Master's degree thesis

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Downstream Supply Chain Design of Petrochemical /Oil Companies: A Case of GOIL

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Preface

This thesis is submitted in partial fulfilment of the requirement for Master of Science in Petroleum Logistics at Molde University College. It was conducted from December 2018 to May 2019.

This thesis topic was for downstream supply chain design for petrochemical and oil companies (Ghana Oil Company Limited).

This study was successfully completed with the support and recommendations from our supervisor, Prof Arntzen Halvard. We would take this opportunity to express out deepest gratitude to him.

Summary

The main objective of the research was to study the downstream supply chain design of petrochemical /Oil companies using Ghana Oil Company Limited as a case study. The researchers reviewed several articles on the chosen research theme. Statistics models such as the Analytical Hierarchical Process, multivariate regression analysis and net present value analysis was used. Theories on inventory and distribution management such as vendor management inventory was also used as discussions in the research.

The paper considered the downstream supply chain challenges faced by GOIL and made several suggestions on how the challenges can be resolved by using both qualitative and quantitative approach.

Multivariate forecast regression showed that population has had a major impact on the demand for oil and petroleum products over the past 14 years in Ghana and with population rate on the rise every year demand is therefore projected to increase.

The researchers also discussed the effect of setting up a depot on the supply chain of GOIL and suggested a suitable location using the AHP model. Cost saving analysis was conducted using NPV to determine the profitability of setting up the depot under multiple scenarios. Other supply chain practices such as Vendor Management Inventory was also discussed as suggested solution that can help resolve the challenges faced by GOIL.

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List of Abbreviations

GOIL – Ghana Oil Company

OPEC – Organization of the Petroleum Exporting Countries

NPV – Net Present Value

OMC – Oil Marketing Companies

AMR – Annual Monitoring Report

EIA – Energy Information Administration

OECD – Organization for Economic Co-operation and Development

PTT – Petroleum Authority of Thailand

GAR - Greater Accra Region

AR - Ashanti Region

WR - Western Region

API – American Petroleum Institute

NAA - National Association of Accountants

VMI – Vendor Management Inventory

AHP – Analytical Hierarchical Process

BDC – Bulk Distribution Center

1.0 INTRODUCTION

1.1 Overview

The continuous increase in world's demand for oil and petrochemicals has allowed companies supplying these products to attain more customers, expand their profitability and market share. The world's demand for oil in the year 2018 was 99.2 million barrels per day and is forecasted to rise to 100.6 million barrels per day in 2019. Petroleum products are important source of energy that has satisfied more than 30% of the world's demand for energy (EIA 2016).

Products such as oil, gas and petrochemicals need particular transportation modes such as pipelines, tankers, railroads and vessels. These products are created in certain and finite areas of the world but are required all over the world because they constitute an important source of energy and raw materials for many industries. This type of industry usually experiences long lead times from the point of production to the final customer's location. Companies in this industry have therefore realized that, a better supply chain planning and design, amounts to enormous area for cost savings particularly in the logistics area evaluated to be around 10 to 20% of revenue (Hamilton,2003). Moreover, the oil industry is a considered as a material flow intensive industry, therefore successful distribution cost management is critical in the industry (Elsaghier,2017).

Regardless of the significance of the oil industry in our everyday life, the operational difficulty and complexity involved in managing its supply chain continues to persist.

1.2 Background

Ghana Oil Company (GOIL) was established as a private limited liability company on 14th June 1960. Its main roles were to market petroleum products and other crude oil products such as Liquefied Petroleum Gas (LPG), bitumen, kerosene, lubricants, etc. On 1st August 2007, the company was turned into a public company.

The company's major role is the marketing and distribution of petroleum products in Ghana. Sales from Diesel and Gasoline provides the company with most of its revenue. It is managed by ten management teams being headed by a Managing Director. GOIL has the biggest retail network in Ghana. The main distribution points for fuels include the Central Depot and the Takoradi Depot with numerous consumer outlets. GOIL also has service stations across the country to provide services to customers.

1.3 Problem Statement

The oil industry has had a major impact on the global economy. The supply chain of successful oil companies in this ever-competitive industry is what makes them different from the others. An effective and efficient supply chain reduces waste, enhances productivity, increases profitability and increases customer's satisfaction (Bozchalui et.al 2012). The main goal of a supply chain in the oil industry is to provide the right quantity, regular supply of oil, reduction in lead time and reduced distribution cost (Hussain et al. 2006). The oil industry in other to meet the demands by customers has made managing their supply chain more complex and challenging (Coia 1999; Randall et al. 2003). Oil supply chain management has to solve a lot of challenges caused by the supply complexity, long lead times, and limited transportation forms at the different stages in the supply chain and limited primary distribution capacity.

Just like the other oil companies, GOIL has been facing distribution and transportation challenges over the past few years. Asamoah et.al. (2012) stated that the current demand for petroleum products outstrips supply options due to infrastructural inadequacies. The main goal of this research is to redesign GOIL's supply chain by analyzing the demand for its petroleum products to meet service requirements whilst investigating and making suggestion to improve the supply of petroleum products by analyzing GOIL's supply chain system.

1.4 Research Questions

This research aims to provide answers to the questions below;

- What is the demand trend for petroleum products in Ghana?
- What are the major challenges in GOIL's supply chain?
- In which way will building a new depot solve problems for GOIL?
- What will be the suggested location(s) for such a new depot?

- Will a new depot be profitable to GOIL, given different scenarios for cost and savings forecast?
- What other alternative logistics solutions can improve the supply chain of GOIL?

1.5 Objectives

The primary objective of the research will be to design GOIL's supply chain in terms of distribution to increase service levels and also look at the possibility of acquiring a depot. These are the specific objectives;

- To ascertain the demand trend for petroleum products in Ghana.
- To identify the major challenges in GOIL's supply chain.
- To determine the effect of building a depot on GOIL's supply chain issues.
- Identify suitable location(s) for a new depot
- To identify whether building a new depot be profitable to GOIL, given different scenarios for cost and saving forecast.
- To identify the alternative logistics solutions that can improve the supply chain of GOIL.

1.6 Justification of the Study

The use of petroleum products over the years has increased significantly. Oil companies, therefore, face challenges when determining the right supply chain design to satisfy customers demand. This study seeks to find and suggest solutions to the distribution channel that creates shortages at customer retail outlets (service stations).

1.7 Organization of the Study

Chapter 1 comprises a brief history of GOIL, research questions, objectives of the study and the justification of the study.

