Addis Ababa University
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SUPPLY CHAIN MODELING FOR OIL COMPANIES: IN THE CASE OF LIBYA OIL ETHIOPIA LIMITED

BY

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A THESIS SUBMITED TO ADDIS ABABA UNIVERSITY SCHOOL OF COMMERCE FOR THE PARTIAL FULLFILMENT OF THE REQUIRMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ARTS IN LOGISTICS AND SUPPLY CHAIN MANAGEMENT

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DEDICATION

This thesis is dedicated to my mother, **BirkineshTegegn**, who gave me everything of her. My success has come with her priceless support and dedication.

DECLARATION

I, Firew Abera declare that the work which is being presented in this thesis entitled Supply Chain Modelling for Oil Companies in the Case of Libya Oil Ethiopia Limited: 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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CERTIFICATION

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

Confirmed by: **Shiferaw Mitiku (PhD)** Signature: _______________ Date______________

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ACRONYMS/ABREVATIONS

DES Discrete-Event Simulation

DEDS Discrete-Event Dynamic Simulation

LOEL Libya Oil Ethiopia Limited

SC Supply Chain

SD System Dynamics

SCM Supply Chain Management

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ABSTRACT

The purpose of this paper was to highlight the oil supply chain performance in fulfilling its customers need, analyze the essential characteristics of sustainable SCM in the oil company, identify the main challenges and opportunities of oil supply chain in the oil company, develop strategies to improve forecasting problems and delivery performance of the Ethiopian oil supply chain performance and to develop an integrated oil supply chain model from the depot to the end customer. No research has been conducted regarding oil supply chain simulation in Ethiopia.

A Discrete-Event Simulation model of SCM is constructed using Arena software to implement the four-target scenarios. 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 oil industry supply chain performance with a special focus on the downstream suppliers of oil.

This paper analyses the oil supply chain operations and proposes four supply chain scenarios. Four scenarios on the inventory replenishment strategy for the oil industries are developed. After running the trials, a significant method to control the inventory level of the oil while keeping the operating performance in a reasonable level is achieved. The outputs are also analyzed to share inventory stock information and help assigned SC managers to make decisions based on facts rather than assumptions in uncertain environment. The simulation results show the optimal supply chain strategy that demonstrates the best economic performance in the oil industry.

The research recommends the application of the developed model for all oil industries with slight modification of the model and the input data provided for the purpose of making this study more realistic and applied in the oil industry.

Key words: ***Supply Chain, Inventory Management, Discrete-Event simulation modelling, Oil Industry.***

CHAPTER ONE

INTRODUCTION

The first chapter of this study includes background of the study, statement of the problem, general and specific objectives, research question, scope and limitations of the study. The researcher has reviewed articles and reports to find out the problems in the oil industry.

1.1. Background of the Study

Many major decisions faced by a manager of a business focus on the best way to achieve the objectives of the firm, subject to the restrictions placed on the manager by the operating environment. These restrictions can take the form of limited resources, such as time, labor, energy, material, or money; or they can be in the form of restrictive guidelines, such as a recipe for making cereal or engineering specifications. One of the most frequent objectives of business firms is to gain the most profit possible or, in other words, to maximize profit. The objective of individual organizational units within a firm (such as a production or packaging department) is often to minimize cost. (Taylor W. 2013)

Considering the amount of inflexibility involved, meeting the broadening prospect of oil demand and its derivate while maintaining high service-levels and efficiency is a major challenge in the petroleum industry. (Morton, 2003, p. 31)

The oil industry faces many problems setting several constraints and challenges for the industry. Resulting from the above mentioned, demand growth, eased trade barriers and technological growth built a strong competition among the petroleum corporations (Jenkins & Wright, 1998; Anderson, 2003; Himola, 2011). Although the whole business world, especially the private sector is characterized by a high level of competition, it has a greater significance in the oil industry because of the enormous amount of money involved in (Anderson, 2003; Gainsborough, 2006).

Discrete event simulation permits the evaluation of operating performance prior to the implementation of a 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. (H. L. Lee, V. Padmanabhan and S. Whang, 1997)

Finding options for optimization of the oil supply chain is important because any cost saving means vast amounts of money for the oil companies, therefore optimization is at the center of attention in the oil supply chain management (Gainsborough, 2006; MOL, 2012).

Hussain et al. (2006) emphasize that despite the economic importance and the complexity of supply chain management in the oil industry, oil supply chain optimization is still in its infancy (Hussain et al., 2006).

Most of simulation tools are designed as interactive tools to be used by a human planner not as real time decision-making tools, which are directly linked to control system to dispatch tasks. Simulation tools aid human planner to make a right decision by providing information.

However, human planner should be able to interpret and modify the plan in order to achieve better supply chain performances.

Chang and Harris (2003) stated the benefits of supply chain simulation as follows:

- It helps to understand the overall supply chain processes and characteristics by graphics/animation.
- Able to capture system dynamics: using probability distribution, user can model unexpected events in certain areas and understand the impact of these events on the supply chain.
- It could dramatically minimize the risk of changes in planning process: By what-if simulation, user can test various alternatives before changing plan.

1.2. Statement of the Problem

Due to the Bullwhip effect, a poor plan can easily propagate to the whole supply chain areas (H. L. Lee, V. Padmanabhan and S. Whang, 1997). The impact of a poor plan on the overall business is huge. It causes cycles of excessive inventory and severe backlogs, poor product forecasts, unbalanced capacities, poor customer service, uncertain production plans, and high backlog costs, or sometimes even lost sales. SCM solutions may provide lots of benefits to industries but using the solutions for academic research is too costly.

Anthony Osoro, (2015) sated that current trends such as timeliness forecasting, proactive stock level management, IT, just in time delivery and e-procurement has not been well embraced by the registered oil companies. Most of these companies' as confirmed from qualitative data, did not have performance policies or strategy and hence had not made performance of their staff apriority despite the current market competition in the level of skills (Anthony Osoro, 2015).

The oil supply chain is also known to be a very complex chain compared to other industries' (Jenkins & Wright, 1998; Hussain, Assavapokee & Khumawala, 2006). It is due to several reasons. The whole oil supply chain is divided into up and downstream segments based on activities before and after the refining stage. However, the distance from the oil exploitation point to the final consumers could often be thousands and thousands of kilometers (km) which is the main reason for the oil supply chain having longer lead time than in other industries. In addition, crude oil has to go through a complex, capital intensive refinery process as well (Gainsborough, 2006; Ribas, Leiras & Hamacher, 2011). The long lead time also indicates the involvement of various means of transport such as ships, pipelines, rail and road as well as high transportation cost (Hussain et al., 2006; Ribas, Leiras&Hamacher, 2011).

As per the Internal audit report of Libya Oil Ethiopia Limited (LOEL), the company has paid Br 7.3 million in the year 2013 only as demurrage and storage charge on fuel importation which has affected the company's profitability. The same report also revealed that the company is exposed to stock out situation as it fails to position oil products in its warehouse due to delay on the activities along the supply chain. If logistics and supply chain can be sources of competitive advantage and LOEL is taking longer lead time to position products to its warehouse and incurring demurrage and storage costs due to delay in the activities along the supply chain which affect company profitability, then the activities along the oil supply chain of LOEL need to be thoroughly studied (Petros Gulma, 2014).

Currently the Ethiopian Oil industries are suffering from shortage of fuel supply, forecasting problems, application of technology, on time delivery and transportation. Integrating companies supply chain with upstream and downstream partners makes the supply chain work better and at lower cost than would be possible by managing each segment of the chain independently. According to Petros (2014) the fuel supply chain of oil companies needed to be studied thoroughly.

Despite Oil companies in Ethiopia have improved to its fuel supply chain, internal reports are showing that there is still a gap.

Antony states that high oil prices have exacerbated the poor financial states of the national oil companies in some countries with price subsidies, leading to the inability to procure petroleum products on time, acute fuel shortages, and high black market prices; Fuel price subsidies in the face of high world prices have increased incentives for diversion to black markets and smuggling to neighboring countries. (Anthony Osoro, 2015). According to Antony, shortage of fuel supply, unnecessary costs related to fuel product distribution, and longer lead time of fuel products are few of the challenges.

In this study, the current fuel supply chain challenges faced by the oil companies which affect the fuel supply in Ethiopia were investigated and a new supply chain model was presented with the aid of Arena simulation software which helps managers make informed decision. The collected data was investigated and analyzed to make it ready for management to make realistic decision. The analyzed results were further described and interpreted well in order to make it readily available for decision-making based on facts.

1.3. Research Questions

The research has answered the following research questions:

- ✓ What is the current performance level of oil supply chain system?
- ✓ What are the essential characteristics of sustainable SCM in the oil company?
- ✓ What are the major challenges and opportunities of oil supply chain?
- ✓ What type of supply chain model will be appropriate to ensuring an integrated fuel supply chain system from the depot to the end customer?
- ✓ What kind of strategies will be appropriate to improve forecasting problems, delivery performance and the Ethiopian fuel supply chain performance?

1.4. Objective of the Study

1.4.1. General Objective of the Study

The main objective of the study is to analyze the existing oil supply chain performance and develop supply chain modeling for oil companies in Ethiopia

1.4.2. Specific Objective of the Study

The specific objectives of the study are:

- ✓ to assess oil supply chain performance in fulfilling its customer need,
- ✓ to analyze the essential characteristics of sustainable SCM in the fuel company,
- ✓ to identify the main challenges and opportunities of oil supply chain in the oil company,
- ✓ to develop an integrated fuel supply chain model from the depot to the end customer;
- ✓ To develop strategies to improve forecasting problems and delivery performance of the Ethiopian fuel supply chain performance and.

1.5. Significance of the Study

Generally, the relevance of conducting a research in the field of supply chain is unquestionable. Even though, Oil Companies along with its stakeholders (government, suppliers, and banks) has implemented different measures to address the challenges in the Oil industry, they are still facing different kinds of challenges. Hence, this research has a significant contribution for further studies in improving the supply chain in the Oil sector in specific and supply chain simulation modeling in general. Therefore, this study has both theoretical, as well practical significance in supply chain management.

1.6. Organization of the Study

The study has organized in five 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 through its components and behaviors up to its inherent management challenge. It also reviewed framework for decision making.

Chapter three provides sufficient information regarding the different methodologies employed to solve various supply chain management challenges. In this chapter the appropriate methodology and tool (software) are presented with justification.

The content of chapter four mainly contains the Arena model that was developed for LOEL supply chain with clear and step by step description. This chapter includes the data collected and the conceptual model that is developed latter which is converted in to computer model. Chapter four mainly focuses on the design of simulation experiments and analysis of the simulation output with the execution of different scenarios that was developed.

Chapter five includes the summary of the findings, conclusion of the research results, limitations of the study and provides recommendations. Finally, this thesis will give a direction for future research that can be used as an extension of this research.

1.7. Scope of the Research

Since the research was conducted on the supply chain of oil companies, it is limited to the supply chain management in the oil industry and its optimization. But, due to the obvious time and financial constraints the research does not cover the entire supply chain network throughout the country rather the study focuses on Libya Oil Ethiopia Limited in Ethiopia. The choice of Libya Oil Ethiopia Limited is due to the success in Ethiopian regions and also an opportunity to gain valuable information from the company. Further research on studying other successful companies in the oil industry and analyzing their similar and different supply chain optimization techniques would improve this research topic in the future.

This research also gives more attention to the downstream section of the supply chain in the oil industry. Due to the time limit as well as the greater significance of the oil, this thesis focuses on the supply chain in the oil industry and identifies the main options for optimizing and improving it towards a more cost efficient and customer focused supply chain. The given time limit delimits the work to analyze only one company.

CHAPTER TWO

REVIEW OF RELATED LITERATURE REVIEW

This chapter of the study includes theoretical framework of the study, empirical literature review, conceptual framework of the study, identified literature gap and decision framework. Under this section the researcher reviewed many literatures and journals regarding supply chain management, modeling and simulation.

2.1. Theoretical Framework of The Study

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. In sophisticated supply chain systems, used products may re-enter the supply chain at any point where residual value is recyclable (Paul Groenewoud, 2011).

Assey (2012) mentions that supply chain management is focused on the management and examining of the network within the supply chain for gaining a better cost saving and providing a better customer service. Ganeshan and Harrison (1995) define supply chain management as a network or chain of facilities and distribution options that execute the process of the obtainment of products, the transformation of these products into intermediate and finished goods, and the distribution of these finished goods to customers.

