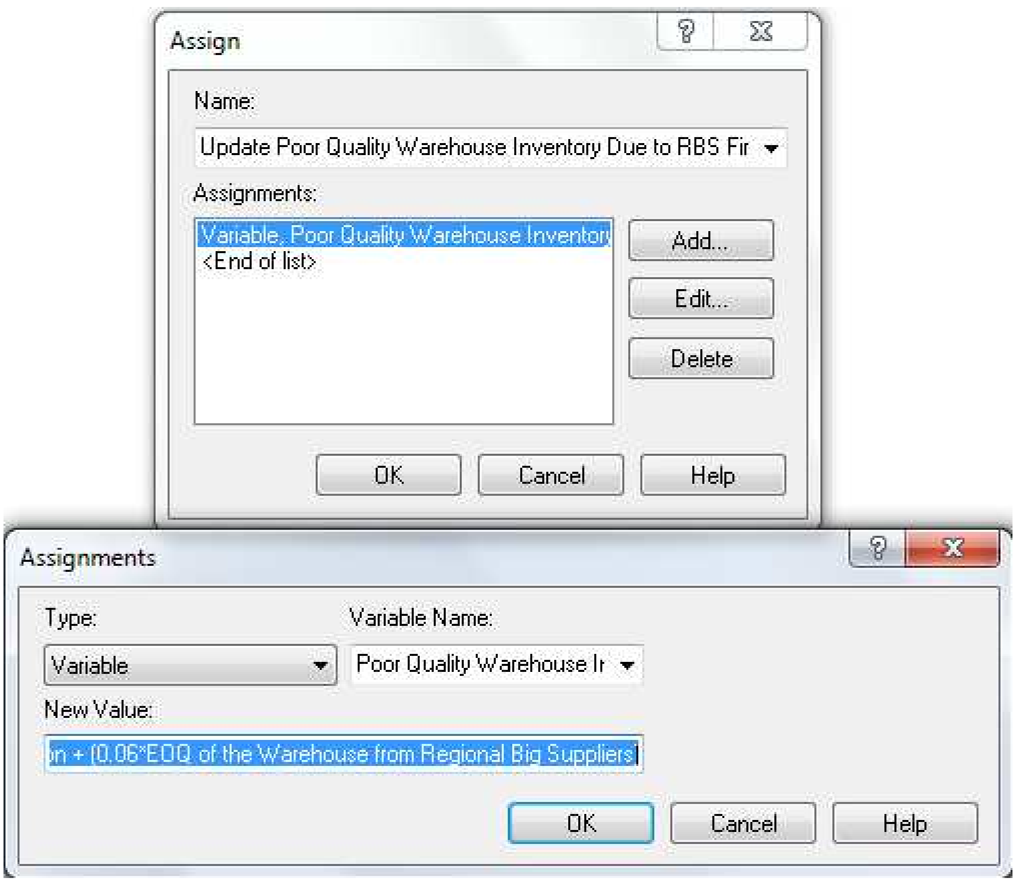


Figure 5.13 Dialog box of the Assign module Update Poor Quality Warehouse Inventory Due to RBS first time shipment.

5.8.4. INVENTORY MANAGEMENT SEGMENT/SUB-MODEL FOR DIRE HIDE & SKIN PROCUREMENT AND COLLECTION CENTER (DHSPCC)

Figure 5.14 depicts the Arena model's inventory management segment for the DHSPCC. This model segment generates incoming tannery orders, updates DHSPCC inventory levels, triggers replenishment orders from the AA big traders and abattoirs from Addis Ababa, sends shipments to the tannery warehouse, and updates the tannery warehouse inventory level.

The basic modelling concept is the same as that of Arena model of the Inventory Management segment/Sub-model for Regional Big suppliers of hide and skin except the decision help when there is no enough inventory in the stock for shipment. In this sub model when there no enough stock during order from the tannery (less than the EOQ of order from tannery to DHSPCC which is initially set at 1000 skins, which is equal to one transportation truck full load) the order from tannery or demand of skin from DHSPCC will be lost and disposed for waiting the next order arrival to DHSPCC.

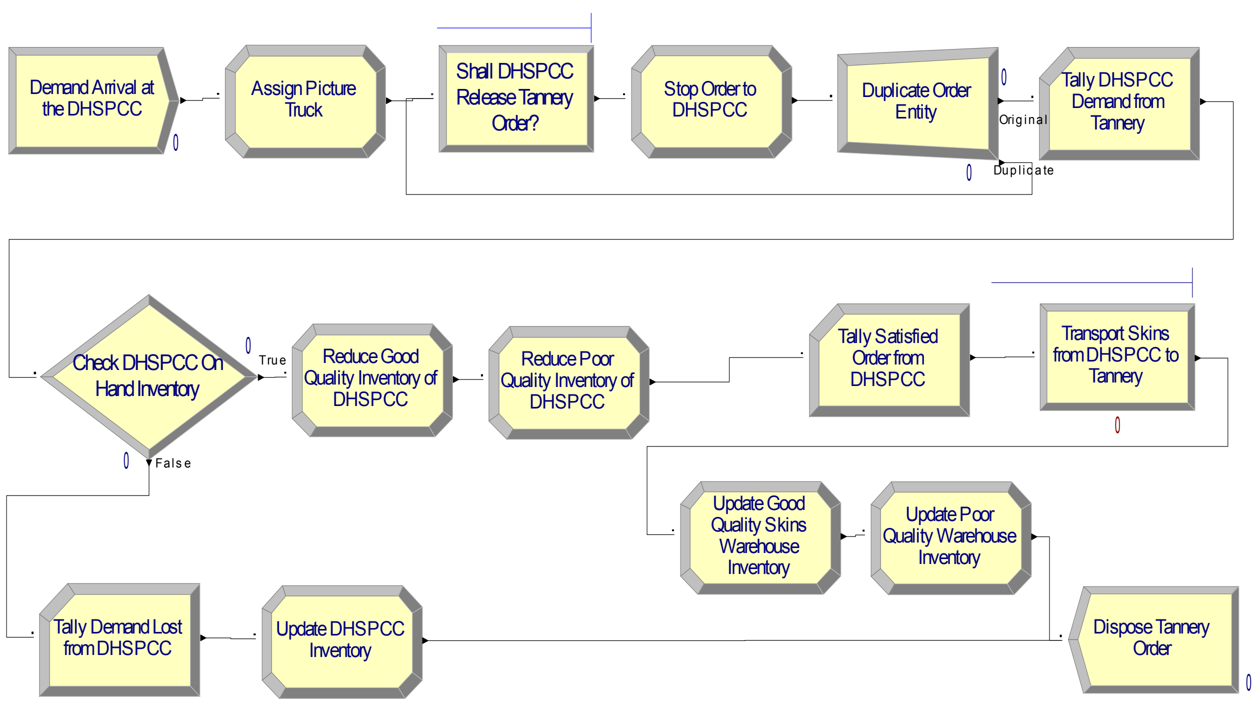


Figure 5.14 Arena model of the inventory management segment for the DHSPCC

The input data regarding the inventory updates and the transportation delay times are different from the Inventory Management segment/Sub-model for Regional Big suppliers of hide and skin which is taken as per the collected data and assumptions taken. In this case the ratio of good grade quality and poor grade quality is 0.99326 and 0.00674 respectively. While the average transportation and other delays to send shipment to the tannery is uniformly distributed between 5 to 8 hours.

5.8.5. INVENTORY REPLENISHMENT CONTROL STRATEGY OF TANNERY SEGMENT/SUB-MODEL

This sub- model is designed and developed to perform basic tasks of the tannery in determining the time between consecutive orders and the amount of skins required by the tannery so as to place the order in any of the two big suppliers of the tannery, DHSPCC and RBS.

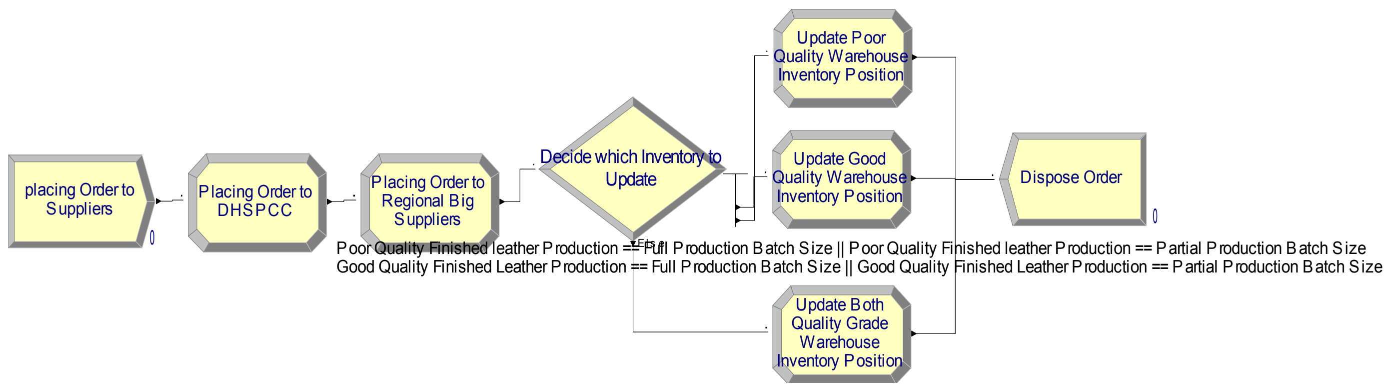


Figure 5.15 Arena model of inventory replenishment control strategy of tannery

The figure above (figure 5.15) indicates the sub model only used if the order is placed with in fixed time interval as well as for fixed quantity of order. This is done in the first scenario of the experiment test part of this study. This sub-model varies for developing and testing each of the four scenarios. Each of the sub models will be described in each of the forthcoming scenario design and analysis part of this study.