Chapter 2 will consist of a literature review and definitions of concepts related to the topic.

Chapter 3 which is the methodology involves the scope of the study, population, sample size, sampling method and processes used to collect data, sources of data.

Chapter 4 presents discussions and presentation of results. Data analysis is also conducted in this chapter.

Finally, chapter 5 will summarize the findings together with conclusions and recommendations.

2.0 LITERATURE REVIEW

2.1 Supply Chain Design

According to Melnyk et.al (2009), supply chain plays an important role in the marketplace. A robust supply chain can have a significant relevance such as lower inventory, effective response rate and good return on investment. This can be achieved by establishing an appropriate link between customers and suppliers. A report by "Annual Monitoring Report", a reputable research institution in the United States of America, stated in 2008 that, supply chain companies ranked from first (1st) to twenty-fifth (25th) as efficient supply chain practicing companies had an average return of 17.89% as compared to percentages between 3.53% and 6.43% for average performing companies (Reuters, 2018)

Fine and Charles (1998), defined design as an important component of a supply chain management that goes further beyond the process of making and buying, the relationship between buyer and supplier or the type of integration between companies. Not much research has been done to define the scope, borders, and content of this concept. Processes that can be regarded as effective in one setting may not be a good fit for another company or market. Hussain et.al (2006) in their paper "Supply Chain Management in Petroleum Industry", asserted that an oil company may need a different supply chain design from what companies such as Wal-Mart and Toyota deploy.

Supply chain design according to Corominas (2013), comprises of factors or decisions that affect investment patterns undertaken by a company that cut across different supply chains. These decisions affect the performance of the supply chain partners, measurement of performance with respect to supply chain visibility and vulnerability of the supply chain.

Supply chain design can be categorized as a dynamic concept (Melnyk et .al, 2010). Dynamic because it can identify the desired strategic outcomes. It also manages resources, processes and all relationships across the supply chain to achieve set targets.

2.2 The Oil and Gas Industry

The oil and gas industry can be considered as one of the largest, most complex and important industries in the world (Inkpen and Moffet 2011).

The Chinese were the first to discover and extract oil in the year around 600 BC (Biresselioglu & Mehmet, 2016). According to historians, this was by accident because their main purpose for digging was to look for salt.

In the nineteenth-century modern oil and gas industry began in the United States of America. Dams were being constructed in western Pennsylvania as a deposit site for petroleum (Cone, Andrew and Walters, 1870).

Just around that period, seeps of oil were found in California. Seeps usually occur from an outcrop of oil-bearing rocks normally under low pressure or flow. The seeps were used by the people in California to serve as fuels to their lights.

Table 1 below shows the pioneer multinational oil and gas companies and the year they were founded.

Table 1. Multinational Oil and Gas Companies with their Years of Establishment

Oil Companies	Year Founded
Standard Oil Company	1870
Gulf Oil	1890
Texaco	1901
Royal Dutch Shell	1890
Anglo Persian Oil Company	1909
Turkish Petroleum Company	1910

Source: Hassan(2013)

In the year 2018, the United States of America was ranked first in terms of oil production. Producing an amount close to 11 million barrels a day (EIA, 2018)

Table 2 below is information provided by United States Energy Administration indicating oil production and consumption from 2017 to 2019. It also gives forecasted values for the year 2020.

Table 2. Oil Production and Consumption from 2017 to 2019(Forecast 2020)

Years	2017	2018	2019	2020
OPEC Production	37.33	37.27	35.95	35.5
Non-OPEC Production	60.71	63.23	65.62	67.69
World's Production	98.05	100.50	101.57	103.28
OECD Consumption	47.23	47.61	47.94	48.19
Non-OECD Consumption	51.23	52.33	53.45	54.66
Total World Consumption	98.46	99.94	101.39	102.85

Source: EIA,2019

From the table countries which do not belong to the organization of petroleum exporting countries (OPEC) produce most of the global petroleum products. The most dominant of such countries include the United States of America, Canada, Qatar, China, Russia, Norway, and Brazil. In terms of consumption countries that do not belong to the organization for economic co-operation (OECD) tend to consume a clear majority of petroleum products. Countries which dominates this list includes Russia, Countries on the African Continent, China and India.

Another important factor in the oil industry is pricing. Oil prices are typically determined by the role of demand and supply. The global economy usually has the greatest effect on demand whilst factors such as conflicts, new discoveries, extraction technology and decisions made by the Organization of the Petroleum Exporting Countries (OPEC) and non-OPEC members all have influences on the supply side (Arezki, et .al, 2017)

The Petroleum Authority of Thailand (PTT), categorized the factors that affect petroleum prices into three (3). These factors are fundamental, sentimental and miscellaneous. These factors are explained below:

a. Fundamental Factors

The variables which make up this factor includes

- Economic Growth

This factor positively corresponds to oil prices. In times of economic growth, oil in individuals daily lives and economy expansion results in an increase in demand. In cases where the total world's production is not able to take care of or meet the growth, prices will rise. On the other hand, prices will decrease when there is low economic growth, due to oversupply.

- Weather

Consumption trends in areas of the world such as the United States and Europe are determined by changes in weather conditions. In winter demand for products such as heating, and fuel oil is very high. Oil manufacturers and suppliers try as much as possible to increase stock of heating oil in the fourth quarter of every year. As a result, prices are higher during such periods. During the summer, on the other hand, individuals tend to drive more so demand for certain types of oil such as gasoline increases which also leads to price increment.

- OPEC Production Capacity and Policies

Countries with high reserves and production capacity usually have a negotiating power for prices. Most oil producing countries are members of OPEC. This implies that OPEC is in the position to manage the supply of oil. Members of OPEC produces the largest amount of oil in the world. Therefore, any policy to lower production or increase production can affect the oil prices.

- Other Reserves of World’s Major Consumer

Countries such as the USA and European countries pay lots of attention to their oil inventory. As a large consumer of oil, there is the need to keep the right inventory level to satisfy the demands in order to cut down costs. If there is an adequate level of inventory in storage the probability of shortages is decreased, hence, a decrease in price. On the other hand, if the demand is more than the projected demand inventory decreases which will, therefore, lead to undersupply, hence, increase in prices

- Alternative Energy

Other alternative sources that can serve as substitutes for oil such as natural gas, coal, nuclear, wind and solar, if they are produced at competitive prices and is able to meet the consumers need. This will gradually decrease the demand for oil and lead to price fall.