2.1.1. Supply Chain Management for Competitive Advantage

There is no doubt that contemporary businesses endeavor to achieve competitive advantage over their competitors in order to be successful (Witt & Meyer, 2005). The competitive advantage derives from the capabilities of the businesses which make them able to provide a superior product or service among their competitors in a certain market (Johnson, Scholes & Whitington, 2009). This idea arises from the resource-based view which asserts that the resources such as physical assets, financial resources, human capital and intangible resources result in distinction among businesses (Buller & McEvoy, 1999). It also stresses the importance of sustainability. This is supported by Johnson *et al. (2009) t*hey state that besides gaining competitive advantage, the businesses have to exploit such capabilities that contribute to sustain the competitive advantages.

2.1.2. The Oil Supply Chain and Its Characteristics

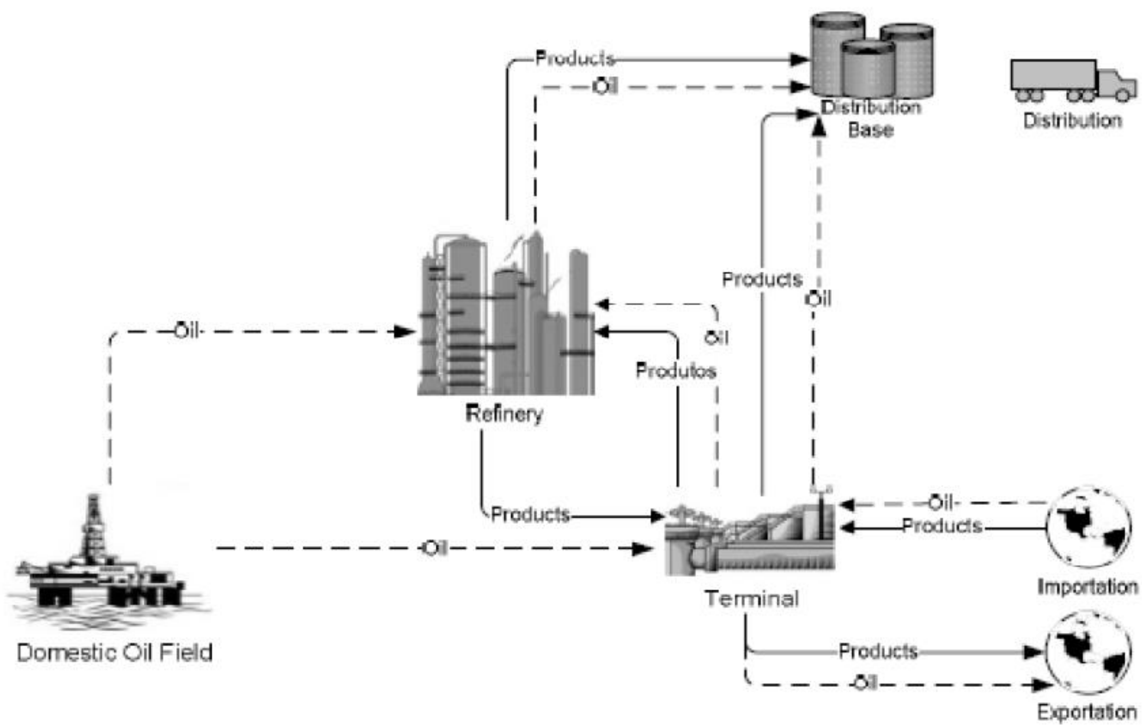
There are three core characteristics which have been identified based on the analyzed researches and literatures. Complexity and inflexibility are two elements which bear the most uncertainties, therefore many constraints and challenges can be derived by them. Due to the many variables and the inflexible nature of the oil supply chain are the main reasons that oil companies are integrated vertically in order to have a greater control on all over the chain. This section examines these attributes in more detail (Daniel Szucs and Kedir Hassen 2012).

2.1.3. Complex Supply Chain

Hussain *et al.* (2006) describes how the whole supply chain in this industry as very complex compared to other industries. The crude oil has to make a long journey from the point of production to the refineries. Long distance results in a long lead time of several weeks and in numerous players in the supply chain. The production is concentrated in certain areas but the product itself is demanded all over the world. The refinery process is a complex and capital-intensive part of the chain. The refined products are distributed either by road, water, rail or pipeline (Hussain *et al.*, 2006).

Gainsborough (2006) states that the oil supply chain is fundamentally based on a traditional model and the different stages in the chain also illustrate it. The oil companies have their classic way to serve the customers with products being 'manufactured', marketed, sold and distributed. The main goals are the same like in other industries, deliver the right product to the users in the right time and at the right price. The oil supply chain essentially can be divided into two closely linked major segments: upstream and downstream supply chain. The supply chain as a whole consists of 6 main stages where the middle refining stage separates the up- and downstream parts of the chain, although procurement as a vital function has to happen before refinery stage in order to provide the inputs for it (Stabell, 2001; Hussain *et al.*, 2006; Jasuja, Sowmya, Chaudhary, Kanade& Panda, 2009).

Figure 2.1 Typical Oil Supply Chain



(Ribas et al., 2011)

Upstream

Upstream basically starts with the gaining of crude oil and with the related operation such as exploration and production. Afterward logistics management has to be involved in order to deliver the crude oil from the exploitation point to the refinery.

1. Exploration: This stage involves seismic and geological operations.

2. Production: This stage is bout exploitation of the crude oil from the reservoir by drilling. Production needs highly qualified engineering work and it also links to other activities such as procurement, transportation. The crude oil produced is transported by pipelines or oil tankers to the terminals for storage. From here it is either to transport directly to the refinery or export to other companies' refineries (Ribas *et al., 2011*).

Downstream

The first stage is the refining process which is based on demand forecasting and triggers the procurement and the logistics activities in order to supply crude oil to the refinery and deliver its derivatives to the customers.

3. Procurement: This is sourcing of and managing the supply of the raw material to the refinery in the right time and in the right quantity.

4. Refining: This is a complex, well planned process which involves the transformation of the crude oil into different types of derivatives based on demand forecasting. Therefore, this has a tight link to the next stage, to the marketing activities and also involves inventory management.

5. Distribution: Logistics management assures that the right products get delivered to the right customers in the right time preferably in a cost efficient way (Stabell, 2001; Hussain*et al.*, 2006; Jasuja 2009)

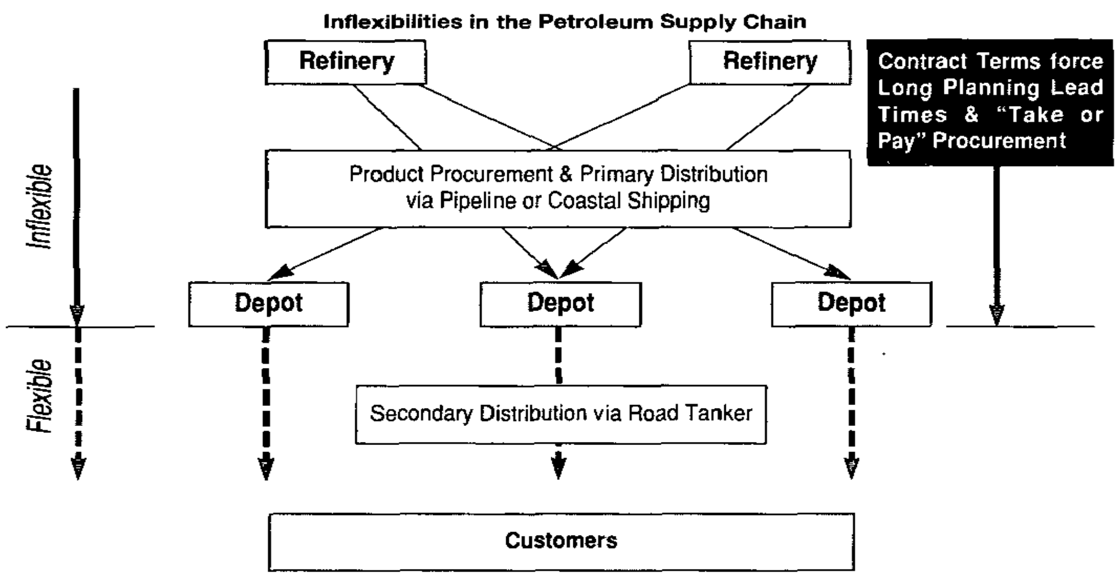
6. Marketing: This deals with marketing the different crude oil derivatives to the right customers. Marketing has to have an accurate knowledge about the current inventory level and refinery activities in order to manage its sale function.

2.1.4. Inflexible Supply Chain

One of the main characteristics of the oil supply chain is its inflexibility. Jenkins and Wright (1998) derive this inelasticity from three features of the oil industry. First of all, the purchase of the product has to be determined 9 months prior to the actual sale. Secondly the primary distribution occurs with fixed pipeline capacity or with fixed coastal shipping capacity. Finally, since the depots' capacity for the secondary distribution is limited, it has to be booked on a take-or-pay basis (Jenkins & Wright, 1998; Ribas*et a*l., 2011). Take-or-pay agreement in oil business means that one party agrees to purchase from other party a minimum amount of oil for certain period of time or to pay the same amount even if the oil is not needed (Your dictionary, 2012).

The increasing level of competition and high quality requirements increase the complexity of the oil supply chain (Gainsborough, 2006). Hussain (*2006)* also highlights reasons for the inflexibility such as long lead time, manufacturing capacity and limited means of transportation. The long distances between supply chain partners and the slow means of transportation increase the lead time from shipping point to the end users. It becomes hard to meet a required service level but it also could hurt customers who have to keep costly safety stock (Hussain et al., 2006). However, Jenkins and Wright (1998) asserts that the logistics can be a flexible element of the supply chain which could increase the responsiveness to any change or could be a source of cost saving. Figure 2.1 below illustrates the inflexible and flexible parts of the downstream supply chain.

Figure 2.2 Inflexibilities in the Petroleum Supply Chain



(Jenkins & Wright, 1998)

2.1.5. Vertically Integrated Supply Chain

Fundamentally the oil supply chain is a vertically integrated chain coupled with a push system approach (Stabell, 2001; Hall, 2002; Gainsborough, 2006). Based on the theory of Fisher (1997) about the basic supply chain strategies, the pushed chain couples with low cost. Hall (2002) underpins this by stating that low cost is the primary goal of this industry. Demand pull appears only at the scheduling activities for the delivery of the product to the customers. So, positioning the decoupling point in the downstream segment and securing transportation can reduce the bullwhip effect. Using reliable transportation mode and placing inventory closer to the final users enhances the customer satisfaction because faster lead time and faster product availability can be achieved (Hall, 2002). On the other hand, inventory is costly, however, exceeding production is not a preferable option of the oil companies because a possible production shut down is costly or it could result in massive discounting on price therefore they rather store it (Hall, 2002). Gainsborough (2006) also supports Hall's thought that the vertically integrated nature bears a potential advantage within the oil industry by having great control all over the chain.

2.1.6. Supply Chain Optimization in the Oil Industry

As it was already mentioned, the analysis concentrates more on the downstream segment since this segment bears a greater potential for enhancing the flexibility and for cost saving (Jenkins & Wright, 1998; Gainsborough, 2006; Hussain *et al., 2006*). It should not also be forgotten that first of all the objective of optimizing oil supply chain has to be clarified. Normally it is aligned with the supply chain strategy and aims to achieve profit maximization by being cost efficient and satisfying customers (Jasuja*et al., 2009*). Jasuja*et al.* (2009) states that optimization is also a value creating opportunity for the oil companies as well as for gaining competitive advantage.

Supply chain optimization is the biggest opportunity for most companies to significantly reduce their cost and improve their performance (Ratliff, 2007). Optimization strives to achieve the most efficient, optimal way to manage the supply chain in order to satisfy customer needs on the lowest cost. The desired quantity, regular supply of the crude oil, reduced lead time, lower production and distribution cost are one of the main goals of the oil supply chain (Hussain et al., 2006). But which crude oil should be refined in which refinery? How much inventory should be kept in stock? When is it best to move the products? Which transport mode should be used? These are just a few of the questions which need to be answered. Supposedly supply chain optimization finds the answer which contributes to make the right decision in the long term planning. In this stage of the thesis, the options for optimizing the oil supply chain will be determined by analyzing and extracting the key information of the literatures. These options can serve as essential enablers for optimizing oil supply chain and for facilitating decision making activity.

Hasini (2008) states that supply chain optimization is basically a practice in which resources are proficiently utilized in satisfying the customer's order, yet, subject to the restrictions and limitations on the use and flow of these resources throughout network of companies. Geunes and Pardalos (2005) define supply chain optimization as the implementation and application of optimizing models in order to manage the supply chain and the components within the pipe line or supply chain channel members. The optimization of the supply chain helps firms make the right decisions in view of the fact that every company has its distinctive resources, opportunities and limitations. On top of these, it is mentioned that supply chain optimization focuses on growing and maximizing the firms' returns on assets (Bryan & McDougall, 1998).