In general and common for all scenarios this sub model will generate order to the suppliers, checks on hand inventory level of the tannery, updates the inventory position of the tannery and determines the time between consecutive orders and the quantity of shipment as per the economic order quantity concept. In the other way this segment generates the demand stream, handles demand fulfilment, and triggers replenishment orders from the DHSPCC and regional suppliers.

5.8.6. PRODUCTION/INVENTORY MANAGEMENT SEGMENT/SUB-MODEL FOR THE TANNERY

Figure 5.16 depicts the tannery inventory management and production control segment of the Arena model. This model segment manages raw-material consumption and finished goods production by keeping track of a circulating control entity that modulates the suspension and resumption of production.

A control entity is created in every one day at the *Create* module *production process skin demand* and determines the quantity of demand in the *Assign* module *Production Batch Sizes* as per the collected data from the case tanning industry, Dire tannery. These values are “5e+003 + EXPO (505)” for full production batch size and “2.5e+003 + EXPO(253)” as the data gained from the input analyzer of the Arena software. Then the production control entity proceeds to the *Hold* module *Shall the Tannery Produce?* to scan the condition for production is active (Inventory Position of Finished Leather <= Minimum Reorder level of Finished leather). Then the entity will lead to four *Decide* modules to check the quantity of both grades of skins available on hand and determine the capacity utilization of the tannery. If the level of good quality warehouse inventory in the input buffer/tannery is greater or equal to the full production batch size the entity will take the true exit and proceed to production. If it is false the entity gets out in the other direction and checks the poorly graded skin inventory. Remember this is done because production process is held for the two graded skins separately and will never been processed together. If the poor quality warehouse inventory satisfies the minimum quantity for full production the entity will take the true exit and goes for assigning the tannery for full capacity production. If it is false the entity also goes for checking the on hand inventory whether the inventory quantity available fulfils minimum requirement for partial production for both quality grade skins. If the entity takes the true exit in any one of the four Decide module the production (socking ship skins) will be activated in the *Assign* module *Proceed To Production* assigning the variable Socking *Ship Skins or Production* to 1 and seize the tannery resource for hours. Here remind that the utilization of the tannery capacity might be fully or partially as per the available on hand inventory If the tannery faces with scarcity of the raw material, inventory level less than partial production the factory will be starved at all and the entity goes to dispose module through decision module made for finished leather inventory update.

After production process is held the entity will go for updating/reviewing the on hand inventory position of the tannery by deducting the produced/processed amount from the stock. Here the production may be full or partial, good or poor quality so that at a single day only one of them can be held for the same case the updates will be conducted with respect to the production type. The production control entity then leads to the *Delay* module *Production Process Delay* with an average delay time of 12 hours. Then the entity goes to *Release* module *Release Seized Socking Drum* for freeing the sized factory resource after completing the assigned task. Then the finished leather inventory will be updated as per the quantity processed in the tannery either full or partial production quantity.

Finally the control entity will go to the *Decide* module and check the inventory level of the finished leather. Remember the previous discussions that there is no any market problem of the finished leather and hence it couldn't be the reason for production termination. But for generalization of the model I added it so that if the inventory level of the finished leather exceeds the target stock production will be terminated.

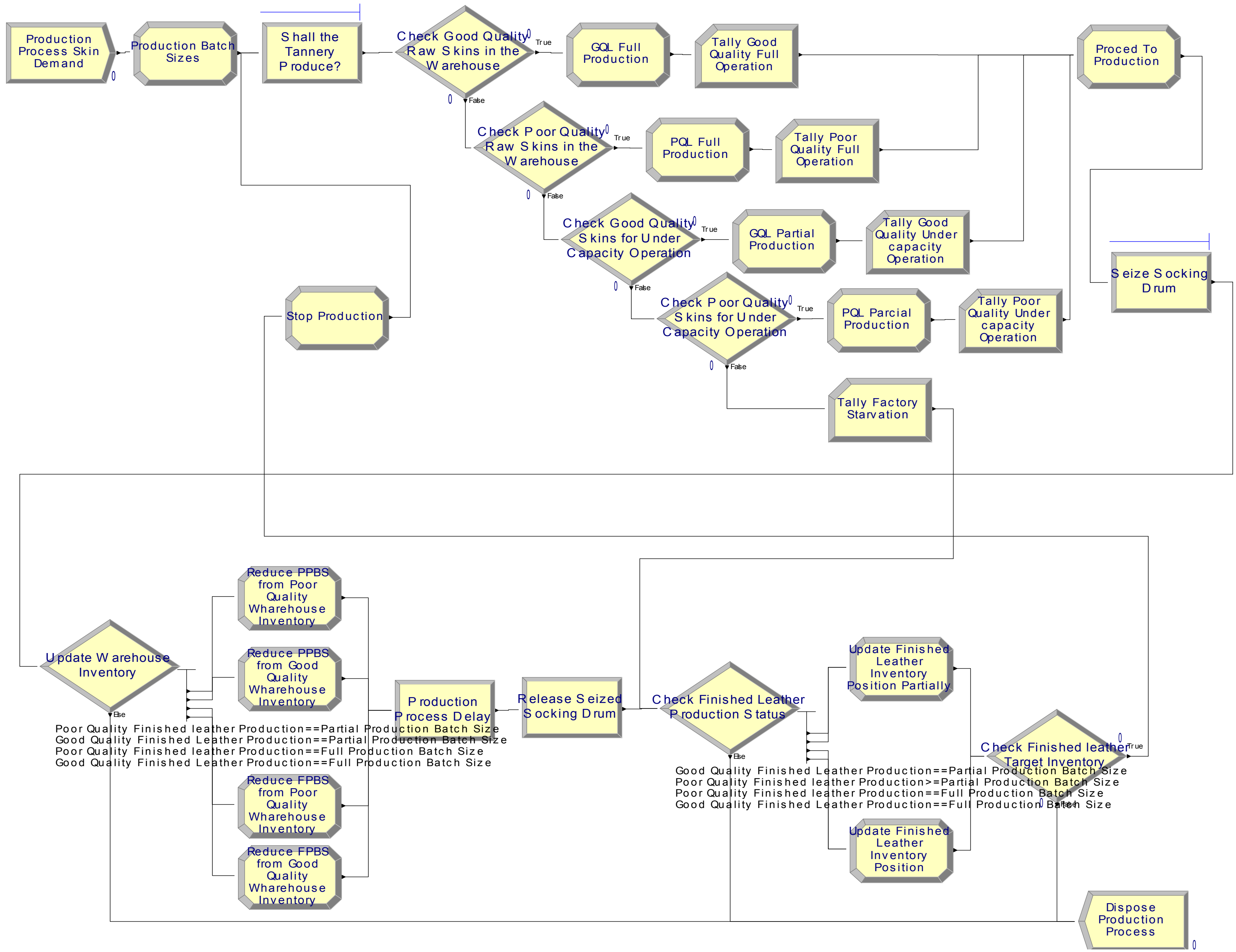


Figure 5.16 Arena model for production/inventory management of the tannery

5.8.7. FINISHED LEATHER INVENTORY MANAGEMENT SEGMENT/SUB-MODEL

As described earlier this sub-model is developed to generalize the model so as it can be used for other companies who face such problem of managing the finished product inventory. For the case of this study it is taken as the daily demand of the finished product exceeds the daily production. At the same time the finished leather target stock is assumed to be 100,000 to abandon production termination due to excess finished product stock. The model developed with the help of Arena simulation software is depicted below on figure 5.17.