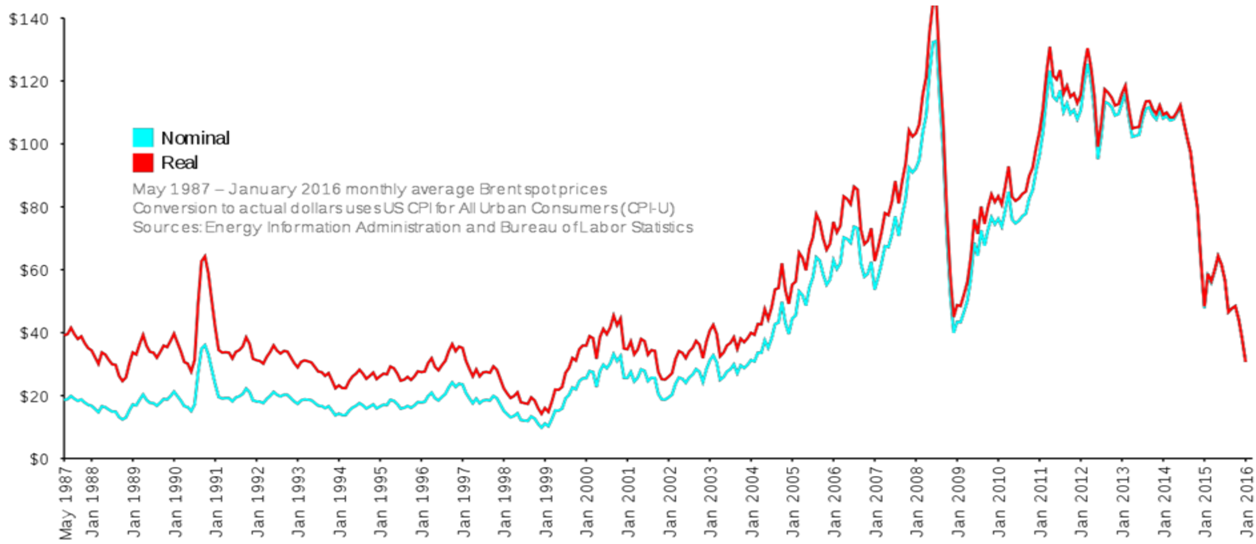
b. Sentimental Factors

Political occurrences across every region can affect oil prices. Situations such as war in predominant areas such as the North Sea, Middle East, and the USA can affect the prices of oil.

c. Miscellaneous Factor

Oil is sold internationally using the US dollar. Therefore, a countries performance against the US dollar affects oil prices. On the other hand, when there is a devaluation in the US dollar imported crude will cheaper whilst an appreciation of the dollar can cause countries to buy oil at higher prices.

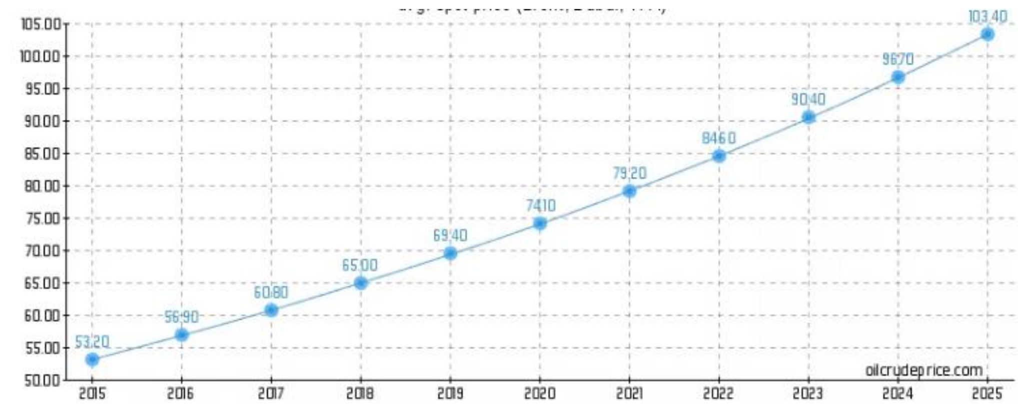
Figure 1. Brent Oil Prices from 1997 to 2016



Source: Golombek et.al 2018

Figure 1 above shows Brent oil prices from 1997 to 2016. From all indications, prices were between 50 to 80 USD. There was a major rise in price in 2008 and a sharp fall in 2009. Then another sharp decline in 2014-15. By 2019 the prices are back around 70 USD.

Figure 2. Crude Oil Price 2015 to 2020.



Source: Fantazzini and Fomichev, 2014

Figure 2 shows the industry's projected price forecast. According to this forecast, prices continue to rise from 2018 to 2025. This by no means is certain because of the aforementioned factors that can affects prices and demand within the years under consideration.

2.3 Supply Chain of the Petroleum Industry

Petroleum chemical companies over the years have experienced an increase in customer, profitability and market share due to the rise in global demand for oil products. This can be attributed to the existence of international trade (Al-Hussan, Assavapokee & Khumawala,2008).

According to forecasts, the demand for petroleum product is set to increase by 2% per year for the next ten years. There is a certain level of uncertainty due to the political unrest in the Middle East which is by far the largest producing region in the world. Oil producing companies are therefore always encouraged to keep high safety stock.