First the optimization process is reviewed and then, those approaches of supply chain management which inevitably need for optimizing the whole process in the oil industry, are discussed. The different divisions and their important functions in the downstream oil supply chain can be placed into five optimization activities which is explained in the next section below (Bryan & McDougall, 1998). Therefore, these divisions of oil downstream supply will be examined in view of linking them into the five optimization activities.

2.1.7. Supply Chain Modeling Methodologies

There are a number of supply chain modeling 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 modeling 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 modeling 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 modeling.

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 centers, 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 minimize the transportation costs from factories to distribution centers with certain production output from each factory.

Simulation modeling- 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 behavior of their real-world equivalents.

2.1.8. 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.

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).

2.1.9. 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) classifies 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 behavior 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 behavior. 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 modeled, 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.

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, optimization, and robustness analyses.

The simulation modeling 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 fulfillment, 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.

2.1.10. Role of Simulation and Modeling 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 modeling 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 modeling 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) summarized the main motivations for supply chain modeling:

- 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 behavior 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.*

2.1.11. Steps in Modeling and Simulation of Supply Chain

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, and Analyzing output data

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.

Taylor states that a **model** is an abstract mathematical representation of a problem situation. Management science encompasses a logical, systematic approach to problem solving, which closely parallels what is known as the scientific method for attacking problems. This approach follows a generally recognized and ordered series of steps: (1) observation, (2) definition of the problem, (3) model construction, (4) model solution, and (5) implementation of solution results. Taylor (2013).

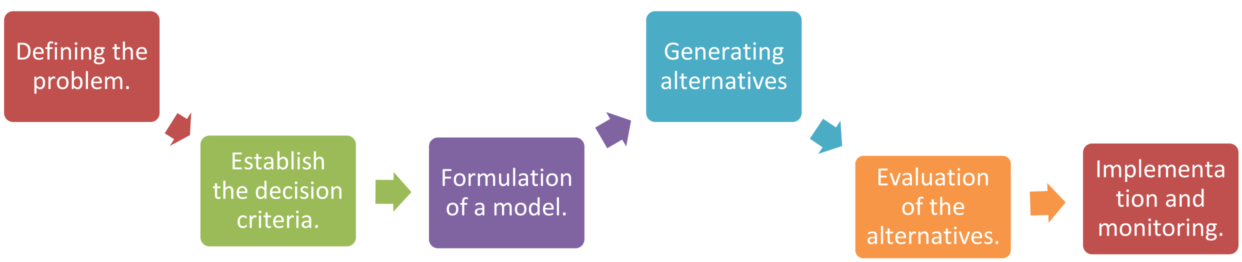
2.1.12. Framework for Decision-Making

Taylor (2013) states that many decision-making situations occur under conditions of *uncertainty*. Decision situations can be categorized into two classes: situations in which probabilities *cannot* be assigned to future occurrences and situations in which probabilities *can* be assigned. A decision-making situation includes several components—the decisions themselves *and* the actual events that may occur in the future, known as states of nature.

S. Anil Kumar and N. Suresh (2009) states the following steps for an analytical and scientific framework for decision.

- Defining the problem.
- Establish the decision criteria.
- Formulation of a model.
- Generating alternatives
- Evaluation of the alternatives.
- Implementation and monitoring.

Figure 2.3 Framework for Decision MAking



Source: S. Anil Kumar and N. Suresh (2009)

2.2. Empirical Literature Review

Crude oil and natural gas are the raw materials of the petroleum industry. Hussain *et al.* (2006) described the production process briefly. The production of crude oil can be found either deep underground or in offshore areas. These are used for the production of petrochemicals and oil derivatives. After crude oil is accessed, it goes through a distillation process and different fractions of it are produced (Hussain*et al* 2006). Fuel gas, liquefied petroleum gas, kerosene and naphtha are examples of the main fractions of the crude oil which are transferred to the refineries as a feedstock. That is followed by the cracking process and new products can be extracted for the petrochemical industry such as olefins and aromatics. Later, out of for instance ethylene, propylene, butadiene, benzene, toluene and xylenes, petrochemical plants can produce more specified products such as plastics, soaps, detergents and healthcare products, synthetic fibers, furniture, rubbers and paints (Hussain *et al.*, 2006).

Hilmola (2011) mentions that the recent decades' global economic trends and the oil industry have turned out to be inseparable and they have a great impact on each other. The supply of oil and gas has become a necessity for the national economies and shows a growing demand tendency (Hilmola, 2011; Tierney, 2004;).With globalization the trade barriers have also been eased for smoother trade and technology development has clearly intensified (Jenkins & Wright, 1998). Hall (2002) notes that faster delivery, reliability and lower cost have also appeared as a need from the customers' point of view. He also stresses that all these factors create a strong competition among the oil industry players and to be in the 'game' supply chain management plays an indispensable role. In a competitive market the companies aim to be more effective, more efficient and more profitable than their competitors.

The oil market is also exceedingly volatile because of various unpredictable factors. Anderson (2003) explained that one of the main factors is the frequent price fluctuation and the frequent political changes. Clearly these factors are affecting changes in the demand and supply which has an impact on the whole supply chain and its management. Ribas*et al* (2011) add that volatility can be the result of unforeseen events as well, such as a natural disaster or broken down equipment. The result is tremendous uncertainty surrounding the industry which makes the supply chain manager's job and supply chain optimization more challenging. The high level of uncertainties actually is one of the main reasons for the oil industry adopting a unique supply chain management approach (Ribas*et al* 2011).

2.3. Conceptual Framework of the Study

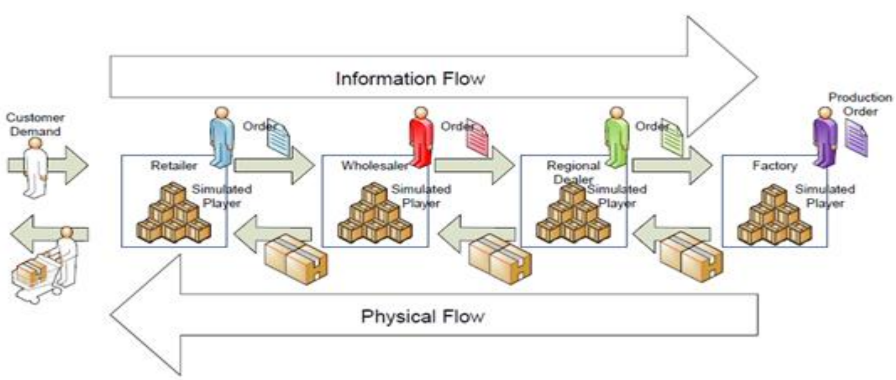
SCM faces a lot of challenging issues involving difficult decisions which can be company oriented and customer-oriented issues. In this study customer-oriented issues has discussed. The demand from customers may not be fully fulfilled from stock and the shortage may be backordered or the sale may be lost. Either way, it is desirable to balance the stock cost which depends on the size of inventory against the cost of not fully satisfying customer demand.

In studying such issues, modelers typically focus on the following key performance metrics, which eventually can be translated to monetary measures: customer service levels, average inventory levels and backorder levels, rate and quantity of lost sales, and inventory cost.

Typically, when an order is performed by a producer or retailer, there is a lag in time (called lead time) after which the order is received. The lead-time demand is the magnitude of demand that arises during lead time, and is typically random and therefore can result in stock-outs. Consequently, to decrease the uncertainty in lead-time demand, companies constitute safety stock, which is extra inventory stocked to maintain good customer service levels. Companies may also use to place new orders before previous ones are received. Therefore, ordering decisions are typically made based on inventory positions rather than inventory levels.

Companies to get feasible inventory management use scientific inventory policies which based on mathematical models. These models describe the behavior of the inventory system. Inventory models are classified according to whether the demand is known (deterministic) or whether it is random variable having a known probability distribution(stochastic). In the last case the chance of the exact solution is very limited therefore the researcher uses simulation.

Figure 2.4. Basic Supply Chain – Information and Physical Flow



Source: Paul Groenewoud (2011)

2.4. Identified Literature Gap

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.

None of the reviewed articles try to create balance between the supply quantity and the inventory level for oil products. This research 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 oil supply chain. 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.

A lot of work has been done on evaluating the challenges of supply chain on firm performance in Ethiopia but emphasis should also be laid down on the effect of supply chain flexibility on supply chain performance of oil companies. In Ethiopia, very few academicians had used simulation in general and ARENA simulation software in particular for studying supply chain modeling. So, future researchers must focus on using ARENA simulation software for supply chain modeling specially in oil companies.

In order to improve and verify the supply chain performance models; a wide range of empirical research of problems must be carried out for future research. A large number of models have been used for measuring flexibility but further research is required to compare the efficiency of the different models.

CHAPTER THREE

METHODOLOGY OF THE STUDY

In order to develop a sound methodology that adheres to the criteria outlined above, a detailed research methodology must be defined. In the literature, there is a clear understanding of the steps required to complete a sound simulation study.

3.1. Description of the study area

Libya Oil Ethiopia Limited; which has been in existence since 2008 having taken over Shell's business, is a subsidiary of Libya oil Holding Limited, a company established to undertake investments in Africa. Libya Oil Holdings Limited, the Group, operates as an oil exploration and production company. The group is one of the fastest growing energy companies engaged in providing energy solutions to a number of its customers and partners around the world. OiLibya, is the brand name used by the affiliates owned by Libya Oil Holdings and previously known as Tamoil Africa. The company is currently operating in 22 countries across Africa in the North, West & Central and Eastern Africa in all downstream segments and is continuing its advance to the southern Africa region (Libya, Egypt, Senegal, Ivory Coast, Cameroon, Gabon, Kenya, Mali, Burkina Faso, Niger, Chad, Eritrea, Uganda, Nigeria, Mauritius, Morocco, Tunisia, Ethiopia and Sudan). In Europe, also, it is functioning under the Tamoil brand.

It is running over 1000 Retail stations, 63 owned and JV Fuels Terminals of which 54 are Aviation Terminals in 16 countries. It has also owned and operating 8 Lubricants Blending and Filling Plants (LBFP) and is intending to continue expanding further.

As part of its expansion plan, Libya Oil Ethiopia Limited Constructed Ethanol Blending plant in its depot. The newly constructed facility has an ethanol storage capacity of 200,000 liters and this combined with the existing storage capacity for Mogas regular or Benzene enabled the company to mix 120,000 liters of blended fuel in just an hour.

Libya Oil Ethiopia Limited also constructed the biggest Jet A-1 tank with 1.5-million-liter storage capacity at its bole Aviation Depot.

3.2. Research approach and design

A computer assisted simulation model was developed from the data that were collected and analyzed with the help of simulation software. In this research a discrete-event simulation approach with the help of ARENA® (Rockwell software) were used to develop the simulation model, to measure SC performance and perform sensitivity and what if analysis.

3.3. Data Source, Type and Sample

Secondary data are collected regarding the daily fuel demand, inventory capacity and retailers demand from LOEL through document revision and discussion with the experts of the oil (fuel). Six month of daily oil demand were collected (180 data samples) as a sample data. There are data which are accessible for some reason. Some data was also collected by discussing and interview with the delegated experts in the supply chain of the fuel.

Raw data from the data base of LOEL on Import transactions used as secondary data source. Data from Newspapers, published books, Journals, Magazines, articles, internet, report provided by the government, research conducted by research agencies, and Invoices used as additional source for analysis of supply chain drivers.

3.4. Data Collection Procedure

The first step to collect data is to determine the number of observations that the data should include. To decide this, it is very important to understand the behavior of the production of oil and fuel. Oil and fuel products are always in need. Organized interview and a broad discussion is conducted to collect information about oil, fuel, the marketing system and the supply chain as a whole. Gathering actual data and information from the stakeholders, different files, and recordings were made. 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.

3.5. Data Analysis

After the collection of the data (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 investigated and analyzed before interpretation to make it ready for management factual decision making process. The analyzed result was interpreted in order to make it readily available for decision-making based on facts.

3.6. Validity and Reliability

Validity

Arena has been on the market for nearly a quarter century. With 300,000 users world-wide and growing, Arena advice and support is easy to find. Arena is supported by academic as well as commercial users. Arena is taught in most universities around the world that offer these degrees as well as in many business schools. The model is built such that the model's behavior reflects that of the real system sufficiently well for the specific purpose.

The simulation model was tested for short periods of time and also for few simulation trials. It was also tested if the model was operating correctly. It was accurately replicating the system being simulated.

Reliability

To determine whether the model reliably represents the system being simulated, the simulation results can sometimes be compared with actual real-world data. Several statistical tests are available for performing this type of analysis. However, when a model is developed to simulate a new or unique system, there is no realistic way to ensure that the results are valid.