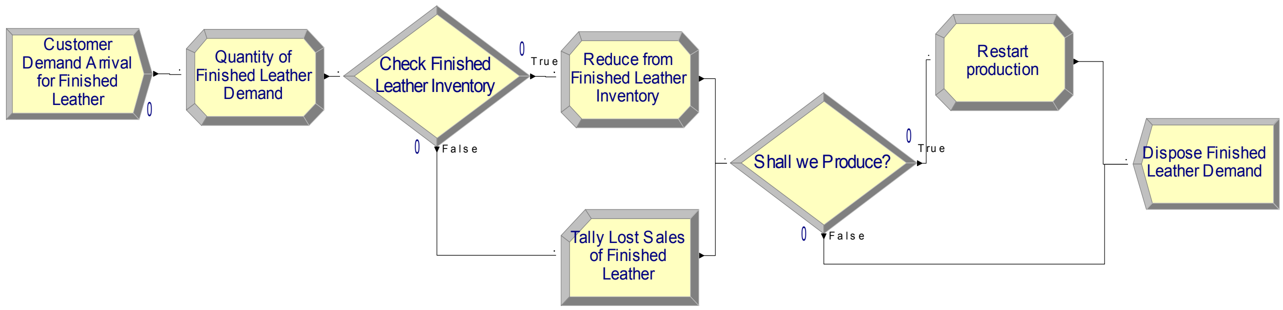


Figure 5.17. Finished leather inventory management segment/sub-model

As shown figure 5.17, finished leather inventory management segment/sub-model order entities are continuously created in the *Create* module *Customer Demand Arrival for Finished Leather* on daily basis with demand quantity of greater or equal to the daily production to avoid excess stock. Here the daily demand is taken as UNIF(5000,6000) which means demand is uniformly distributed between 5000 and 6000 processed leathers and assigned in the *Assign* module *Quantity of Finished Leather Demand*. Keeping this quantity in mind the control demand entity then proceeds to the Decide module to check whether the inventory on hand can satisfy the demand or not. If it is true the on hand inventory will be reduced by the demand amount if false demand will be assumed as lost. With a continuous fashion the inventory is checked whether it reaches the target or not, which helps to monitor the production. If the on hand stock exceeds the predetermined target production will be forced to terminate if no production will proceed as usual. Finally the control demand entity will be disposed after performing those assigned tasks.

5.9. MODEL VERIFICATION

The validation and verification steps are the most important part of simulation modelling. If these steps are not done before accurate all model errors, the result of the simulation study can be doubtful. It is applied to ensure model is running properly or not. Several verification techniques can be applied to the model to make sure that the model has been conducted correctly and obtain various purposes of simulation in organizations or companies. These techniques are checking the output for reasonableness, watch the animation for correct behaviour and use the trace and debug facilities provided in the simulation software.

For example a manufacturing process is being simulated then the model can be run under known conditions, and the outputs from the model compared with the historical outputs from the real system. If a good match is obtained then the model may be considered valid, at least for that particular set of conditions.

A fundamental difficulty of validation is that simulation is normally employed to gain understanding of a system under conditions that have not (yet) occurred in reality. The best that can be achieved is to test the model under a combination of known conditions and predictable extreme conditions. If it behaves well and predictably under such conditions then the user can have some confidence that the model's behaviour under unknown conditions is also likely to be a good match to the real system.

In the case of this study simulation modelling, each part of model was run with different set of inputs and the obtained outputs were compared with actual outputs. It is much easier to find problem and errors that are occurred during modelling rather than when the whole model was performed. The model was checked step by step. Corrective action was done immediately, if it was necessary. In addition experts who have good knowledge of the software are also able to hiss and criticize the model and corrective actions are taken.

CHAPTER SIX

DESIGNING SIMULATION EXPERIMENTS AND ANALYSING OUTPUT DATA

6.1. INTRODUCTION

Among the eight steps required for the successful simulation study of the Ethiopian leather industry supply chain, the determination of the run parameters, simulation experiment design and output data analysis are the major steps next to the development of the Arena computer model that significantly affects the final result of the study. These steps are investigated and performed as accurate as possible since this study result mainly depends on these activities.

6.2. DETERMINING RUN PARAMETERS OF THE SIMULATION

To get a relevant output it is necessary to provide the appropriate value in the dialog box of run Setup that is displayed on *Run/Run Setup* in the menu bar. In this option a number of basic information should be provided before running the simulation in order to get relevant data based on the objective of the study. Figure 6.1 depicts the run setup dialog box of the developed Arena simulation model with the values provided.

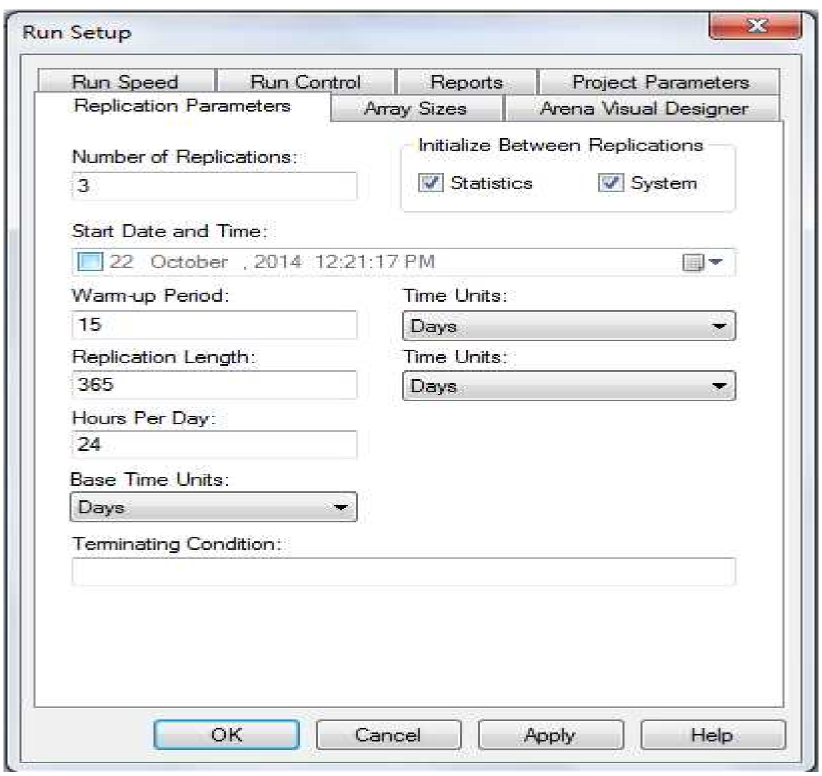


Figure 6.1 dialog box of Run Setup

The major run parameters that should be assigned and provided for this study are

- ✓ Warm up period
- ✓ Initial conditions for each simulation run.
- ✓ Number of replications
- ✓ Replication length
- ✓ Base time unit and Time units

6.2.1. WARMING UP PERIOD DETERMINATION

Based on the behaviour of the system, it is necessary to determine the warm up period. In our case study, the system behaviour represents steady state. In such situation warm up period should be identified, because entities can be in different parts of the system while it is not working. While the system restarts, entities continue their routes to leave the system. So it is important to consider warm up period for the model. For this study a warm up period is taken as a time at which a skin elapses from time of entry in the supply system to time of production, which is 15 days on average.

6.2.2. SETTING INITIAL CONDITIONS FOR EACH SIMULATION RUN

To start simulation run and provide relevant stochastic output it is necessary to provide some initial values for the global variables in the Arena simulation model available in the variable spread sheet of basic process template. In the simulation model under study variables and initial values provided are tabulated below by keeping in mind that the initial values will never affect the long run simulation output of the model. Some of the values are considered as the same as the value available in the system under study during the development of the model.

Table 6.1: Initial values of the Arena simulation run

S. No.	Variable Name	Initial Value	Remark
1	Socking Ship Skins or Production	N/A	0 or 1
2	Good Quality Warehouse Inventory	7000	
3	EOQ of the Warehouse from DHSPCC	1000	Exp. Parameter
4	EOQ of the Warehouse from Regional Big Suppliers	4000	Exp. Parameter
5	Good Quality Inventory Position of DHSPCC	2000	
6	Good Quality Inventory Position of Regional Big Suppliers	4000	
7	Place Order to DHSPCC	N/A	0 or 1
8	Place Order to Regional Big Suppliers	N/A	0 or 1
9	Minimum Reorder point of Warehouse		
10	Minimum Reorder point of DHSPCC		
11	Minimum Reorder point of Regional Big Suppliers		