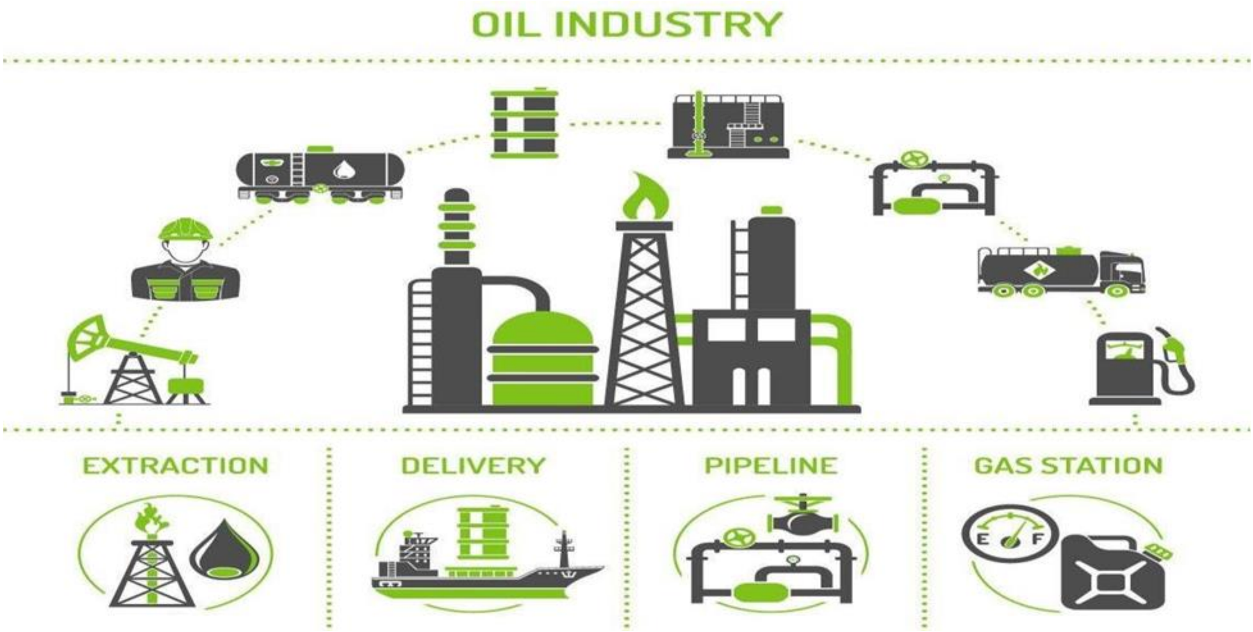
Modes of transport used to carry oil, gas, and petrochemicals includes tankers, pipelines, and railroads. Demand for these products is global because they are needed by numerous industries as a source of energy. This results in higher lead times. It takes almost five weeks to for example transport from the Persian Gulf's oil to the United Stated (Schwartz & Beth, 2000).

A decision such as building a depot or distribution center to provide services to widespread customers has the tendency to reduce lead time and cut down transportation costs. The disadvantage of building these facilities is the high initial cost and an increase in inventory cost (Al- Hussan, Assavapokee & Khumawala,2008).

Hamilton (2003) indicated that companies have realized that an efficient and robust supply chain can help to reduce costs and therefore increase cost savings of an average between 10 and 20 percent. Researchers such as Coia (1999) concludes that companies are now competing with different supply chains.

An article published by Petrobloq (2017) summarizes the supply chain of the oil industry in the figure 3 below.

Figure 3. Supply Chain of the Oil Industry



Source: Petrobloq,2017

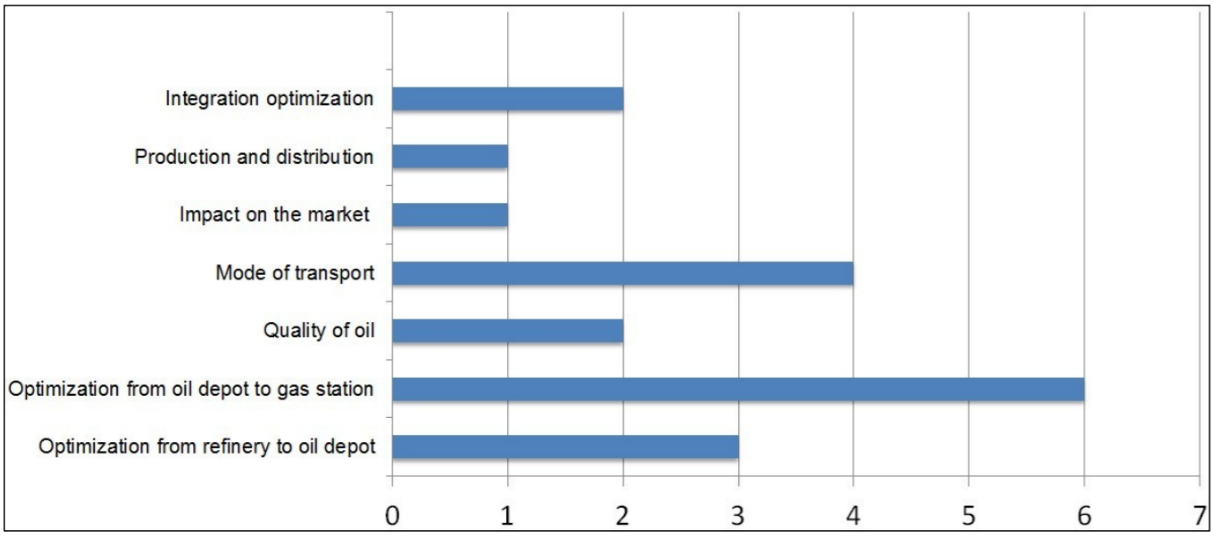
Elsaghier (2017) classified the functions of the petroleum industry's supply chain into upstream, midstream and downstream.

Upstream activities include exploration and extraction activities such as production, drilling, facility engineering, and reservoir. This part of the supply chain is considered as the highest level with a major influence on the entire supply chain. Midstream consists of activities such as transportation and refineries. The downstream involves processing, marketing, distribution, and transportation to the final customers.

2.3.1 Challenges in Oil Industry's Supply Chain

Figure 4 below illustrates problematic aspect of the supply chain of the oil industry gathered from a survey conducted by Karakaya and Bai in 2012. From the figure the process of transporting oil from depot(s) to gas stations (service station outlets) is the most challenging. This process usually involves inventory management, identifying re-order points, transportation planning, monitoring and selection of mode of transportation from depot(s) to service stations. It is an area in the supply chain where the industry pays major attention to. Other challenges included integration optimization, production and distribution, market impact, quality of oil and optimization from refinery to depot.

Figure 4. Graphical Representation of Challenges in Oil Industry's Supply Chain



Source: Karakaya and Bai 2012

2.4 Petroleum Market in Ghana

In Africa, Ghana is found on the West coast and shares borders with countries such as Togo to the east, Burkina Faso to the north, Ivory Coast to the west and the Atlantic Ocean in the south.

Figure 5 below shows the geographical position of Ghana on the World map.