CHAPTER FOUR

RESULTS, DISCUSSION AND INTERPRETATION

In this chapter the researcher reviewed activities of oil supply chain from placing order to positioning oil products to oil stations. The researcher also reviewed the oil supply chain performance, oil supply chain model and characteristics of sustainable supply chain in the oil company.

4.1. Result

4.1.1. Oil Supply Chain Performance

For many years, the oil industry has been working with different and unpredictable challenges. The time taken to blend ethanol with benzene and to deliver the final product are also the challenges for the oil companies.

Table 4.1. Lead time for the year 2016 and 2017

	Year	
	2016	2017
• Total lead time to supply oil from Djibouti to oil stations.	14 Days	13 Days
• Total lead time to supply oil from Akaki depot to A.A oil stations.	3 Hours	4 Hours
• Total Lead time to Blend Fuel at Akaki depot.	2 Hours	3 Hours
Total	14 days & 5 hours	13 days and 7 hours

Source: Own compilation 2017

Based on the figure above, the average lead time during the year 2016 and 2017 are 14 days and 5 hours and 13 days and 7 hours respectively.

Table 4.2. Lead time for April 2017

SHIP TO	Town	lead time
Bole Airfield (Stock)	Addis Ababa	10:33
Bole Airfield (Stock)	Addis Ababa	16:25
Akaki Depot(Stock)	Addis Ababa	17:21
Oromia Roads Authority-Assela-Fuel-(D)	Assela	16:04
Dangote Industries Ethiopia Plc-Fule-(D)	Mugher	15:32
Dangote Industries Ethiopia Plc-Fule-(D)	Mugher	17:21
Akaki Depot(Stock)	Addis Ababa	16:23
Akaki Depot(Stock)	Addis Ababa	17:44
Akaki Depot(Stock)	Addis Ababa	17:43
Sur Construction Mayhummer -(D)	Sheraro	17:04
Sur Const.Plc Aykel Zufan Road Proj-(D)	Gonder+80 Kms	16:40
Shire Adikentiba Oilibya F/S-Fuel-(D)	Shire	1:16
Akaki Depot(Stock)	Addis Ababa	19:50
Dangote Industries Ethiopia Plc-Fule-(D)	Mugher	20:51
Dangote Industries Ethiopia Plc-Fule-(D)	Mugher	19:40
Amhara Road Works Ent.-Bahirdar-Fuel-(C)	Bahir Dar	21:28
Al Asab Gen.Trn.& Con.Esta-Asebe T+80-D	Addis Ababa	18:59
Cfhe Plc Gashena 115 Kms-Fuel-(D)	Gashena 115 Kms	20:17
Akaki Depot(Stock)	Addis Ababa	21:07
Akaki Depot(Stock)	Addis Ababa	22:04
Bole Airfield(Stock)	Addis Ababa	3:49
Bole Airfield(Stock)	Addis Ababa	10:52
Bole Airfield(Stock)	Addis Ababa	12:06
Bole Airfield(Stock)	Addis Ababa	11:26
Bole Airfield(Stock)	Addis Ababa	2:54
Steely R.M.I Plc -Fuel-(D)	Debrezit	17:54
Akaki Depot(Stock)	Addis Ababa	18:17
Horizon Addis Tyre S.C.-Fuel-(D)	Addis Ababa	19:28
Assela City Center S/S-Fuel-(D)	Assela	19:36
Bole Airfield(Stock)	Addis Ababa	5:14
Average		15:31

Source: Own compilation 2017

Based on the figure above, the average lead time during April 2017 is 15:31. The maximum lead time is 22.04 with destination Akaki Depot of Addis Ababa and the minimum lead time is 1:16 with destination Shire, North of Ethiopia.

Table 4.3. Daily Oil demand in the year 2016 and 2017

ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

Company's Product Requirement Vs Actual Lifting

DJIBOUTI SUDAN & DEPOT

FROM FEBRUARY 01-28/2017

Company	Product requirment forecast						
	MGR		ADO	JET	KERO	LFO	HFO
	SUDAN	Djibouti					
TOTAL	3,040	5,020	47,620	14,094	4,135	1,040	970
OIL LIBYA	4,100	6,142	44,050	23,127	4,212	285	1,449
NOC	5,970	5,639	67,884	19,899	8,174	967	842
YBP	1,989	2,480	25,658	0	4,566	778	376
KOBIL	58	491	1,946	-	811	0	0
NILE	0	0	0	-	0	0	0
WAS	243	146	4,271	-	1,081	0	50
TAF	501	1,656	11,060		2,278	283	50
DALOL	0	32	3,680	-	305	-	-
OLWAY	59	289	2,070	-	167	-	-
GOMEJU	313	614	4,931	-	1,328	-	-
YESHI	28	143	1,747	-	565	-	-
GENET	600	788	9,046	-	2,175	-	-
Sum	16,901	23,449	223,973	57,120	29,787	4,253	3,737
Performance in percentage (%)							

Company	Actual Lifting						
	MGR		ADO	JET	KERO	LFO	HFO
	SUDAN	Djibouti					
TOTAL	3,067	4,878	44,620	7,175	2,199	2,242	1,740
OIL LIBYA	3,747	6,270	42,159	25,906	2,738	366	1,497
NOC	5,512	7,162	63,110	23,471	3,834	853	498
YBP	1,719	3,012	26,553	0	2,075	433	673
KOBIL	48	391	1,946	-	264	-	-
NILE	0	50	416	-	50	-	-
WAS	96	401	3,860	-	417	-	-
TAF	636	2,148	13,875	-	1,177	117	36
DALOL	-	50	2,759	-	173	-	-
OLWAY	147	441	1,699	-	96	-	-
GOMEJU	374	1,256	7,111	-	570	-	-
YESHI	95	609	2,951	-	388	-	-
GENET	701	1,420	10,977	-	907	-	-
Sum	16,142	28,088	222,036	56,552	14,888	4,011	3,944
Performance in percentage (%)	96	120	99	99	50	94	106

Company	Variance						
	MGR		ADO	JET	KERO	LFO	HFO
	SUDAN	Djibouti					
TOTAL	77	-151	-3,010	-6,919	-1,976	302	270
OIL LIBYA	-353	128	-1,891	2,779	-1,474	81	48
NOC	-458	1,523	-4,774	3,572	-4,340	-114	-344
YBP	-270	532	895	0	-2,491	-345	297
KOBIL	-10	-100	0	0	-547	0	0
NILE	0	50	416	0	50	0	0
WAS	-147	255	-411	0	-664	0	-50
TAF	135	492	2,815	0	-1,101	-166	-14
DALOL	0	18	-921	0	-132	0	0
OLWAY	88	152	-371	0	-71	0	0
GOMEJU	61	642	2,180	0	-758	0	0
YESHI	67	466	1,204	0	-177	0	0
GENET	101	632	1,931	0	-1,268	0	0
Sum	-759	4,639	-1,937	-568	-14,899	-242	207
Performance in percentage (%)	4	(20)	1	1	50	6	(6)

NB: BY MARKET SHARE

PETROLEUM UP LIFTING FROM DEPOTS
FOR THE MONTH OF FEBRUARY 1-28/2017

COMPANY	ADO	KERO	MGR
OILIBYA			566
TOTAL			237
NOC			481
YBP			91
TAF			281
GOMEJU			140
G.TOTAL	0	0	1,796

Source: Ethiopian Petroleum Supply Enterprise

Table 4.2 shows company's oil product requirements and their actual lifting from Sudan and Djibouti for the month February. From the table we can see that LOEL has lifted the highest volume of the product.

Table 4.4. Daily Oil demand in the year 2016 and 2017

Oil Demand	Year	
	2016	2017
Daily Oil Demand in Liters	4,000,000	4,500,000
Daily Oil Demand in m^3	4,000	4,500

Source: Own compilation 2017

Table 4.3 shows that oil demand is increasing. Oil demand in daily bases also increasing from time to time. Blending ethanol with benzene also another challenge for the oil companies.

Table 4.5. Daily Oil demand in the month April 2017

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Veh. Arrival Da	Veh. Arriv	schedu	VID	plate no.	Ord.	order no.	Trip no	ordered	schedule	Carrier no	Carrier	Con	Prod	qty to	customer	SHIPTO	address	Town	lead time
6	3-Apr-17	7:30	9:30	1487	80530/24662	SA	776782	751893	03/27/17	04/03/17	11304672	GMT INDU	1	AGO	10530	11807448	SUR CONSTRUCTION PLC WELA	ATO ZEMENFES	SHERARO + 125 KM	8:21
7	3-Apr-17	7:30	9:30	1487	80530/24662	SA	776782	751893	03/27/17	04/03/17	11304672	GMT INDU	2	AGO	10820	11807448	SUR CONSTRUCTION PLC WELA	ATO ZEMENFES	SHERARO + 125 KM	8:21
8	3-Apr-17	7:30	9:30	1487	80530/24662	SA	776782	751893	03/27/17	04/03/17	11304672	GMT INDU	3	AGO	12700	11807448	SUR CONSTRUCTION PLC WELA	ATO ZEMENFES	SHERARO + 125 KM	8:21
9	3-Apr-17	7:30	9:30	1487	80530/24662	SA	776782	751893	03/27/17	04/03/17	11304672	GMT INDU	4	AGO	10950	11807448	SUR CONSTRUCTION PLC WELA	ATO ZEMENFES	SHERARO + 125 KM	8:21
10				**1487 Total**											45000					
11	3-Apr-17	7:30	9:30	1574	04538/01676	ST	10137783	751911	03/14/17	04/03/17	11304686	ABEBA TR	1	MGR	10530	115310	Akaki Depot(Stock)	Akaki Depot(Stock)	Addis Ababa	12:15
12	3-Apr-17	7:30	9:30	1574	04538/01676	ST	10137783	751911	03/14/17	04/03/17	11304686	ABEBA TR	2	MGR	10630	115310	Akaki Depot(Stock)	Akaki Depot(Stock)	Addis Ababa	12:15
13	3-Apr-17	7:30	9:30	1574	04538/01676	ST	10137783	751911	03/14/17	04/03/17	11304686	ABEBA TR	3	MGR	12200	115310	Akaki Depot(Stock)	Akaki Depot(Stock)	Addis Ababa	12:15
14	3-Apr-17	7:30	9:30	1574	04538/01676	ST	10137783	751911	03/14/17	04/03/17	11304686	ABEBA TR	4	MGR	11960	115310	Akaki Depot(Stock)	Akaki Depot(Stock)	Addis Ababa	12:15
15				**1574 Total**											45320					
16	3-Apr-17	9:20	10:11	1615	50286/16624	SA	774035	751919	03/13/17	04/03/17	11304699	ANGESOM	1	AGO	11330	11807878	SUR CONST.PLC AYKEL ZUFAN F	SUR CONST.PLC AYKEL ZUFA	GONDER+80 KMS	15:55
17	3-Apr-17	9:20	10:11	1615	50286/16624	SA	774035	751919	03/13/17	04/03/17	11304699	ANGESOM	2	AGO	11020	11807878	SUR CONST.PLC AYKEL ZUFAN F	SUR CONST.PLC AYKEL ZUFA	GONDER+80 KMS	15:55
18	3-Apr-17	9:20	10:11	1615	50286/16624	SA	774035	751919	03/13/17	04/03/17	11304699	ANGESOM	3	AGO	12850	11807878	SUR CONST.PLC AYKEL ZUFAN F	SUR CONST.PLC AYKEL ZUFA	GONDER+80 KMS	15:55
19	3-Apr-17	9:20	10:11	1615	50286/16624	SA	774035	751919	03/13/17	04/03/17	11304699	ANGESOM	4	AGO	9800	11807878	SUR CONST.PLC AYKEL ZUFAN F	SUR CONST.PLC AYKEL ZUFA	GONDER+80 KMS	15:55
20				**1615 Total**											45000					
21	3-Apr-17	9:20	10:11	1384	01749/02663	SA	777999	751920	04/03/17	04/03/17	11304594	AYAL TEZA	1	AGO	10830	11807885	DODOLA OILIBYA S/S- FUEL-(D)	DODOLA OILIBYA S/S	DODOLA	17:30
22	3-Apr-17	9:20	10:11	1384	01749/02663	SA	777999	751920	04/03/17	04/03/17	11304594	AYAL TEZA	2	AGO	10700	11807885	DODOLA OILIBYA S/S- FUEL-(D)	DODOLA OILIBYA S/S	DODOLA	17:30
23	3-Apr-17	9:20	10:11	1384	01749/02663	SA	777999	751920	04/03/17	04/03/17	11304594	AYAL TEZA	3	AGO	11850	11807885	DODOLA OILIBYA S/S- FUEL-(D)	DODOLA OILIBYA S/S	DODOLA	17:30
24	3-Apr-17	9:20	10:11	1384	01749/02663	SA	777999	751920	04/03/17	04/03/17	11304594	AYAL TEZA	4	AGO	11620	11807885	DODOLA OILIBYA S/S- FUEL-(D)	DODOLA OILIBYA S/S	DODOLA	17:30
25				**1384 Total**											45000					
26	3-Apr-17	9:20	10:11	1513	44865/14691	SA	774666	751921	03/16/17	04/03/17	11304673	ALENE AD	1	AGO	11010	11807854	ARAB CONTRACTORS PLC YIRG	ARAB CONTRACTORS PLC	YIRGACHFE + 77 KMS	17:38
27	3-Apr-17	9:20	10:11	1513	44865/14691	SA	774666	751921	03/16/17	04/03/17	11304673	ALENE AD	2	AGO	11040	11807854	ARAB CONTRACTORS PLC YIRG	ARAB CONTRACTORS PLC	YIRGACHFE + 77 KMS	17:38
28	3-Apr-17	9:20	10:11	1513	44865/14691	SA	774666	751921	03/16/17	04/03/17	11304673	ALENE AD	3	AGO	12100	11807854	ARAB CONTRACTORS PLC YIRG	ARAB CONTRACTORS PLC	YIRGACHFE + 77 KMS	17:38
29	3-Apr-17	9:20	10:11	1513	44865/14691	SA	774666	751921	03/16/17	04/03/17	11304673	ALENE AD	4	AGO	10850	11807854	ARAB CONTRACTORS PLC YIRG	ARAB CONTRACTORS PLC	YIRGACHFE + 77 KMS	17:38
30				**1513 Total**											45000					
31	3-Apr-17	10:43	11:18	1457	80406/24480	SA	776228	751923	03/24/17	04/03/17	11304672	GMT INDU	1	AGO	10560	11829095	COMBOLCHA HEKMA S/S-FUEL-	ESHETU AMDIE/NEGISTE/AE	COMBOLCHA	16:05
32	3-Apr-17	10:43	11:18	1457	80406/24480	SA	776228	751923	03/24/17	04/03/17	11304672	GMT INDU	2	AGO	10830	11829095	COMBOLCHA HEKMA S/S-FUEL-	ESHETU AMDIE/NEGISTE/AE	COMBOLCHA	16:05
33	3-Apr-17	10:43	11:18	1457	80406/24480	SA	776228	751923	03/24/17	04/03/17	11304672	GMT INDU	3	AGO	12600	11829095	COMBOLCHA HEKMA S/S-FUEL-	ESHETU AMDIE/NEGISTE/AE	COMBOLCHA	16:05
34	3-Apr-17	10:43	11:18	1457	80406/24480	SA	776228	751923	03/24/17	04/03/17	11304672	GMT INDU	4	AGO	11010	11829095	COMBOLCHA HEKMA S/S-FUEL-	ESHETU AMDIE/NEGISTE/AE	COMBOLCHA	16:05