12	Target Stock of the Warehouse	75000-90000	For 15 days Prod.
13	Target Stock of DHSPCC		
14	Target Stock of Regional Big Suppliers		
15	Place Order to AA DHSPCC Suppliers	N/A	0 or 1
16	Place Order to Regional Small Suppliers	N/A	0 or 1
17	Finished Leather Inventory	10000	
18	Inventory Position of Finished Leather	5000	
19	Finished Leather Inventory Target Stock	100000	No market constraint
20	Minimum Reorder level of Finished leather		
21	Grade IV Quality Skins Collected from Regional Small Suppliers	2500	
22	Regional Big Suppliers Good Quality Skins Inventory	7000	
23	Regional Big Suppliers Poor Quality Skins Inventory	2000	
24	Grade IV Quality Skins Collected from AA Suppliers	1000	
25	Good Quality DHSPCC Inventory	4000	
26	Poor Quality DHSPCC Inventory	1000	
27	Poor Quality Warehouse Inventory	3000	
28	Poor Quality Inventory Position of Regional Big Suppliers	1500	
29	Good Quality Warehouse Inventory position	5000	
30	Poor Quality Warehouse Inventory position	1500	
31	Poor Quality Inventory Position of DHSPCC	1000	
32	Backorder of Warehouse from Regional Big Suppliers	0	
33	Collected Skin at Regional Small Suppliers	6000	
34	Poor Quality Finished leather Production	3000	
35	Good Quality Finished Leather Production	4000	
36	Collected Skin at AA Suppliers	2000	
37	Demand for Finished Leather	-	UNIF(5000,6400)
38	Good Quality Skins Collected from Regional Small Suppliers	4000	
39	Good Quality Skins Collected from AA Suppliers	1800	
40	Poor Quality Skins Collected from Regional Small Suppliers	1000	
41	Poor Quality Skins Collected from AA Suppliers	500	

6.2.3. DETERMINING THE REPLICATIONS LENGTH

To determine the replication length first is mandatory to study the behaviour of the system. As described earlier the behaviour of the supply of raw hide and skin is seasonal, because of the availability of the raw material varies with time. This behaviour varies the quantity of the supply of hide and skin on a monthly basis. This is because skins can't be found in sufficient amount when needed rather it is available when meet is needed due it's by product nature. Therefore since meet demand is highly vary from month to month the amount of skins also varies with the same rate. Skins will be available with higher quantity when there are religious as well as national holidays in the country. Researchers agree that there is abundant skin on September (Ethiopian New year), January (Christmas) and April (Easter). This raw material availability will repeat itself annually hence it has a cyclic behaviour yearly. Therefore the replication length of the simulation should not be less than a year. For the system understudy it is determined that for a single replication the time shall be a year (365 days) to have a representative and relevant result. The base time units are preferred to be days because of the performance measure parameters are based on daily performance of the tannery. So as every available data is converted to daily bases.

6.2.4. DETERMINING THE NUMBER OF REPLICATIONS

One of the important steps in any validation procedure is to determine the number of replications, because it has directly effect on result accuracy. In this study to determine the number of simulation runs it is important to study the real system result in the previous times. At the same time higher number of replications will result in more accurate result. Therefore by considering both points in this study the number of replication is preferred to be three years.

6.3. DESIGN OF EXPERIMENT FOR SIMULATION

This part will focus on designing experiments that should be executed in the Arena simulation model developed for the study of the dynamics of the supply chain of the Ethiopian leather industry. The design should also point towards answering those objective questions of the research. In this section of the study, I strive for developing experiments with selected model parameters, so as to improve the Tannery service level or fill rate (probability that the demand of the tannery fully satisfied).

The discipline of supply chain management (SCM) sets itself the mission of producing and distributing products in the right quantities to the right locations at the right time, while keeping costs down and customer service levels up. In studying such issues, modellers typically focus on the following key performance metrics, which eventually can be translated to monetary measures:

- Customer service levels (e.g., the fraction of satisfied customer demands, known as fill rate)
- Average inventory levels and backorder levels
- Rate and quantity of lost sales

For the case of this study two basic performance criteria are selected and considered while modelling the system with the help of Arena software. These are the customer fill rate, meaning the fraction of the tannery demand for raw hide and skin and the quality of the skins, meaning the fraction of quality of skins with defect naturally or defects arising from the handling system (obsolete inventory). In addition to this the average number of back orders in the upstream suppliers particularly Regional Big Suppliers will be under consideration. While studying all these performance measurements in the system basic issues like the quantity of the raw material and the lead time required for sending shipment in between the echelons is considered. To achieve good performance, for the supply chains under study each customer (mainly the tannery) should employ inventory control policies that regulate the issuing of orders to replenish stocks. This strategy is also the only solution to balance the two conflicting objectives of the tannery so that it is one of the objectives of this study to be addressed.

Here below are the four major inventory replenishment policies/order release mechanisms which are designed to address the objective of the study and perform simulation experiments on the model developed.

1) The tannery places order for its suppliers at a fixed time interval and fixed quantity of skins
2) The tannery places order for its suppliers at a variable time interval to supply fixed quantity of skins
3) The tannery places order for its suppliers at a fixed time interval and a variable quantity of skins
4) The tannery places order for its suppliers at a variable time interval and variable quantity of skins.

Based on these four experiments the performance of the tannery based on fill rate (capacity utilization) and quality (inventory level) will be tested and the output will be analyzed to help tannery raw hide and skin section personnel to make decisions regarding the subject based on facts rather than assumptions.

Based on this inputs the output result and the objective of the study will round on the number of days that the factory operates with its full capacity or under capacity operation processing ether the good or poor quality skins which are available in stock.

6.4. SCENARIO BASED OUTPUT ANALYSIS

Traditionally the case tannery has no a defined inventory replenishment policy/order release mechanism. Most of the time the raw material availability pushes itself downstream to the tannery as per the previous agreements and customer loyalty unless there is scarcity of the material during which the tannery is forced to see different sources and collect it with price competition. This creates an abundant inventory in the tannery. Dire tannery try to overcome this problem by sharing stock to its sister company, Modjo tannery but other tanneries face the trouble of obsolete inventory (inventory stored for more than 15 days).

As described in the data collection part of this study the maximum daily skin available through one wing of the tannery supply (DHSPCC) is 2300 skins and through the other wing (RBS) supplies more thousands of skins on daily basis. If the tannery has willing to collect more than this skins daily it should have to see other sources of the raw material otherwise it is limited to this collection capacity. Therefore the scenarios are developed in ordering the suppliers in between these values of collection per day with constant and variable ordering times. Order quantities from DHSPCC shall vary from 0 to 2000 and order quantities from RBS shall vary from 0 to 8000 on daily basis. The order quantities may exceed this value and vary depending on the time between the consecutive orders to satisfy the tannery demand.

The scenarios are developed to create balance between the two conflicting objectives of the tannery, meaning satisfying the daily tannery demand keeping the quality of the skin meaning through avoiding stock of skins for more than fifteen days. Here we should have remind that the skins may not be available in sufficient amount in the market when needed rather the availability follow seasonality behaviour due to its by product nature (skins are available when meat is needed). Here below are the four scenarios developed including cases in each scenario and to be tested in the developed simulation model with the help of Arena software. The simulation run is performed for each scenario and case by varying the input data provided in the developed model.

The developed arena model is more general, meaning it can be used to test and measure different parameters as needed. But for the purpose of this research I prefer to see few of them depending on the objective and the research questions stated earlier. The basic performance measurement criteria for this system under study is the factory status of tanning operation (four operations and a starvation) and the daily average and maximum inventory available in each suppliers and tannery warehouse stock. As described earlier the more time the skins are stored the less quality of skins. The five status of tanning operation are that are the primary measurement criteria for the performance of the supply chain system under study are:

a) The number of days that the tannery processes good quality skins with full capacity (Full capacity utilization)
b) The number of days that the tannery processes Poor quality skins with full capacity (Full Capacity utilization)
c) The number of days that the tannery processes good quality skins with under installed capacity (under capacity utilization)
d) The number of days that the tannery processes poor quality skins with under installed capacity (under capacity utilization)
e) Tannery number of days that the tannery is fully Starved (No socking of skins at all)

These conditions are varied due to the availability of the raw material on hand. These all are measured in days out of the operating 365 days (one year simulation).

The other output of the simulation that is used as the performance measurement criteria for the supply chain system under study is the average and maximum value of on hand inventory under stock in each echelons. These are

a) The average and maximum skins inventory in DHSPCC stock
b) The average and maximum skins inventory in RBS stock
c) The average and maximum skins inventory in tannery warehouse stock

This is selected because of the skins quality deterioration when stocked for more than fifteen days as well as to know and share information between echelons regarding the inventory status in each suppliers and customers. Based on this regard below are the four basic scenarios and cases under each scenario to be tested and the analyzed output of the simulation model.

6.4.1. SCENARIO 1: ORDER IS PLACED WITH FIXED TIME INTERVAL AND FIXED QUANTITY OF SKIN

In this scenario the tannery places fixed quantity of skins based on the economic order quantity (EOQ) concept with fixed time interval. The orders are placed to both of the tannery suppliers (DHSPCC and RBS) based on the collection capacity they have as described in the data collection section of this study. Here once the tannery decided to order a fixed quantity of skins at a fixed time interval it is not subjected to timely inventory replenishment planning so that the order is independent from the amount of on hand inventory.