Figure 5. Geographical Position of Ghana

Source: World Atlas, 2019

Ghana has conducted an intense search for petroleum resources for the past 20 years. The private and public sector both invested in the quest to search for petroleum resources (Osei-Tutu,2013)

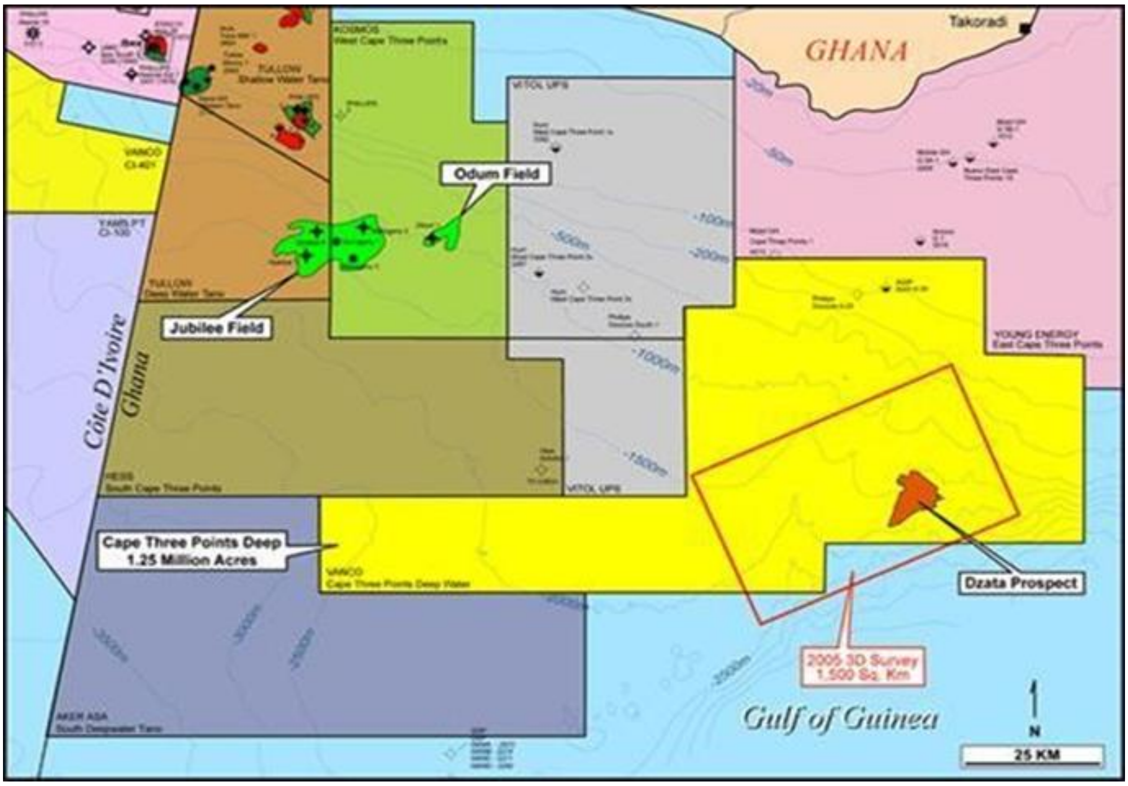
Kosmos Energy and Tullow Oil in 2007 discovered oil in commercial quantities in the Western part of Ghana.

Jubilee oil field was discovered In July 2007 by Tullow Oil and Kosmos Energy in commercial quantities in the western region of Ghana (Kastning, 2011).

This discovery led to the discovery of other oil fields such as the Tweneboa Field which is the second largest in the country.

The Jubilee oil field lies on the Ghana-Ivory Coast border in the Gulf of Guinea. It is on the Tano water and is located West of Cape Three Point. The wells have depth of approximately between 1100 and 1300 meters (Kastnin, 2011). It covers a 110-kilometer square.

Figure 6. Geographical Position of Oil Fields in Ghana



Source: ghanaweb.com,2010

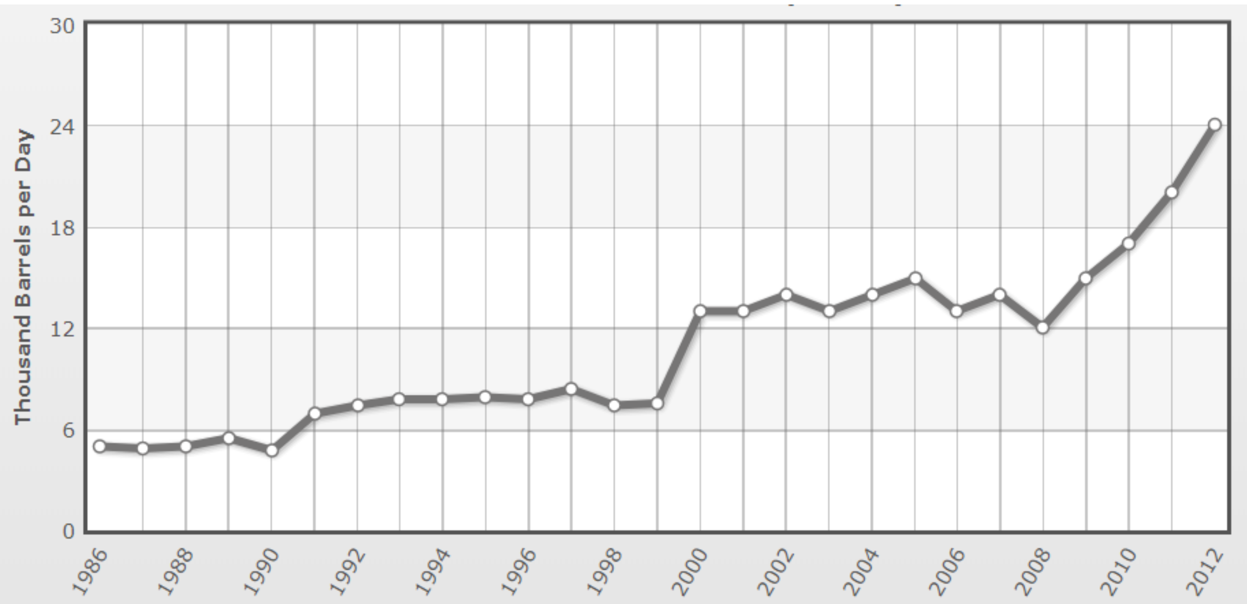
The figures on the amount of oil expected in the Jubilee field, published by Ghanaian newspapers, vary between 1 and 2 billion barrels of crude oil. One barrel is 158,987 liters.

Other fields such as the Tweneboa field is estimated to contain 1.4 billion barrels of oil equivalent (bboe). Minor fields such as the Odum field were also discovered.

As stated by Kastning (2011), oil from the Jubilee field is light and sweet with an API Gravity of 37.6 degrees and Sulphur content of 0.25%. These attributes represent high quality. These characteristics match the standards set by worldwide refineries and can, therefore, compete with international price reference oils.

Figure 7 below shows the consumption of petroleum products from 1980 to 2012. From the diagram, it can be noticed that the demand for petroleum products has been increasing since 1986.