Source: LOEL

Table 4.5 shows the daily oil demand. It shows the order date, vehicle arrival date, order number, trip number, scheduled date, carrier number, product type, load date, quantity of the product, customer account, customer name, destination, address, town, and lead time. The average lead time for the month April is 16.28.

4.1.2. Characteristics of Sustainable Supply Chain Management in the Oil Company

After the simulation runs of the oil sustainable SCM model based on the four proposed scenarios, the key performance indicators of output are categorized and analyzed in aspects of cost analysis, inventory and service level in order to optimize supply chain model in the fuel industry.

The simulation results of the sustainable oil SCM model based on the four scenarios indicate that the performance factors are improved as the inventory levels of the supply chain decrease, which result in improved supply chain flexibility and reduced production volume caused by lower safety stocks. In the cost analysis, the highest total costs occur in scenario 3; whereas scenario 1 has the highest production costs. The lowest costs are shown in scenario 2 with the minimum inventory levels.

The importance of sustainable supply chain management lies in integration and achievement of the economic and social goals of the fuel industry. The fuel sustainable SCM framework is modeled with Arena according to the discrete event simulation procedures. The essential success factors of the fuel supply chain model are analyzed in the simulation study.

This research has faced challenges in regards to limitations of data collection and software capacity along the stages of the simulation modeling. Although most of the input parameters are collected and calculated from reliable sources; there are still limitations such as technical data and storage cost. In addition, transport and storage cost was not generated due to lack of data. Incorporating the storage cost would make the simulation results more precise without changing the conclusion of optimal strategy because the inventory levels are decreasing from scenario 1 to 3.

Despite the research limitations, the simulation results are presented in the output analysis. In the future, the social dimension as well as storage costs should be quantified in subsequent researches.

4.1.3. The Main Challenges and Opportunities of Oil Supply Chain in LOEL

For many years, the oil industry has been working with different and unpredictable challenges. Discussion with supply managers revealed that there are many challenge in the oil industry. Government regulations, political risks, rivalries, and price changes are some of the issues mentioned from the oil company supply managers as challenges of supply chain performance. According to the supply managers the main challenges that LOEL facing is production and delivering the final products to customers at the least cost possible. The time taken to blend ethanol with benzene is also one of the challenges for the oil companies.

Currently, no specific method has been adopted to determine when companies should attempt to make different decisions. An interview with supply chain managers in LOEL revealed that the only method used is worksheets. Even though worksheet approaches may improve accuracy in many decision-making problems, it should not be the only methods for problem solving. This method cannot guarantee an optimal solution.

4.1.4. Constructing a Computer Simulation Model

Arena uses an entity-based, flowcharting methodology for modeling dynamic processes. Arena is a Visio-compatible, flowcharting tool. Entities in an Arena model proceed through a flow chart of the process and seize control of resource capacity as they are processed. The flowchart approach to model building makes the most sense to engineers and to process designers who must be able to carefully document a process in order to accurately model it and analyze it. This results in models that become highly detailed documents of the processes being studied.

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 this study is too complex than modeling manufacturing systems because the Arena model of the study is composed of sub-models, each associated with an inventory-holding barrier in a system echelon. Each sub model is subjected to the following events: order arrival, inventory updating, replenishment order triggering, and order shipment. Figure 4.1 displays all the variables of the developed Arena model. Random initial values for some variables are provided to activate the model at the startup period.

Even though the 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.

Figure 4.1 Dialog spreadsheet of the Variable module for the Arena model of the Libya Oil Ethiopia Limited supply chain.

Variable - Basic Process

	Name	Comment	Rows	Columns	Data Type	Clear Option	File Name	Initial Values	Report Statistics
1	Inventory				Real	System		1 rows	☐
2	Target Stock				Real	System		1 rows	☐
3	Batch Size				Real	System		1 rows	☐
4	Reorder Point				Real	System		1 rows	☐
5	Demand				Real	System		0 rows	☐
6	Total Customers				Real	System		0 rows	☐
7	Lost				Real	System		0 rows	☐
8	Amount Lost				Real	System		0 rows	☐
9	Production				Real	System		0 rows	☐
10	Demand Met				Real	System		0 rows	☐

Source: Own compilation, 2017

4.1.4.1. Collecting the Data and Defining Oil SC Model

It is challenging to get a relevant data for modeling and simulation. The necessary data is collected from LOEL through document revision and discussion with the experts of the oil. 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 oil. The major data required for running the simulation and get relevant output based on the objective of the research are: The daily oil supply which are in Addis Ababa, the daily oil demand, the total lead time to supply the oil and the existing inventory level of the oil.

The first two data are collected from the LOEL 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.

Even though the installed stock capacity of the case company is considered to be 22,500 metric cube per day, it is not always the same even if there is enough stock. The following table indicates daily oil demand of the case company in the months of November 2016 to April 2017.

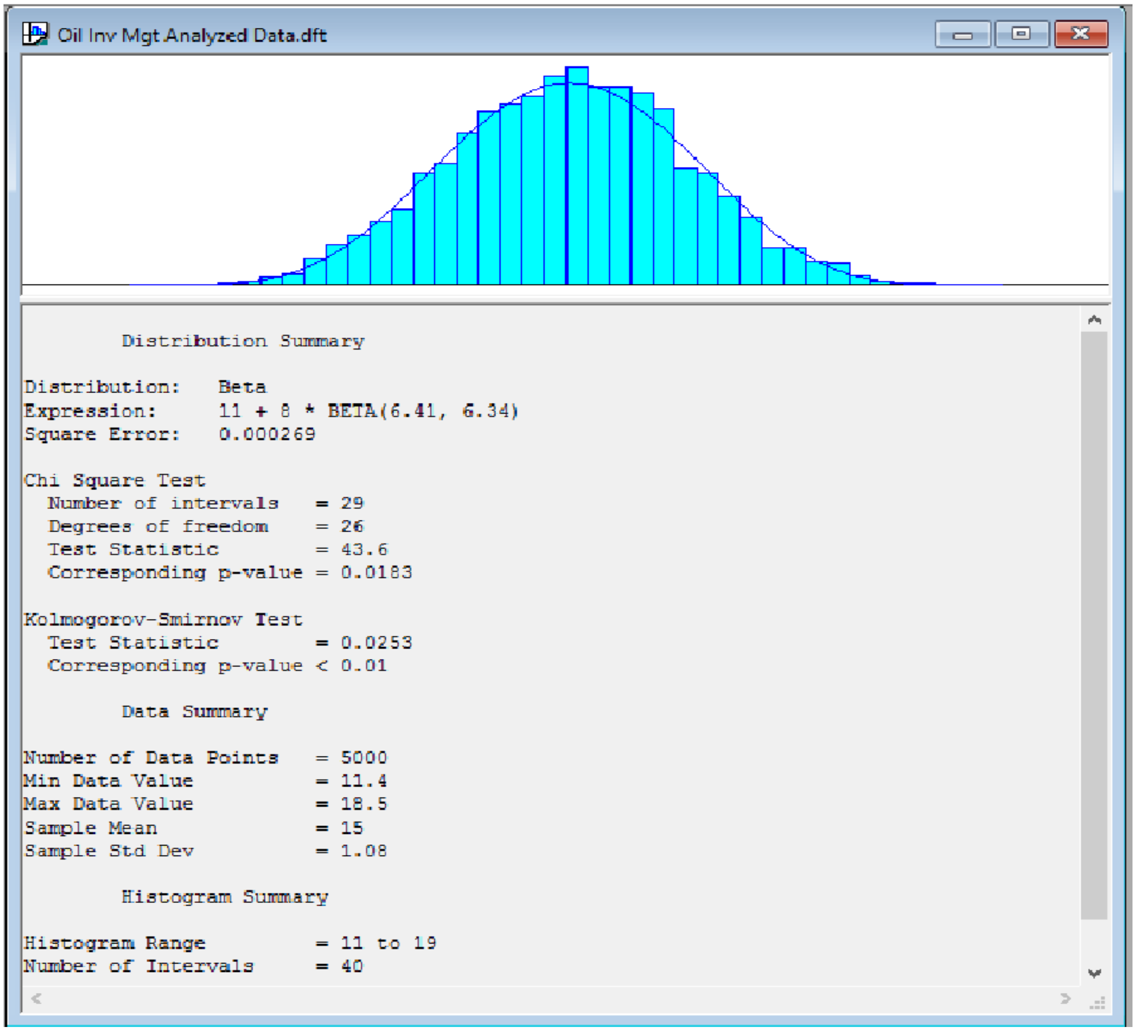
Table 4.6 The daily fuel demand of LOEL

Date	November	December	January	February	March	April
1	3450100	4237130	3479530	3880180	4321370	4691910
2	4100200	4586240	3677150	3946110	3847500	3784440
3	3930420	3418950	3896240	4708730	4023200	3970050
4	5200010	3912240	4078100	2979870	5011200	3229500
5	3569000	3117950	4212300	4509590	4467640	4804010
6	5640020	3790480	3900200	3657940	3697290	4668090
7	4321330	3748920	4378000	3886230	4186420	6246080
8	3547100	3967450	4197900	4918690	3614970	3661380
9	3423700	3978080	4676500	3812450	3092150	3344220
10	5002300	4260200	3949060	5100460	5000540	3986320
11	4567850	4306320	3860180	4385670	4299670	3859530
12	3597160	3904870	3706110	3871000	3476000	3497130
13	4686230	4517420	4504940	3009700	3489550	3686240
14	3518910	3219570	3517670	3824760	3454080	4518980
15	3012450	5857940	2909590	4168090	4507320	4012210
16	5110940	4016630	5000230	3237800	3904870	4117930
17	4785670	4105230	4789100	4090010	4317520	4690580
18	3021000	4126340	4795800	3950090	3919670	4647900
19	3229500	4301000	3957820	4220050	5737960	4057650
20	3524060	3324700	4309870	3995600	4116980	4749060
21	3568090	3691010	5740020	3807500	3905230	3660180
22	4037800	4350040	4521780	3868700	4126340	3706110
23	3790010	4520050	3847190	5046010	3701000	4704940
24	4000500	3795500	3673800	4661300	4024600	2217670
25	3256200	3904000	5007600	3578200	3791310	2809590
26	4610000	3568700	4678900	4108300	4250140	2357940
27	3203020	5446050	3697100	3966500	4820150	3916630
28	4360060	4861500	4467290	4306810	4412530	3428230
29	3674500	3978290	3518910	0000000	3397000	3146390
30	4609300	4008600	3562450	0000000	4387100	3128430
31	0000000	3656500	5100980	0000000	3804000	0000000

Source: Own compilation, 2017

Six-month data was collected to implement the research. The above table is showing the daily oil demand of LOEL from November 2016 to April 2017.