To test this hypothesis on the developed Arena simulation model the quantity of skins that are going to be ordered and the time interval at which the order to be placed couldn't be taken as a random value, rather it shall depend on the amount required by the tannery per unit time. As illustrated in the data collection and analysis part of this study, the daily demand of raw skins of the tannery is not certain so as the availability of the raw material in the market. Let us take the value of this scenario as "if the tannery places an order to its both aggregated suppliers on a daily basis with a fixed amount of 5000 skins, 1000 skins from DHSPCC and the remaining 4000 from regional big traders of hide and skin". The amount of order quantity is selected based on the economic order quantity concept and taken from the case company raw hide and skin department experts. One way of the tannery to decide the economic order quantity is that the skins should be a one full truck load for shipment. So that the tannery has its own truck with a maximum loading capacity of 1000 skins, which it uses to transport skins from DHSPCC to the tannery. At the same time big suppliers use a medium load capacity truck with a loading capacity of 4000 skins to transport skins from region to Dire tannery, located in Addis Ababa. If there is a need to test the tannery status by placing order with two days interval we can double the quantity also to get a better result. That is why this amount of skins per order is selected and all other tests can be conducted by making an order quantity of a multiple of the above two results, 1000 and 4000 skins from DHSPCC and RBS respectively.

Now let us take if the tannery places order to its suppliers on daily basis of 1000 skins from DHSPCC and 4000 skins from RBS. To test this case in the simulation model developed with the help of Arena software, we will do only two activities. These are

a) Opening Inventory Replenishment Strategy Control Segment/Sub-Model show on figure 5.15 and set *constant* in the type field of the *create* module called *Placing Order to Suppliers* and providing 1 in the value box as shown in the figure below. This indicates we are ordering suppliers every one day.

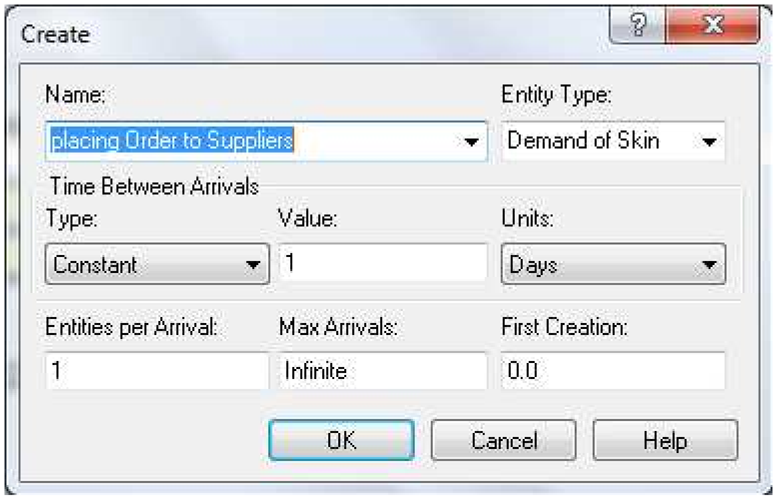


Figure 6.2: dialog box of create module placing order to suppliers

b) In the variable spreadsheet in the basic process template of the project bar edit the value of *EOQ of the Warehouse from DHSPCC* and *EOQ of the Warehouse from Regional Big Suppliers* as 1000 and 4000 respectively.

Providing the above two changes and allowing the simulation run the Arena report will generate the following outputs on table 6.2 and 6.3 as per the performance measurement criteria.

Table 6.2 One year tannery performance for scenario 1

S. No.	Performance Measurement Criteria	Days
1	Number of days the Factory Fully Operates With Good Quality Skins	117
2	Number of days the Factory Fully Operates With Poor Quality Skins	2
3	Number of days the Factory Operates Under Capacity With Good Quality Skins	159
4	Number of days the Factory Operates Under Capacity With Poor Quality Skins	26
5	Number of days the Factory is Starved	46

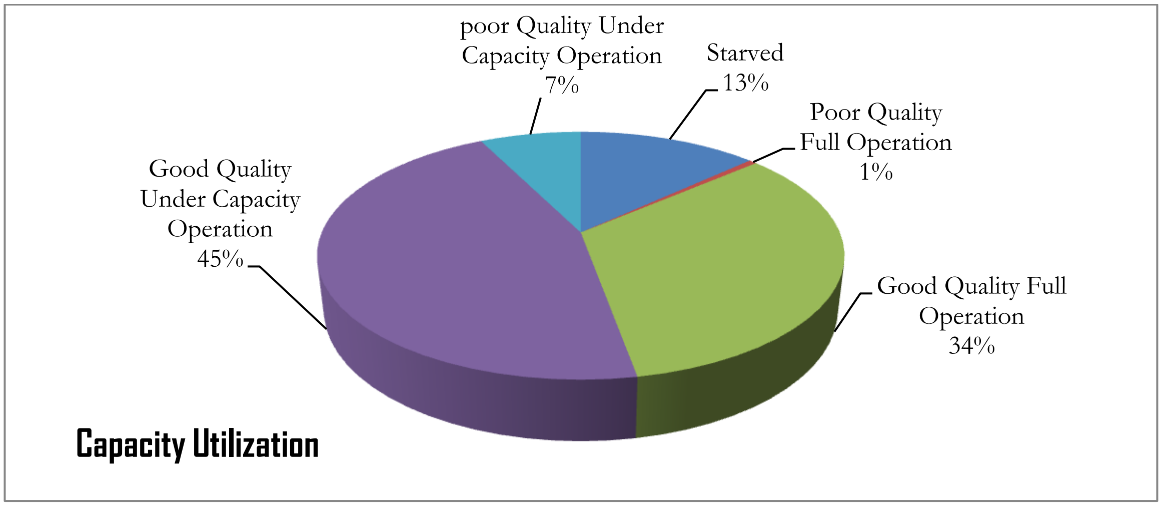


Figure 6.3 Chart for operating performance of the tannery for scenario 1

As we see in the above table 6.2 which is taken from the output report of the simulation, if the tannery places order daily with a constant amount of 5000 skins (1000 from DHSPCC and 4000 from RBS) at the end of the year among the 350 days (15 days are deducted for warm up) the tannery will be on operation with full capacity only 117+2=119 days. That means 117 days with good quality skins and spent 2 days while processing poor quality skins which is 35% of the total operating time. The tannery will be forced to operate under capacity for 159+26=185 days by neglecting one of the two socking drums available in the beam house of the tannery. Then after the factory will never process socking skins for 46 days or 13% of time and remain starved due to shortage of raw material and forced to perform other activities other than the stated one.

On the same case the following table shows the maximum and average inventory level of the raw material in each suppliers and the tannery.

Table 6.3: Inventory level of each Raw material in each suppliers and tannery input buffer for scenario

S. No	Tier /Echelon and Description	Average Daily Inventory	Maximum Daily Inventory
1	Good Quality tannery Input Buffer Inventory	4593	10561
2	Poor Quality tannery Input Buffer Inventory	2390	5780
3	DHSPCC Good Quality Inventory	1649	3625
4	DHSPCC Poor Quality Inventory	11	25
5	RBS Good Quality Inventory	340293	722434
6	RBS Poor Quality Inventory	24789	50919

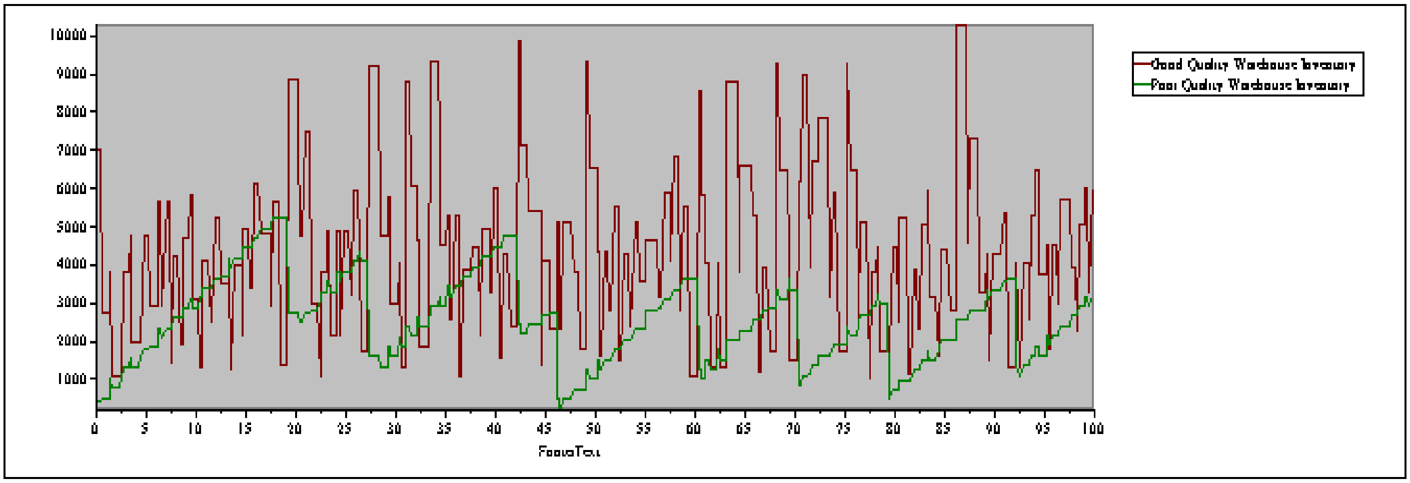


Figure 6.4 Diagram showing inventory level of tannery warehouse over the first 100 simulation days

Tracking the inventory levels of each echelon has two basic advantages; the first one is helps to monitor the inventory in stock which also helps to estimate the time duration of the skins detained in stock, secondly it helps to share information between echelons regarding their inventory level in stock so as improve the supply chain performance.