Figure 7. Consumption of Petroleum Product from 1980 to 2012



Source: Index Mundi, 2019

2.5 Supply Chain Management Processes

One of the most important variables to be managed in any company is inventory. Inventory can be described as materials that are stored, consumed, produced, sold during a firm's course of operation (Hugos ,2018).

Enhancing efficiency and the level of competitiveness depends highly on inventory management practices. There is, therefore, the need for firms to practice effective inventory management processes as a key area to improve customer satisfaction (Rajeev,2008)

However, finding the right amount of inventory for a specific period with respect to demand can be challenging. Keeping a lot of inventory can be space consuming and increases overall logistics cost. That notwithstanding, having none or a small amount of inventory can halt business operations and decrease customer satisfaction (Krajewski et.al 2013). This, therefore, implies that there is the need to have a prudent inventory management system. This may include knowing the cost of acquiring a certain level of inventory and the inventory holding cost.

Seasonality in demand which can be attributed to factors such as weather conditions and change in taste and preferences of consumers are some of the few factors that encourage suppliers to keep a certain level of stock as a buffer. This helps to reduce lead time and supply uncertainties (Cachon, and Oilvares 2010).

In the petroleum sector retailers and distributors of petrochemical products sometimes keep a certain level of buffer stock to deal with uncertainties. Sometimes keeping such products turn to come with massive logistical cost due to the safety precautions related to keeping such product.

Nyabwanga et.al. (2012) indicated that, as part of a survey conducted by "The National Association of Accountants" (NAA) on 351 companies including oil producing companies showed that the Just-In-Time inventory management, time phase re-ordering and vendor management inventory system is gaining more popularity.

Just-In-Time was defined simply by Singh et.al (2012) as the process of getting end products to consumers exactly when they are needed. Time-phased ordering involves deciding the reorder point based on supply and demand. This method uses past ordering trends to determine changes in demand and to plan future orders. In a Vendor Management Inventory system, as explained by Johnson et.al (1999), the manufacturer decides when replenishment is made to all suppliers or distributors. The manufacturer monitors the inventory levels at each supply point usually through an electronic means and makes periodic supply decisions such as shipping, quantities, and timing.

All these inventory management techniques depend on certain measures to be in place to ensure effective operations. Infrastructural development is key to implementing all these management techniques. For instance, in order to use the vendor inventory management technique, both suppliers and distributors will have to come up with a synchronized system that will enable manufacturers to monitor inventory regardless of how far each distributor is located. Time-phased ordering method requires manufacturers to be able to determine the order trend and demand fluctuations. This can be very devastating if manufacturers are unable to come up with an effective method of forecasting. Just in Time is one of the proven most efficient way of managing inventory but that notwithstanding decisions such as accurate knowledge to timing and quantity can be very complex (Monden,2011).

2.5.1 Vendor Management Inventory

Vendor Management Inventory is a supply chain management inventiveness which permits distributors to supervise stock of inventory (Angulo et.al. 2004). This supply chain practice allows the distributor to make replenishment decisions. The distributor observes the seller's inventory levels and decides when to make supply decisions such as quantities to supply and shipping time. Vendor managed inventory allows the distributor to determine the fluctuations in demand pattern. The distributor therefore has a better chance to synchronize shipments to individual customers. This can enable the vendor to schedule or defer shipments depending on production schedules, transportation capacity and inventory levels. In a VMI, distributor performance is determined by service levels and the inventory levels at various retailers or sellers. Service levels in a VMI-based distribution system is usually high because of distributor's possibility to plan operations better. This helps to increase sales because stock availability increases.

Implementation of a VMI implies that the two parties involved, that is, the retailer and distributor are willing to exchange and allow information flow on a regular basis. According to Pol and Inamdar (2012) information is usually shared on the following:

- Inventory Levels

The retailer provides information on inventory levels. This information usually includes current stock quantity, back order quantity, quantity in order.

- Sales History

The retailer informs the distributor about sales quantities. The retailer can also provide the distributor with sales forecast.

- Order Proposal

This information is from distributor to retailer. The distributor informs the retailer about the quantities to be supplied. It contains information such as shipment location and order quantity.

According to Marques et.al., (2006), the objective of VMI is to guarantee higher consumer service level whilst reducing inventory costs. On the part of distributor is to decrease production, inventory and transportation cost.

2.6 Forecasting

Forecasting was defined by Stevenson et.al (2007) as a prediction or estimate of certain occurrences in the future. It is a prediction or an estimation of actual value in a future time period or for another situation. Forecasting can also be a tool that reveals the future value of interest for a specific period that is used as prime output in the decision process of supply chain management.

In terms of decision-making, forecasts can be very critical for businesses, organization, and governmental bodies. Yokuma and Armstrong (1995) identified the importance of forecasting by indicating that accuracy is the benchmark for all forecasts.

Forecasting involves operation management and control of activities such as hiring, production, inventory, pricing, distributing, advertising and accounting. There are many objects that we might want to forecast.

In business and economics, the forecast object is typically one of three types: event outcome, event timing or time series (Diebold, 2015). This implies that firms use forecasts to determine what to produce, at what time to produce and volume to produce. In terms of human resource management decisions, forecast is used to decide how many shifts to run.

Forecasting with the least margin of error can help maximize value creation in a supply chain (Scala et.al 2016)

Forecasting also affects the internal and external functions of a firm Seifert et.al (2003). It is the first step that commences activities of the supply chain. It is the determining factor during planning and decision making.

Demand management was ranked by the Global Supply Chain Forum as one of the key business processes in the supply chain management (Croxton et.al 2002). Forecasting forms the backbone and a fundamental step during demand management (Datta et.al. 2009).

2.7 Types of Forecasting

There are two major types of forecasting namely quantitative and qualitative.

- Quantitative Forecasting

This type of forecasting uses mathematical models and statistics to predict future occurrence. There are basically two types of quantitative forecast namely projective and causal. According to Vujosevic and Rakicevic (2015), projective methods, that is, time series methods show a picture of history projected in the future whilst causal tries to find the relationship between different variables.

The time series forecasting method is mostly adopted within the supply chain to predict future sales (Davydenko and Fildes, 2013). In other words, a time series can be described as the process of gathering data that gives information within an observed period. Researchers such as Vujosevic and Rakicevic (2015), Chopra and Meindl (2016), Heizer and Render (2008) all used time series to estimate future sales data. Some examples of the time series forecasting include exponential smoothing, weighted moving average, last period estimation, and winter model and regression analysis.