Figure 4.2 Probability Distribution of oil capacity of LOEL



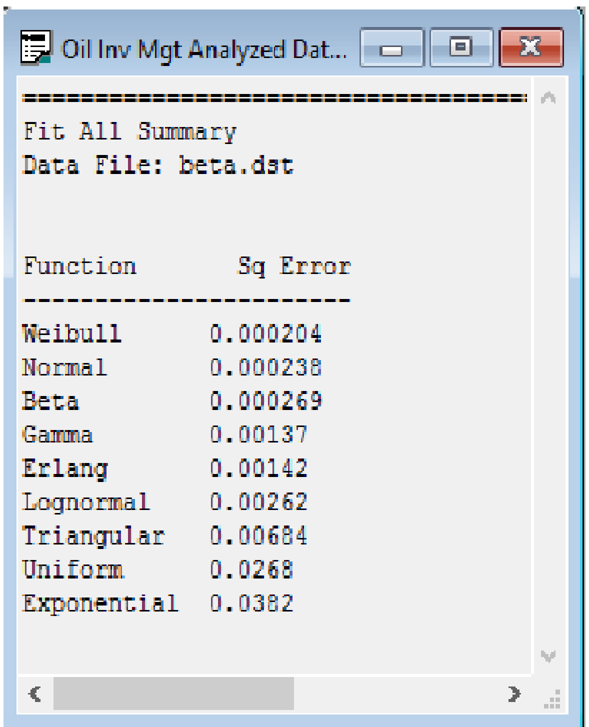
Source: Own compilation, 2017

The results of Chi-square and Kolmogorov-Smirnov goodness-of-fit tests are shown in the figure above. These results are presented in the form of p-values; the p-value is the largest value of the type-I error probability that allows the distribution to fit the data. Since the figure above shows that the p-value is less than 0.01, then it is significant of a good fit at level 0.01 or we would reject the null hypothesis of a good fit at level = 0.10.

As we see in the figure 4.2 the aggregated and daily oil demand can be represented by a Beta distribution with expression 11+8*WEIB (6.41,6.34) and mean Square Error: of 0.000269. The amount of oil is too small comparing with the fuel demand. Above is a picture taken by a cutting tool from the Arena input analyzer software for determining the daily fuel demand.

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

Figure 4.3 Summary of LOEL oil capacity probability distribution



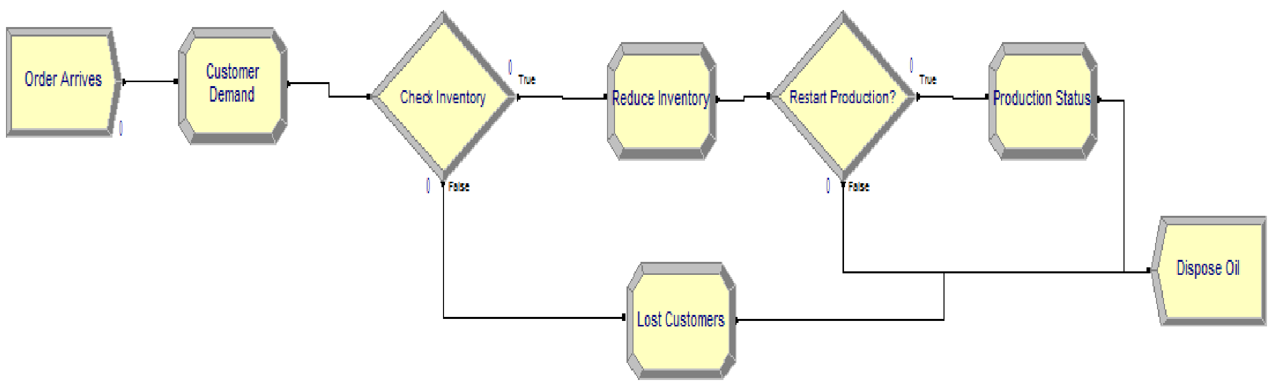
Source: Own compilation, 2017

The figure above lists each of the applicable distribution functions, with its corresponding square error, from best to worst (smallest to largest square error). From the list, Beta (0.000269) is the third best and exponential is the worst. The results of the Fit All calculations are interpreted as guidelines rather than precise scientific calculations, since the relative rankings can be affected by the number of intervals within the histogram or choice of histogram end points. The results of the Fit All calculations allows to distinguish clearly between those functions that fit the data well and those that do not.

4.1.4.2. Oil Supply Chain Management Model

As described earlier this model is developed to generalize the model so that it can be used for other oil companies who face similar problems of managing the oil product inventory. For the case of this study it is taken as the daily demand of the oil exceeds the daily production. At the same time the oil target stock is assumed to be 50,000.00 to abandon production termination due to excess oil product stock. The model developed with the help of Arena simulation software is showed below on figure 4.3.

Figure 4.4. Oil inventory management model



Source: Own compilation, 2017

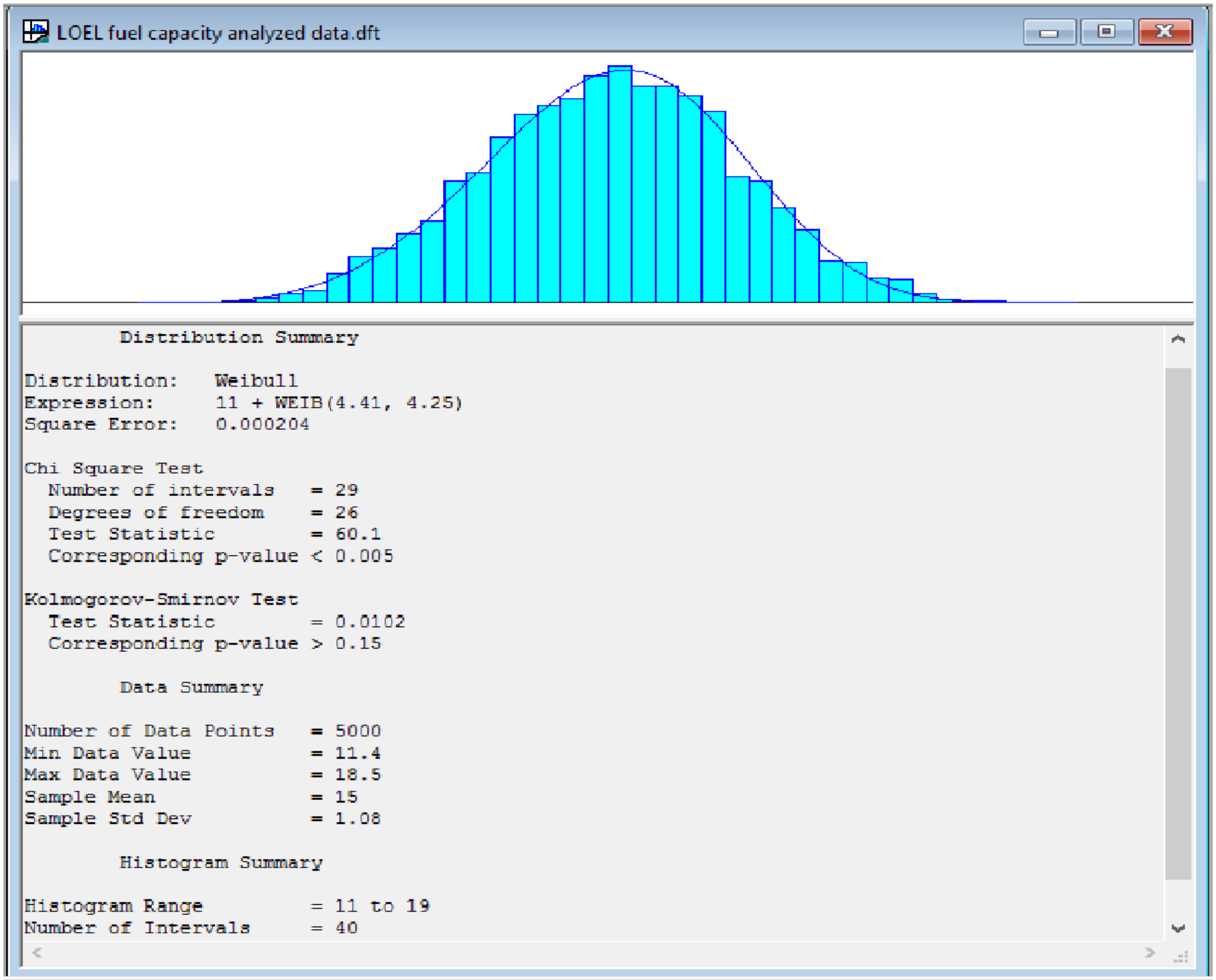
As shown figure 4.4, oil inventory management model order entities are continuously created in the *Create* Module *Customer Demand Arrival for Oil* on daily basis with demand quantity of greater or equal to the daily production to avoid excess stock. Here the daily demand is taken as UNIF (50,100) which means demand is uniformly distributed between 50 and 60 and assigned in the *Assign* Module *Quantity of oil 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 and 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 and if no, production will proceed as usual. Finally, the control demand entity will be disposed after performing those assigned tasks.

4.1.4.3. Collecting the Data and Defining the Model for Fuel

The necessary fuel data is collected from LOEL through document revision and discussion with the experts of the oil. The major data required for running the simulation and get relevant output based on the objective of the research is

Even though the installed stock capacity of the case company is considered to be5,000,000 Lt. per day, it is not always the same even if there is enough stock. The following table indicates daily oil demand of the case company in the months November 2016 to January of April 2017.

Figure 4.5 Probability Distribution of fuel capacity of LOEL

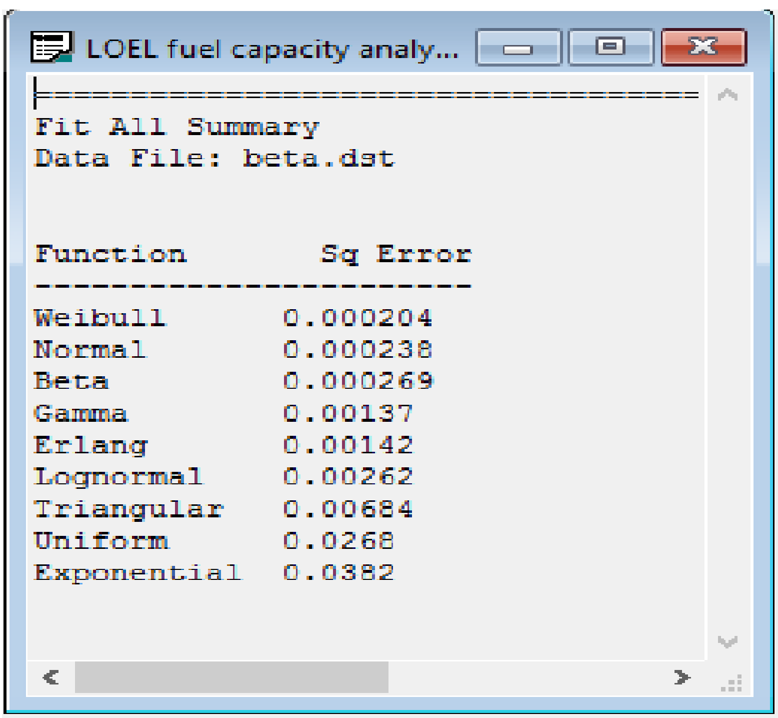


Source: Own compilation, 2017

The aggregated and daily oil demand can be represented by a Beta distribution with expression 11+WEIB (4.41,4.25) and mean Square Error: of 0.000204. The amount of fuel is too small comparing with the fuel demand. Above is a picture taken by a cutting tool from the Arena input analyzer software for determining the daily fuel demand. As we see in the figure 4.6 the oil capacity of LOEL can be represented by a normal distribution with expression 11+WEIB (4.41,4.25).