As can be seen in the above tabulated inventory level output of the simulation run in the predetermined conditions of the ordering time and amount ordered, there is abundant stock in the Regional Big Suppliers (more than 340000 skins on average). Therefore this shows that the tannery can be more flexible in increasing the quantity of order so that it reduces the company under capacity utilization and starvation.

If the tannery is flexible enough on the determination o the quantity of skins per unit order, the Arena process analyzer perform all the performance indicates as shown in the table 6.4 below with different order quantities per a fixed order time of one day.

Table 6.4 Different case tests under scenario 1

	Scenario Properties				Controls		Responses								
	S	Name	Program File	Reps	EOQ of the Warehouse from DHSPCC	EOQ of the Warehouse from Regional Big Suppliers	DHSPCC Good Quality Skins Average Inventory	RBS Good Quality Skins Average Inventory	Good Quality Warehouse Inventory	Poor Quality Warehouse Inventory	Number of days the Factory Fully Operates With Good Quality Skins	Number of days the Factory Fully Operates With Poor Quality Skins	Number of days the Factory Operates Under Capacity With Good Quality Skins	Number of days the Factory Operates Under Capacity With Poor Quality Skins	Number of days the Factory is Starved
1		Case 1	8 : Scen	3	500	1000	41329	782107	1733	1127	0	0	126	9	215
2		Case 2	8 : Scen	3	700	2000	5957	597273	2839	1146	16	0	169	17	149
3		Case 3	8 : Scen	3	1000	2500	1704	473470	2904	1219	57	0	164	21	109
4		Case 4	8 : Scen	3	1300	3000	1799	484071	3644	2857	49	1	229	21	51
5		Case 5	8 : Scen	3	1500	4000	1871	281944	4207	3038	115	8	192	17	19
6		Case 6	8 : Scen	3	1800	5000	2022	137127	7764	1572	208	15	107	11	10
7		Case 7	8 : Scen	3	2000	6000	2039	56376	10570	9741	297	21	26	2	4

Looking at all the above points the tannery raw hide and skin department decision makers are free to make decisions based on facts rather than assumptions. They are also able to test other cases by varying the input data, controls and the responses of the simulation experiment.

Using the same fashion different cases can also be tasted by varying the time interval at which the order is placed. Example by assuming order is placed with two, three or more days interval by keeping in mind that the tannery should not keep stock for more than fifteen days and the daily skin collection capacity of the upstream suppliers.

6.4.2. SCENARIO 2: ORDER IS PLACED WITH FIXED TIME INTERVAL AND VARIABLE QUANTITY OF SKIN

In this scenario the inventory replenishment is supported by material requirement planning, meaning the order quantity is determined by the amount of on hand inventory. The time between two consecutive orders is assumed to be fixed, let it be every two days based on continuous inventory review and the order quantity is based on the economic order quantity. The basic difference made from the scenario 1 Arena model is on the inventory replenishment strategy control segment/sub-model.

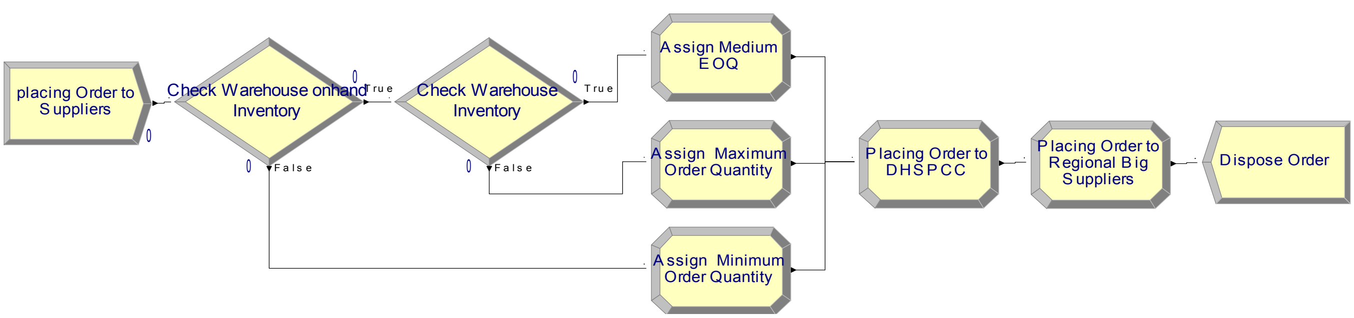


Figure 6.5: Inventory replenishment strategy control sub-model for fixed time interval & variable quantity of order

As shown in the above picture the control entity first checks the on hand inventory available in the warehouse before determining the order quantity. That means the order quantity is directly dependant on the quantity of the skins in the warehouse. For this study the control entity is assigned to check whether the warehouse reaches to the reorder level or not which is estimated to be a stock for three days production (16000 skins). Again the entity leads to the decide module to check the quantity of the warehouse which is less than the reorder level to decide the quantity of skins per order. Then the order quantities are assigned as EOQ from both DHSPCC and RBS with a multiple of 1000 and 4000 respectively.

So that based on these assumptions the Arena simulation model would generate the following output report for the utilization of installed tannery capacity.

Table 6.5 Tannery capacity utilization for scenario 2

S. No.	Performance Measurement Criteria	Days
1	Number of days the Factory Fully Operates With Good Quality Skins	261
2	Number of days the Factory Fully Operates With Poor Quality Skins	14
3	Number of days the Factory Operates Under Capacity With Good Quality Skins	65
4	Number of days the Factory Operates Under Capacity With Poor Quality Skins	6
5	Number of days the Factory is Starved	4

As can be seen from the simulation result the operating performance of the tannery is much better than that of the ordering strategy tested in scenario 1. Here we should have to remind that there is a possibility to get better results by varying the time between the two consecutive orders and the amount of skins that are going to be shipped per unit order.

The following table also shows the average and maximum inventory level of selected supply chain tiers to check the stock status so as to take appropriate measure. Based on the result the accumulated skin stock in the tannery input buffer (tannery warehouse) is not bad due to its lower quantity (Maximum 18964 sheep skins). But the RBS inventory status shows that there is a possibility to supply more quantities of skin hence the RBS Daily average and maximum inventory is much more than that of the tannery.

Table 6.6: Inventory level of each Raw material in each suppliers and tannery input buffer for scenario 2

S. No	Tier /Echelon and Description	Average Daily Inventory	Maximum Daily Inventory
1	Good Quality tannery Input Buffer Inventory	5968	18964
2	Poor Quality tannery Input Buffer Inventory	3420	7305
3	DHSPCC Good Quality Inventory	2427	5723
4	DHSPCC Poor Quality Inventory	17	40
5	RBS Good Quality Inventory	308246	634819
6	RBS Poor Quality Inventory	22598	44928

The following Diagram depicts the tannery warehouse inventory status for the first one hundred simulation days.