The last period estimation method is used when managers assume that the difference between current sales will not be very much different from the next period. When there is a little variation between sales data from period to period, this method can be adopted. It is represented mathematically as:

$f_t = d_t - 1$ (Albulescu.2010)

The arithmetical average method is done by finding the averages of historical sales data. This method does not pay attention to trends and seasonality patterns. Moving average is an alternative to the arithmetical average method. This method does not ignore patterns. Exponential smoothing, on the other hand, can be said to be a weighted moving average where a certain weight (constant) is assigned using an exponential function. (Murray and Marcos, 2015). The influence of historical values is determined by the smoothing constant (Wallstrom & Segerstedt, 2010).

- Qualitative Forecasting

Qualitative research plays an important role in researching. This is because of its ability to engage us with issues that cannot be measured numerically (Mason, 2017). It is used by scholars to seek answers to questions usually about areas such as culture and real-life events. This has resulted in qualitative research gaining a lot of popularity over the years .

Qualitative research was defined by Shank (2006) as a systematic empirical inquiry into meaning. Systematic because it goes strictly by rules set up the qualitative research community. Empirical meaning such researches are based on real-life events. Denzin and Lincoln (2000) described qualitative research as interpretive and a natural approach. This means that researchers come up with meaning to daily life events using information people bring to them.

Qualitative research was categorized into three (3) by Mack (2005). They are participant observation, interviews, and focus groups.
Participant observation is mostly used for collecting data involving behavioural occurrences in their usual context. Interviews are used to collect an individual's personal opinions and experiences. The focus group approach is used to acquire data on the cultural norms of a group of people.

2.7.1 Period under Forecasting

There are basically 3 periods within which forecasting is made. They are short, medium- and long-term forecasts.

2.7.1.1 Short Term Forecasts

Short term forecasts are used to schedule human resource, transportation and production. It used to schedule shift for workers, distribution channels and daily production size.

2.7.1.2 Long Term Forecasts

Long-term forecasts are used in strategic planning. Such a decision must take account of market opportunities, environmental factors and internal resources (Hyndman & Athanasopoulos, 2014).

2.8 Analytic Hierarchy Process

The increase in the complexity of this modern-day world has made the process of making decisions as manager's very difficult (Drucker, 2012). In other to deal with these complexities' managers have to consider all possible available factors and information which will help them make the best decisions. Information gathering as part of decision making is now regarded as a mathematical science (Anagnostopoulos & Petalas 2011). It formalizes the way we think to enable as make decisions transparent in all aspects.
In order to reduce the degree of difficulty associated with making decisions, Thomas L. Saaty developed the Analytic Hierarchy Process. It is used to make different types of

decisions involving economical, complex technological and socio-political problems (Hummel,2001).

According to Haydar and Ersan (2012), any decision that consists of multiple quantifiable criteria can be made using AHP only if it is possible to identify these criteria in a hierarchy.

2.8.1 The Use of AHP in Making Decisions

This section analyses how researchers have used AHP to make decisions.

Akalin et.al. (2014) in her paper "The application of AHP approach for evaluating location selection elements for retail store: A case of cloth store" used AHP to decide. The aim of the paper was to determine the importance of the weight of multiple criteria in making a location decision problem.

The other objective of the paper was to be able to decide which of the possible locations has amongst other alternatives the highest potential by employing a series of criteria and attributes. The researcher put weighted values to match the evaluation criteria whilst considering the related goals of each corresponding criteria. In the paper, a simple AHP was conducted, by coming up with a hierarchically structured problem, assigning priority weight, designing judgment matrix together with weight vector and then finally ranking order of locations with respect to their total weights. A case study approach was used by the researcher to demonstrate the feasibility of this standard approach. In conclusion, the researcher was able to choose a suitable location for the cloth store amongst four (4) different alternatives by applying AHP.

It can be very tough to solve a decision location problem because of the number of conflicting goals that can be associated with making the decision. Ho, Chang, and Ku (2013) were faced with a similar problem when they had to decide on how to choose an appropriate house amongst many alternative locations that will be of an optimum benefit to renters. In their research paper: "Using analytic hierarchy process and multi choice goal programming", they were able to apply AHP to aid in the location decision problem. The researchers used a real case to demonstrate the usefulness of this methodology. Their results indicated that AHP can be a very useful tool to make better decisions.

Hegde and Tadikamalla (1990) used AHP to solve a facility location problem faced by big multinational cooperation. In their paper: "Site selection for a sure service terminal", the researchers' main aim was to locate a position among several positions for service terminal for the spare part department of the company. AHP was applied successfully to determine the best site for the terminal. According to the researchers the company liked this methodology because it gave them the opportunity to take part in the process of decision making. The findings and conclusions drawn from this research were incorporated into the company's business plan.

Partovi (2006) also demonstrated the use of AHP in his paper “An analytical model of locating facilities strategically”. The researcher used AHP amongst two other models to determine the best location of a facility. He used a case study to highlight the model framework and applied basic concepts. To establish the model, he considered variables such as customer’s demand, competitors and characteristics of the possible locations. AHP was successfully applied to decide on the best facility location.

Problems consisting of multi-criteria decision-making methods are very complex because more than one criterion is needed to make a decision. A multi-criteria decision making was defined by Mujumder and Saha(2016) as an objective method of making a decision by considering various criteria before making a decision. AHP is a compensatory multi-criteria decision making that is used to select better alternatives amongst a set of objectives (Mujumber & Saha 2016).

In a research conducted by Tramarico et.al (2015), it was found out that AHP has been the most widely used multi-criteria decision-making method as compared to the other multi-criteria decision methods between 1990 to 2014.

2.8.2 Capital Budgeting

The discussion on capital budgeting has been of enormous importance to many researchers. The dominant methods of capital budgeting include internal rate of returns, accounting rate of returns, payback time and net present value (NPV). Amongst all these option NPV is the most preferred (Wnuk-Pel 2014). Payne et.al. (1999) conducted a survey in the USA which indicated that 75% of the firms which were sampled uses NPV method. In another research Arnold and Hatzopoulos(2000) it was determined that 80% of sampled companies in the UK used NPV. Bennouna and Merchant (2010) also reckoned that 94% of companies in Canada use NPV.

In spite of the aforementioned, the usage of a method varies depending on the size of the firm. The survey conducted by the researchers above were applied to large firms. Other researchers such as Moore and Reichert (1983) and Trahan and Gitman (1995) concludes that small firms prefer the payback method. Small firms tend to depend more on debt financing and are more prone to uncertainties as compared to bigger firms but however the use of different scenarios is one way to deal with uncertainty in the NPV.