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

Figure 4.6 Summary of LOEL fuel capacity probability distribution



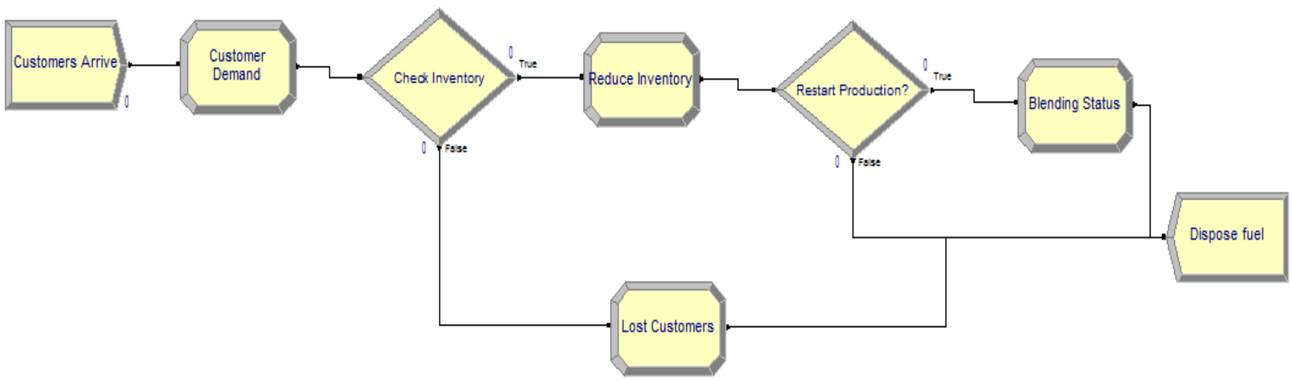
Source: Own compilation, 2017

The figure above lists each of the applicable distribution functions, with its corresponding square error, from best to worst (smallest to largest square error). From the list, Beta (0.000269) is the third best and exponential is the worst. The results of the Fit All calculations are interpreted as guidelines rather than precise scientific calculations, since the relative rankings can be affected by the number of intervals within the histogram or choice of histogram end points.

4.1.4.4. Fuel Supply Chain Management Sub-Model

As described earlier this model is developed to generalize the model so as it can be used for other fuel companies who face similar problems of managing the fuel inventory. For the case of this study it is taken as the daily demand of the fuel exceeds the daily production. At the same time the fuel target stock is assumed to be 5,000,000.00 to abandon production termination due to excess fuel product stock. The model developed with the help of Arena simulation software is showed below on figure 4.12.

Figure 4.7 Fuel inventory management model



Source: Own compilation, 2017

As shown figure 4.9., fuel inventory management model order entities are continuously created in the *Create* Module *Customer Demand Arrival for Oil* 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 (50,100) which means demand is uniformly distributed between 50 and 100 and assigned in the *Assign* Module *Quantity of fuel 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 and if false demand will be assumed as lost. With a continuous fashion the fuel 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 and if no, production will proceed as usual. Finally, the control demand entity will be disposed after performing those assigned tasks.

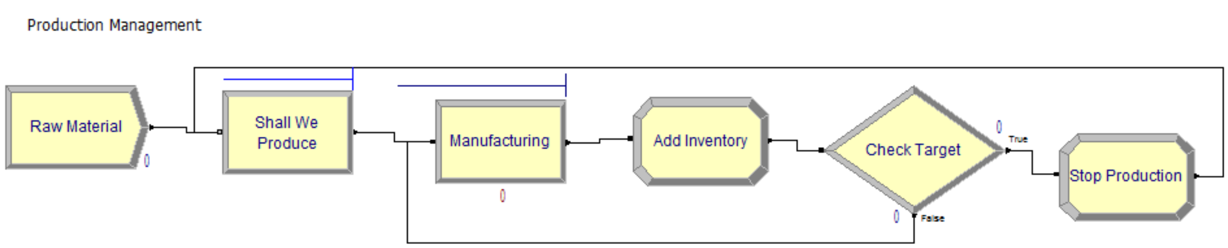
4.1.4.5. Production Supply Chain Management Model for Fuel

Figure 4.13. Shows the fuel inventory management and production control segment of the Arena model. LOEL is blending benzene with ethanol in its Akaki depot. This model 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 fuel demand* and determines the quantity of demand in the *Assign* Module *Production Batch Sizes* as per the collected data from LOEL. Then the production control entity proceeds to the *Process Module Blend Fuel? Shall we Produce?* to scan the condition for production is active (Inventory Position of fuel<= Minimum Reorder level of fuel). Then the entity will lead to *Decide* module to check the quantity of fuel available on hand and determine the capacity utilization of the fuel. If the level of warehouse inventory in the input is greater or equal to (Inventory >= Target stock) 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 fuel inventory.

After production, process is held the entity will go for updating/reviewing the on-hand inventory position of the fuel by deducting the produced/processed amount from the stock. Finally, the control entity will go to the *Decide* module and check the inventory level of the fuel. Here it is assumed that there is no any market problem of the fuel and hence it couldn't be the reason for production termination.

Figure 4.8 Fuel production management model



Source: Own compilation, 2017

Here the researcher used production model as LOEL is mixing ethanol with benzene in its Akaki depot. Ethanol and benzene are considered to be a raw material. This model is designed and developed to perform basic tasks of the fuel in determining the time between consecutive orders and the amount of fuel required by customers to place the order in the supplier of the fuel. The figure above (figure 4.10.) indicates the 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 model varies for developing and testing each of the four scenarios. Each of the models will be described in each of the upcoming scenario design and analysis part of this study.

In general, for all scenarios this model will generate order to the supplier, checks on hand inventory level of the fuel, updates the inventory position of the fuel and determines the time between consecutive orders and the quantity of shipment as per the economic order quantity concept. In the other way, this model generates the demand stream, handles demand fulfillment, and triggers replenishment orders from supplier.

4.1.5. Strategies to Improve Forecasting Problems

As described in the data of this study the maximum daily oil available is 22,000 metric cube on daily basis. If the oil company has willing to sell more than these liters daily, it should have to see other sources of the raw material otherwise it is limited to this demand capacity. Therefore, the scenarios are developed in ordering the oil supplier in between these values of sell per day with constant and variable ordering times. Order quantities from LOEL shall vary from 0 to 100 on daily basis. The order quantities may exceed this value and vary depending on the time between the consecutive orders to satisfy the oil demand.

4.1.5.1. Scenario Based Output Analysis for Oil

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.

Figure 4.9 Scenario case tests

	Scenario Properties				Controls			Responses		
	S	Name	Program File	Reps	Batch Size	Target Stock	Reorder Point	Amount Lost	Lost	Inventory
1		Scenario 1	3 : Model1.p	4	2.0000	50000.0000	100.0000	1385.599	17.000	50.638
2		Scenario 2	3 : Model1.p	4	4.0000	40000.0000	100.0000	205.336	2.500	206.875
3		Scenario 3	3 : Model1.p	4	4.0000	30000.0000	100.0000	205.336	2.500	206.875
4		Scenario 4	3 : Model1.p	4	4.0000	20000.0000	100.0000	205.336	2.500	206.875

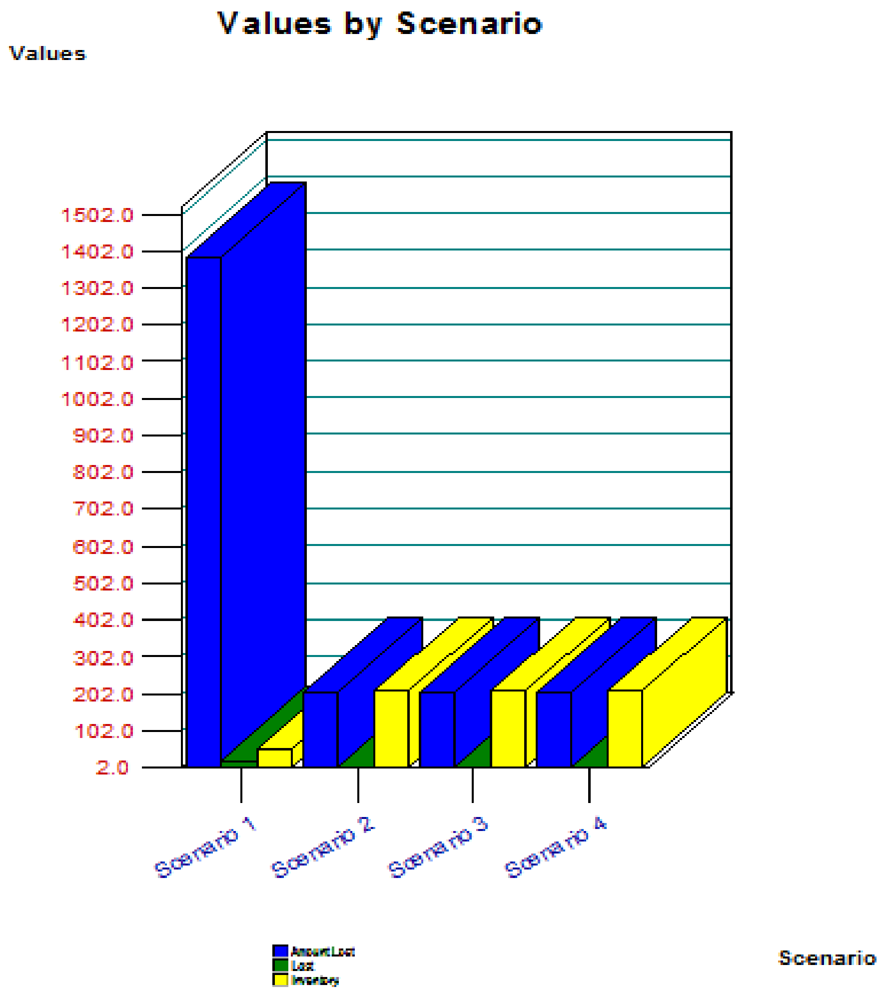
Source: Own compilation, 2017

The developed arena model is more general and it can be used to test and measure different parameters as needed. But for the purpose of this research the researcher prefers 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 daily average and maximum inventory available in the oil warehouse stock.

These conditions are varied due to the availability of the oil 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 echelon.

Figure 4.10 Scenario case tests



Source: Own compilation, 2017

The bar graph above shows the best options from the scenarios. The least inventory level is on the first scenario. The highest amount lost is also in the first scenario.

4.1.5.2. Scenario Based Output Analysis for the Sub-Model

As described in the data above of this study the maximum daily Fuel available is 5,246,080 liters on daily basis. If the oil company has willing to sell more than these liters daily, it should have to see other mechanisms otherwise it is limited to this demand capacity. Therefore, the scenarios are developed in ordering the supplier in between these values of sell per day with constant and variable ordering times. Order quantities from LOEL shall vary from 0 to 100 on daily basis. The order quantities may exceed this value and vary depending on the time between the consecutive orders to satisfy the fuel demand.

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.

Figure 4.11 Scenario case tests

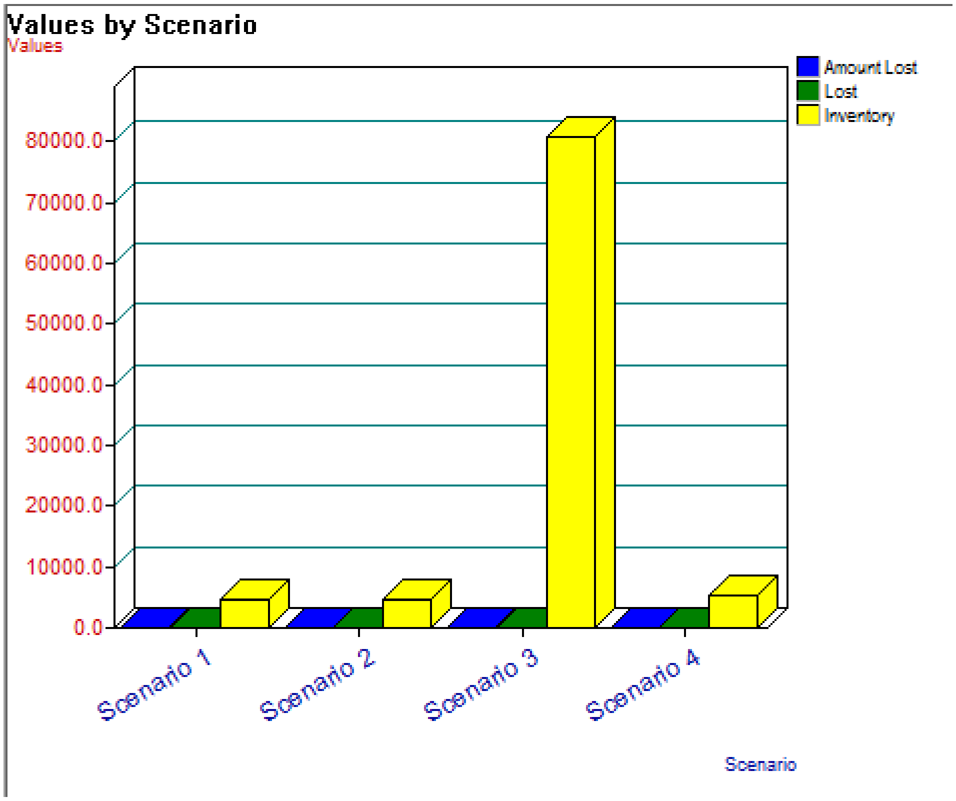
	Scenario Properties				Controls			Responses		
	S	Name	Program File	Reps	Batch Size	Reorder Point	Target Stock	Amount Lost	Lost	Inventory
1		Scenario 1	1 : Fuel Inven	1	5.0000	75.0000	5000.0000	87.906	1.000	4569.978
2		Scenario 2	1 : Fuel Inven	1	5.0000	150.0000	10000.0000	0.000	0.000	4508.334
3		Scenario 3	1 : Fuel Inven	1	5.0000	100.0000	500000.0000	0.000	0.000	80959.429
4		Scenario 4	1 : Fuel Inven	1	5.0000	100.0000	20000.0000	0.000	0.000	5362.568

Source: Own compilation, 2017

Figure 4.14 is showing that the second scenario is the best one followed by the first. Here we can see that scenarios 1,2 and 3 are not losing any order or unit and money. 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 daily average and maximum inventory available in the fuel warehouse stock.