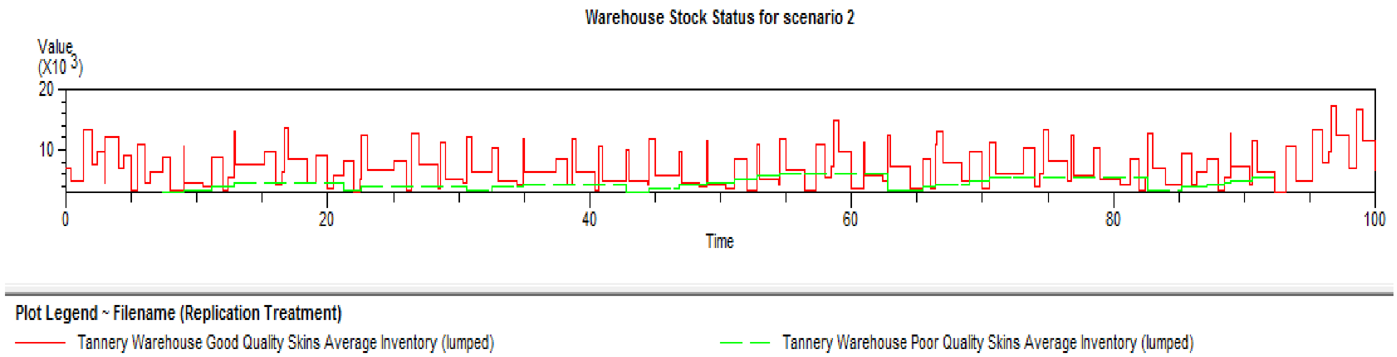


Figure 6.6 Diagram for tracking inventory level in the tannery warehouse for the first 100 days simulation for scenario 2

6.4.3. SCENARIO 3: ORDER IS PLACED WITH VARIABLE TIME INTERVAL AND FIXED QUANTITY OF SKIN

In this scenario as scenario 2, order is placed to the major suppliers if and only but only if there is scarcity of the resource in the tannery. This means the tannery would check its stock status and decide to place order to its suppliers. As usual the inventory replenishment strategy control sub model is redesigned as below shown in the figure 6.7 to match this scenario so as to provide relevant output.

The control entity is first realised from the *Create* module *Placing order to suppliers* and proceeds to check the inventory status of the tannery. If the on hand inventory of the warehouse is below a stock of less than three days of production (assigned as a variable minimum reorder level of the tannery with value 16000 skins on average) order will be released to the major two suppliers. If there is enough stock after the daily check up order will be skipped and disposed. The quantity of skins per order is assumed to be 2000 and 12000 skins from DHSPCC and RBS respectively.

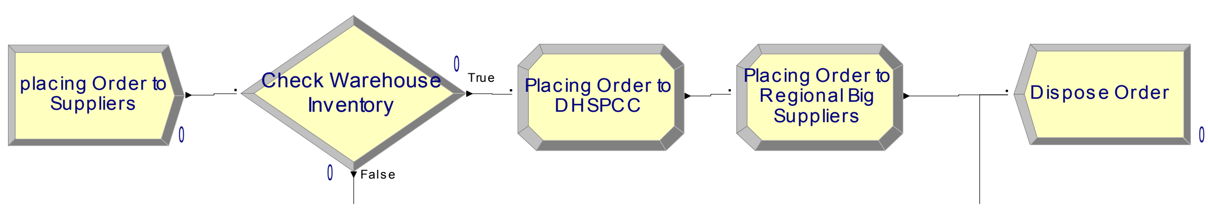


Figure 6.7 Inventory replenishment strategy segment/sub-model for variable time fixed order quantity

Keeping the other sub models all the same as earlier the three replication and one year simulation length of run in the Arena model would provide the following results tabulated regarding the operating performance of the tannery and the average and maximum inventory level of selected echelons. For the case of this scenario a fixed order quantity of 2000 skins from DHSPCC and 12000 skins from RBS is selected for the experiment.

Table 6.7 tannery operating performance for scenario 3

S. No.	Performance Measurement Criteria	Days
1	Number of days the Factory Fully Operates With Good Quality Skins	323
2	Number of days the Factory Fully Operates With Poor Quality Skins	19
3	Number of days the Factory Operates Under Capacity With Good Quality Skins	8
4	Number of days the Factory Operates Under Capacity With Poor Quality Skins	0
5	Number of days the Factory is Starved	0

As seen in the above table, in this developed scenario tannery starvation is not recorded, which is one of the indications of a better order replenishment strategy. The overall operating performance of the tannery can be depicted with the help of pie chart as follows.

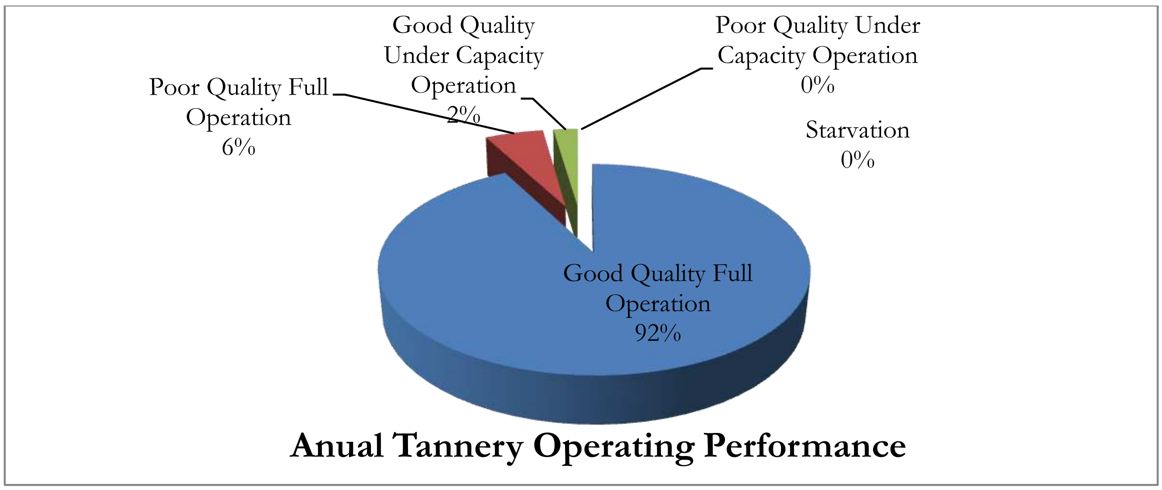


Figure 6.8. Pie chart for operating performance of the tannery for scenario 3

The table below indicates the average and maximum daily inventory level of each echelon during a one year simulation run.

Table 6.8 Inventory level of Raw material in each suppliers and tannery input buffer for scenario 3

S. No	Tier /Echelon and Description	Average Daily Inventory	Maximum Daily Inventory
1	Good Quality tannery Input Buffer Inventory	12718	49072
2	Poor Quality tannery Input Buffer Inventory	5272	12149
3	DHSPCC Good Quality Inventory	4439	11753
4	DHSPCC Poor Quality Inventory	30	80
5	RBS Good Quality Inventory	268598	556205
6	RBS Poor Quality Inventory	19887	39552

With the same fashion as previous scenarios the simulation result shows there is a possibility to have a better result by coordinating the orders in such a manner since there is an abandon skin inventory in the Regional Big Suppliers (RBS). The inventory level in the tannery is also good, i.e. the maximum daily inventory doesn't exceed for fifteen days production to monitor and avoid the skin quality problem arising from long time storage.

6.4.4. SCENARIO 4: ORDER IS PLACED WITH VARIABLE TIME INTERVAL AND VARIABLE QUANTITY OF SKIN

This scenario is developed to allow the tannery freedom not to have excess stock in the ware house and the time at which the order is placed. The following inventory replenishment sub model on figure 6.9 indicates the redesigned sub model for this scenario.

The control entity created daily leaves the *Create* module *placing order to suppliers* and checks the warehouse inventory level, whether it reaches the reorder level or not. If the warehouse inventory level is below the minimum order level (16000 Skins) the entity takes the true exit and proceeds for determining the order quantity depending on the on hand quantity otherwise the entity takes the false exit and order will be bypassed at that time and goes to dispose module. If the stock level is below a one day production inventory level it will set to order the maximum order quantity for each supplier, 3000 and 12000 skins from DHSPCC and RBS respectively. Otherwise the order Quantity will be the minimum EOQ set earlier, 1000 and 4000 from DHSPCC and RBS respectively.

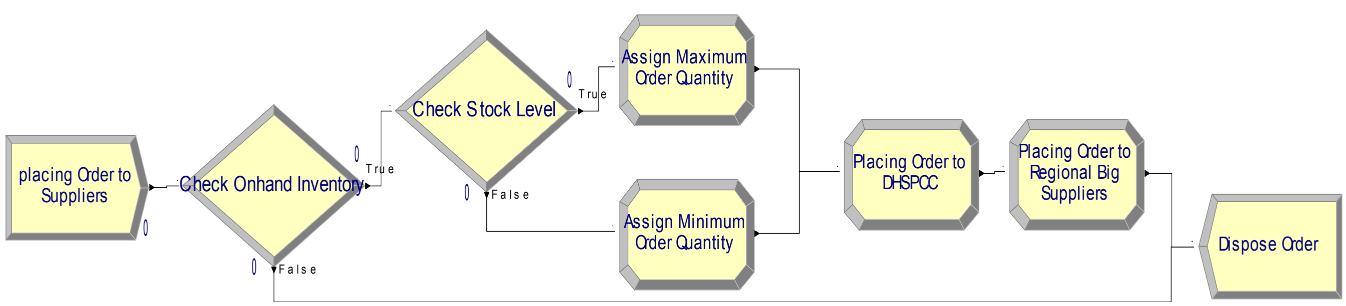


Figure 6.9 inventory replenishment strategy segment/sub-model for variable time and variable order quantity

The simulation result for this developed scenario indicates that there is 1 day starvation of the tannery and the factory will operate 297 days out of 350 while processing good quality finished leathers with full installed capacity. A total of 17+33=50 days the tannery will operate under capacity due to the limitation of the raw material in the tannery warehouse.

Table 6.9 Operating performance of tannery for scenario 4

S. No.	Performance Measurement Criteria	Days
1	Number of days the Factory Fully Operates With Good Quality Skins	297
2	Number of days the Factory Fully Operates With Poor Quality Skins	17
3	Number of days the Factory Operates Under Capacity With Good Quality Skins	33
4	Number of days the Factory Operates Under Capacity With Poor Quality Skins	2
5	Number of days the Factory is Starved	1

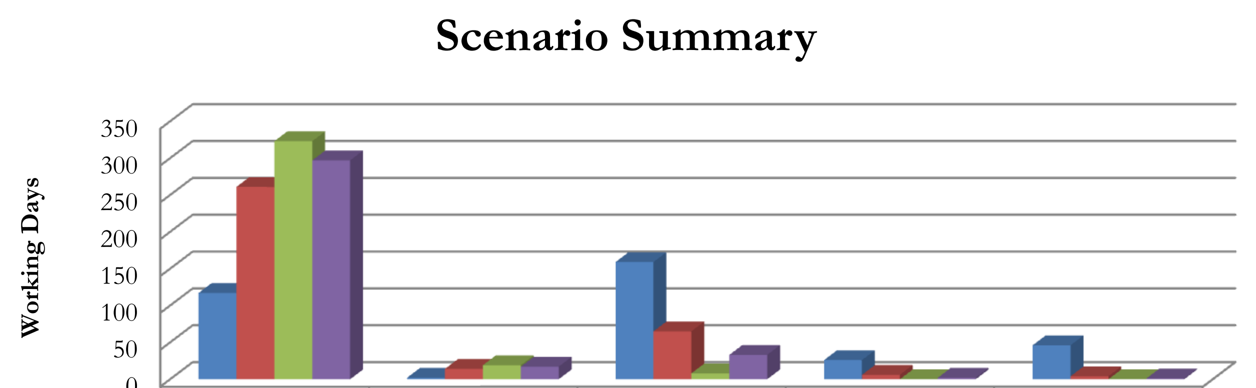
The inventory level report (daily record) indicates there is excess inventory on the RBS suppliers as shown on table 6.10 below. This indicated that there is a possibility of the tannery to increase order quantities so that it can improve the operational performance that is indicated on table 6.9.

Table 6.10 Inventory level of raw material in each suppliers and tannery input buffer for scenario 4

S. No	Tier /Echelon and Description	Average Daily Inventory	Maximum Daily Inventory
1	Good Quality tannery Input Buffer Inventory	8383	32827
2	Poor Quality tannery Input Buffer Inventory	3845	7745
3	DHSPCC Good Quality Inventory	3341	9698
4	DHSPCC Poor Quality Inventory	23	66
5	RBS Good Quality Inventory	380762	790488
6	RBS Poor Quality Inventory	27556	55572

6.5. SUMMARY OF THE EXPERIMENTS

For the case of this study a generalized four experiments are designed and executed in the developed Arena simulation model. All the four designed experiments (scenarios) would result in different outputs as per the provided input. But there is a possibility to result with a much better or worst one by varying the input, which is the time between the orders and the amount of skins per unit order (EOQ). Here below is a diagram comparing the operational performances of the tannery as well as the inventory level of the major suppliers and the tannery itself for all the four scenarios tested.



	Number of days the Factory Fully Operates With Good Quality Skins	Number of days the Factory Fully Operates With Poor Quality Skins	Number of days the Factory Operates Under Capacity With Good Quality Skins	Number of days the Factory Operates Under Capacity With Poor Quality Skins	Number of days the Factory is Starved
Senario 1	117	2	159	26	46
Senario 2	261	14	65	6	4
Senario 3	323	19	8	0	0
Senario 4	297	17	33	2	1

Figure 6.10 summary of operating performance and inventory level for all the scenarios.

Therefore by observing all those parameters the tannery decision makers are able to make decisions based on the tested results so that they are able to make decisions based on facts rather than assumptions. Based on the executed data it can be simply observed that scenario 3 is found the better strategy for replenishing the tannery raw material warehouse.

CHAPTER SEVEN

CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH DIRECTION

7.1. CONCLUSION

Many researchers have been engaged in the subject to overcome those challenges, so as to smooth out the flow of physical goods, information and finance across the different tiers of the supply chain. This study extensively assessed the different mythologies those are used for the evaluation and improvement of a multi echelon supply chain network performance. Then one of those methodologies that best suits for the evaluation and assessment of the Ethiopian leather industry, Discrete-Event Simulation Modelling is selected and applied for this study. Among the number of commercial simulation software, Arena® the Rockwell Automation software is found to be the best for a multi echelon supply chain network so as adopted in this study.

A total of thirty scholar articles, taken from different international journals, are selected and intensively reviewed to identify research areas that didn't get emphasis and so as to fill gaps in this study. Among the evaluation schemas identified for the article revision a big ignorance has been found for the two basic parameters that has an immense point while modelling and simulation of the Ethiopian leather industry. These evaluation parameters are the quality of goods in and out in the supply chain and the availability of the resources in the supply chain at which only two articles each took them for consideration and the remaining articles either neglect or took assumption against the parameters while the Ethiopian leather industries, particularly the tanneries are suffering from the shortage of raw material (hides and skins) as well as its quality problem.

Currently the Ethiopian tanning industries are faced with two conflicting objectives. The first one is regarding the collection of the raw hide and skin when needed. Due to the by-product nature of hides and skins it is available in the market when meat is needed otherwise there is scarcity of the resource. Raw hides and skins are available in the market in abundant during holidays like New Year, Christmas and Ester. Therefore the tanneries one objective is collecting fresh hides and skins in bulk amount and use them when there is scarcity and limited raw material in the market supply. Besides the natural quality problems of raw hide and skin, even after salting (salt is applied) the quality of hides and skins will deteriorate if it is stored for more than fifteen days. Therefore the second objective is keeping the raw material quality with no inventory accumulation for more than fifteen days of production.

This study paved the way to create a balance between the two conflicting objectives while keeping the operating performance of the tannery to the optimum level. A four echelon verified simulation model with the help of Arena software for a single case tannery (Dire Tannery) is developed. Four different scenarios (Inventory Replenishment Strategies) are designed by varying the time between two consecutive orders and the quantity of shipment per unit order. Four scenarios are tested in the model for one year simulation run time with 3 replications to evaluate the tannery operating performance and the amount of on-hand inventory accumulated.

Even though there is a possibility to gain a much better result by executing different values in the model, in this research scenario 3 (Placing order to the suppliers with variable time interval and fixed quantity of skins in a shipment) result in the best operating performance of the tannery by keeping both capacity utilization and amount of raw material inventory in a reasonable quantity.

Therefore the tanneries' raw hide and skin department delegated personnel are able to make decisions based on facts rather than assumptions and in such uncertain environment.

7.2. RECOMMENDATION

For the purpose of making this study more realistic and applied in the tanneries the researcher recommends the following points.

- It is quit commendable to create link between tanneries to share raw hides and inventories when found excess to avoid obsolete inventory.
- The model is more general, so as can be applied in different tanneries by varying the skin collection capacity of the upstream suppliers, the lead time and other delays required for supplying the items for the immediate receiver of the items and the daily installed socking capacity of the tannery. The model also helps to see the average back orders in the RBS, the lost sales of DHSPCC average transportation queues in every echelon since they are neglected for further analysis in this study.
- Applying the concept of the study regarding keeping the inventory stock of the tanneries to the reasonable level will monitor the price hike of raw skins faced by the tanneries by avoiding unnecessary competition of the tanneries to collect excess amount of hides and skins.
- Not only in the leather sector, but also the developed model can be used for other manufacturing industries with a slight modification.

7.3. FUTURE RESEARCH DIRECTION

The following three research areas can be directed as an extension of this study for future work.

- This study tests different scenarios to help the company delegated personnel to make decisions based on facts rather than assumptions. But there is a possibility to determine the optimal value for each scenarios as well as the whole system.
- This research takes under consideration only sheep skins and assumes the model can be used for goat skins and cow hides with a separate run. But there is a possibility to include all raw materials in a single model so as generate a better result with mixed transportation.
- The EOQ may not be all the same. There is a possibility to transport raw materials in the same path with a single truck with minimum cost. Example a truck can collect skins from Dessie-Kombolcha-Shewarobit- Debire Birehan and towns between them till they reach to Addis Ababa without waiting for the EOQ amount from each town suppliers so that improve the tannery operation capacity by minimizing scarcity of the resource in the tannery.

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