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 echelon.

Figure 4.12 Scenario case tests



Source: Own compilation, 2017

The bar graph above shows the best options from the scenarios. The least inventory level is on the first scenario. The highest amount lost is also in the first scenario.

The what-if-scenarios are designed per the fuel push-pull strategies in (Fig. 4.12). Four scenarios are separately implemented which varies in the inventory levels along the fuel supply chain. The reorder points of fuel distribution centers are set based on the storage capacity of fuel.

4.2. Discussion

The average lead time for LOEL to deliver end products is found to be 16.28 days. This could hurt the service level of the company and customer satisfaction. This finding is in tandem with (Cheng Zhang, Chenghong Zhang (2006)), who stated that in a today's highly competitive market manufacturers face the challenge of reducing manufacturing cycle time, delivery lead-time and inventory reduction

Government regulations, political risks, rivalries, and price changes are some of the issues mentioned from the oil company supply managers as challenges of supply chain performance. LOEL is also facing a challenge on production and delivering the final products to customers at the least cost possible. This finding is supported by (Morton, 2003) who stated that the amount of inflexibility involved, meeting the broadening prospect of oil demand and its derivate while maintaining high service-levels and efficiency is a major challenge in the petroleum industry.

A model was developed with the help of Arena simulation for the oil supply chain. The model was developed to satisfy customers, improve supply chain performance and to abandon production termination due to excess oil product stock with the least operational cost. The result of these findings are supported by (Ratliff, 2007) who states that Supply chain optimization is the biggest opportunity for most companies to significantly reduce their cost and improve their performance. Optimization strives to achieve the most efficient, optimal way to manage the supply chain in order to satisfy customer needs on the lowest cost. The desired quantity, regular supply of the crude oil, reduced lead time, lower production and distribution cost are one of the main goals of the oil supply chain (Hussain et al., 2006). It also in tandem with (Cope, Fayez, Mollaghasemi and Kaylani (2007) who states that simulation modeling provides the flexibility to model processes and events to the desired level of complexity, in a risk free, dynamic and stochastic environment. The optimization of the supply chain helps firms make the right decisions in view of the fact that every company has its distinctive resources, opportunities and limitations. On top of these, it is mentioned that supply chain optimization focuses on growing and maximizing the firms’ returns on assets (Bryan & McDougall, 1998).

Four scenarios are separately implemented which varies in the inventory levels along the oil supply chain. The four scenarios have illustrated the best options with maximum order, high customer satisfaction and the lowest cost. These findings are supported by Hall (2002) who notes that faster delivery, reliability and lower cost have also appeared as a need from the customers’ point of view. The findings also supported by (Thierry, Bel and Thomas 2010) who stated that a modeling and simulation approach is the only practical recourse for exploring performance of the large-scale situations that exist in reality. It is also in tandem with (Terzi and Cavalieri, 2004) who stated that simulation is considered as one of the most powerful techniques to apply within a supply chain environment).

After the simulation runs of the oil sustainable SCM model based on the four proposed scenarios, the key performance indicators of output are categorized and analyzed in aspects of cost analysis. The simulation results of the sustainable oil SCM model based on the four scenarios indicate that the performance factors are improved as the inventory levels of the supply chain decrease, which result in improved supply chain flexibility and reduced production volume caused by lower safety stocks. The lowest costs are also shown in the simulation. These findings are supported by According to GoldSim Technology Group LLC (2007) who states that the process of building a dynamic supply chain simulation model provides valuable insights and understanding regarding the behavior and characteristics of a supply chain. It is also supported by Jenkins and Wright (1998) who stated that One of the main characteristics of the oil supply chain is its inflexibility.

CHAPTER FIVE

CONCLUSION, RECOMMENDATION AND FUTURE RESEARCH DIRECTION

5.1. Conclusion

Researchers have been involving to solve supply chain problems regarding the flow of physical goods, information and finance across the different levels of the supply chain. This study widely considered the different traditions those are used for the evaluation and improvement of a multi echelon supply chain network performance. Discrete-Event Simulation modeling is selected and applied for this study which best suits for the evaluation and assessment of Ethiopian fuel industry. From different simulation software, Arena® the Rockwell Automation software is found to be the best for a multi echelon supply chain network and adopted in this study.

The oil supply chain model is developed to generalize the model so that it can be used for other oil companies who face similar problems of managing the oil product inventory. 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. Four scenarios are developed and to be tested in the developed simulation model with the help of Arena software. The simulation results of the sustainable oil SCM model based on the four scenarios indicate that the performance factors are improved as the inventory levels of the supply chain decrease, which result in improved supply chain flexibility and reduced production volume caused by lower safety stocks.

The fuel sustainable SCM framework is modeled with Arena according to the discrete event simulation procedures. The essential success factors of the fuel supply chain model are analyzed in the simulation study. For this study a simulation model with the help of Arena software is developed. Four different scenarios 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 three-years simulation run time with four replications to evaluate the fuel 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 2 result in the best operating performance of the fuel by keeping both capacity utilization and amount of inventory in a reasonable quantity.

Therefore, the fuel SC department delegated personnel can make decisions based on facts rather than assumptions in such uncertain environment.

5.2. Limitation of the Study

This research has faced challenges in regards to limitations of data collection and software capacity along the stages of the simulation modeling. Although most of the input parameters are collected and calculated from reliable sources; there are still limitations such as technical data and storage cost. In addition, transport and storage cost was not generated due to lack of data.

5.3. Recommendation

For the purpose of making this study more realistic and applied in the oil industry the researcher recommends that oil company managers should use scientific forecasting systems for decision. Oil companies should consider the gas emission of their warehouses to avoid global warming. The research recommends that for the purpose of making this study more realistic and applied in the oil industry the researcher recommends the application of the developed model for all oil industries with slight modification of the model and the input data provided.

The model can be used by different oil industries by changing the capacity to import oil from different suppliers. But in Ethiopia there is only one oil (fuel) supplier which is the Ethiopian Petroleum Supply Enterprise. Oil companies should use scientific methods to deliver products on time with minimum cost. The model can also be used for other manufacturing industries.

5.4. Future Research Direction

The following 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 scenario as well as the whole system.

Researchers should quantify the social and environmental dimension as well as storage costs in the future research.

This research takes under consideration only fuel and oil with a separate run. But there is a possibility to include all raw materials in a single model so as to generate a better result with mixed transportation.

References

Anderson, E. (2003). *Supply Chain Strategy in the Oil and Gas Sector*. Business Briefing: Exploration and Production.

Anjali Saxena, Yves Ducq, R.A. Malairajan, (2015) P. Sivakumar. Simulation-based decision-making scenarios in dynamic supply chain. International Journal of Enterprise Network Management, Inderscience, 2010, 4 (2), pp.166-182.

Anthony Osoro, (2015), Factors Affecting Performance of Supply Chain Systems in the Petroleum Industries in Kenya Volume 5, Issue 4, April 2015

Antonio Cimino, Francesco Longo and Giovanni Mirabelli (2010), **A General Simulation Framework for Supply Chain Modeling: State of the Art and Case Study**, International Journal of Computer Science Issues, Vol. 7, Issue 2, No 3

Benita M. Beamon (1998), **Supply Chain Design and Analysis: Models and Methods,** International Journal of Production Economics, Vol. 55, No. 3, pp. 281-294

Bryan, G. & McDougall, D. (1998). Optimize Your Supply Chain for Best-possible Operations: Wood Technology. Forests and Forestry- Lumber and Wood. 125(7), 35- 38.

Caroline Thierry, Gérard Bel and André Thomas (2010) **The Role of Modeling and Simulation in Supply Chain Management,** SCS M&S Magazine – 2010 / n4 (Oct)

Chang-Seop Kim, James Tannock, Mike Byrne, Richard Farr, Bing Cao, MahendrawathiEr (2004), **State-Of-The-Art Review, Techniques To Model The Supply Chain In An Extended Enterprise,** VIVACE Consortium Members.

Cheng Zhang, Chenghong Zhang (2006), **Design and simulation of demand information sharing in a supply chain,** Journal of Simulation Modelling Practice and Theory 15 (2007) 32–46

Daniel Szucs and Kedir Hassen (2012), **Supply Chain Optimization in the Oil Industry: A Case Study of MOL Hungarian Oil and Gas PLC.** pp. 7-8

Dayana Cope, Mohamed Sam Fayez, MansoorehMollaghasemi and AssemKaylani (2007), **Supply Chain Simulation Modeling Made Easy: An Innovative Approach,** Proceedings of the 2007 Winter Simulation Conference.

Fredrik Persson, Jan Olhager (2002), **Performance simulation of supply chain designs**, Int. J. Production Economics 77 (2002) 231-245

Gainsborough, M. (2006). Building World-class Supply Chain Capability in the Downstream Oil Business. *Business Briefing: Oil and Gas Processing Review*. 29-32.

Gainsborough, M. (2006). Building World-class Supply Chain Capability in the Downstream Oil Business. *Business Briefing: Oil and Gas Processing*

GoldSim Technology Group LLC (2007), **Dynamic Simulation and Supply Chain Management,** White Paper

H. L. Lee, V. Padmanabhan and S. Whang, (1997), The Bullwhip effect in supply chain, Sloan Management Review, Spring, pp 93-102.

Hilmola, O. (2011). Logistics Sector Development Potential of World's Oil Exporters. *International Journal of Energy Sector Management. 5* (2), 256-270.

Hussain, R., Assavapokee, T. &Khumawala, B. (2006). Supply Chain Management in the Petroleum Industry: Challenges and Opportunities. *International Journal of Global Logistics & Supply Chain Management. 1*(2), 90-97.

Jack P.C. Kleijnen (2004) **Supply chain simulation tools and techniques: a survey,** International Journal of Simulation and Process Modeling, ISSN 1740-2123

Jasuja, A., Sowmya, A., Chaudhary, A., Kanade S. & Panda, S. (2009). Supply Chain in the Petroleum Industry.

Jenkins, P., G. & Wright, S., D. (1998). Managing Inflexible Supply Chains. *The International Journal of Logistics Management. 9*(2), 83-90.

Jenkins, P., G. & Wright, S., D. (1998). Managing Inflexible Supply Chains. *The International Journal of Logistics Management. 9*(2), 83-90.

Morton, R. (2003, October). Good chemistry in the supply chain. *Logistics Today*, 44, 10, 30.

Paul Groenewoud (2011), The analysis and simulation of a supply chain with Arena. pp. 6-8

PetrosGulma (2014) Logistics Time and Cost Analysis Case of Lubricant Supply Of Libya Oil Ethiopia Limited

Ribas, G., Leiras, A. &Hamacher, S. (2011). Tactical Planning of the Supply Chain: Optimization Under Uncertainty. XLIII SimpasioBrasileiro de PesquisaOperacional. 15(18).

Richard Amponsah (Dr.) and Francis Kelvin Opei, (2014) (Ghana's downstream petroleum sector: An assessment of key supply chain challenges and prospects for growth, June 2014.

S. Anil Kumar and N. Suresh (2009). Operations Management. Published by New Age International (P) Ltd., Publishers

Stabell, C. (2001). New Models for Value Creation and Competitive Advantage in the Petroleum Industry.

Taylor, Bernard W. (2013), Introduction to management science. New Jersey Prentice Hall Inc.

www.decisioncraft.com/scsimulator/images/

Yoon Chang and Harris Makatsoris (2003), **Supply Chain Modeling Using Simulation**, International journal of simulation, Vol. 2 No. 1