The Net Present Value (NPV) technique as a funding appraisal that indicates how an investment venture influences a firm or company's wealth in present value period. Increasing a firm's wealth is a supreme goal for managers. Investment project which has a positive NPV boosts wealth and should therefore be accepted (Benamraou et.al 2017).

NPV is calculated by discounting future cash flows using by applying a discount rate. The discounted cash flows are then deducted from the initial investment of undertaking the project.

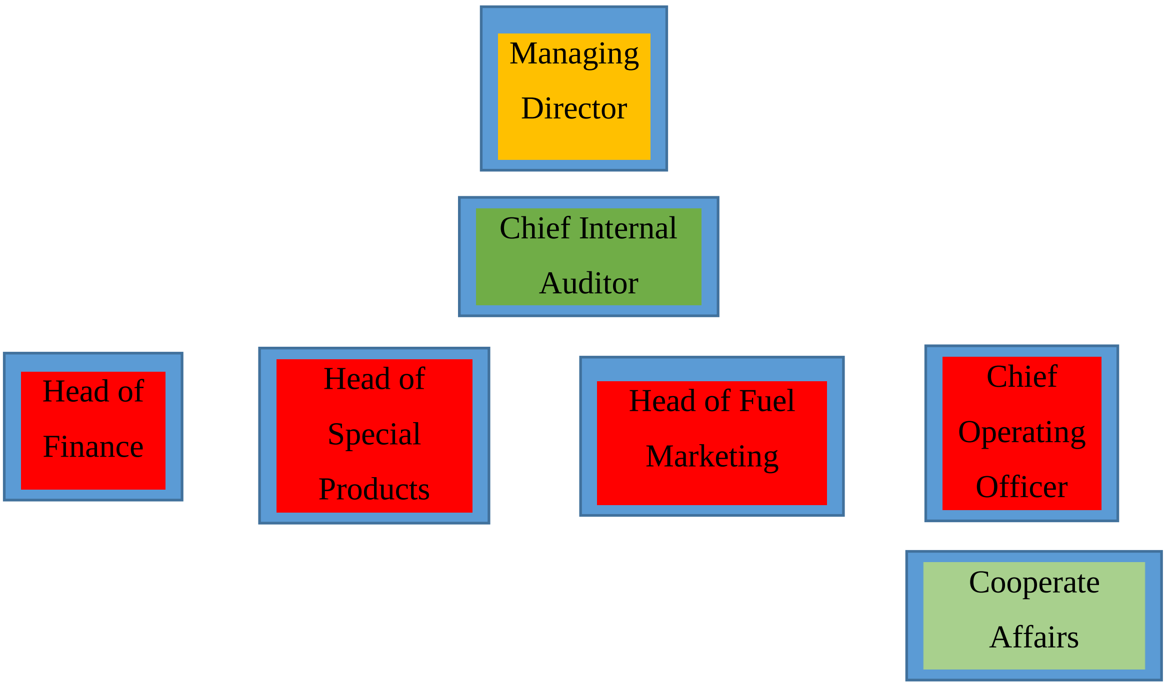
2.9 Overview of Ghana Oil Company Limited

GOIL was established on June 14th 1960, with the main objective of marketing petroleum products such as liquefied petroleum gas (LPG), lubricants and bitumen. The company was owned by AGIP SPA from Italy. In August 2007 the company was converted to a public limited liability company with the government of Ghana being the major shareholder. Currently, GOIL has over 300 service station outlets across the country.

2.9.1 Organizational Structure

Figure 8 below shows the organizational structure of GOIL

Figure 8. Organizational Structure of GOIL



3.0 METHODOLOGY

The methodology employed includes both qualitative and quantitative study. A study was conducted to understand the actual practices in the industry. A comprehensive study was made to identify the challenges and obstacles in the Petroleum industry in Ghana. Possible solutions were suggested by the researcher to help the industry to increase customer satisfaction whilst reducing cost.

Sales data, population and prices of oil from 2004 to 2018 was collected and was used to run a multivariate regression analysis and forecast for the next ten years. This information will determine the demand for petroleum products in Ghana. The Analytic Hierarchy Process was used to suggest a suitable location for a new depot. Information was gathered through an interview to determine the major factors considered before making a location decision problem. Answers from interviews were summarized in chapter 4.

Ghana Company Limited was chosen by the researcher because it is a state-owned company that has been mandated by the government to make petroleum products accessible all over the country. It has supply outlets across the entire country.

3.1 Research Design

In order to suggest the location site for a depot for Ghana oil Company, AHP analysis was conducted. Interviews were conducted with an executive of GOIL and service station managers across the country to learn more about the distribution strategy used by GOIL. Data with regards to oil prices and population was taken from "Trading Economics". A multivariate regression instead of a simple regression analysis was used because it gave the researcher an opportunity to consider factors that could affect the demand of petroleum and petrochemical products.

3.2 Research Instrument

The researchers used both primary and secondary data in this study.

Hox and Boeiije (2005) defined primary data as data collected for the specific research question. Primary data was collected through interviews. To get adequate information from the interviews the researchers used both close-ended and open-ended approach.

Secondary data was described by Denzin and Lincoln (2008) as any existing data, which might have been collected by other researchers, organizations and investigating agencies. For this research, the researchers used AHP analysis, forecasting, books, and published articles. Primary information gathered from the interview was used to perform the AHP analysis and sales forecast. Secondary information from already existing literature will be used to suggest possible solutions to existing problems.

3.3 Validity of Research Instrument

Validity determines how data collected fits the area under investigation (Taherdoost, 2016). The researcher made sure that respondents in the various interviews provided answers without any influence. To ensure this the researchers decided to come up with these objectives for the interviews:

- Questions were straight forward
- Simple English was used and sometimes in special cases where the interviewee was having problems expressing themselves we used the local language.
- The interview was conducted in a comfortable setting.

3.4 Data Analysis Technique

This section describes the various data analysis technique used by the researchers in the study.

3.4.1 Tables, Charts and Graph

The researchers used tables to discuss the data collected from GOIL. This technique was used to enable the researchers to match sales against population and prices. Graphs were also used to show outcomes, trends, and relationships.

3.5 Forecasting

The method used in forecasting is the Multiple Regression. Preacher et.al (2006), Emphasized that multiple regression models describe how one variable Y depends linearly on other paramount predictor variables. The equation for multiple regression (Harbord & Higgins, 2008);

$$Y = a + b_1X_1 + b_2X_2$$

$Y - Predicted\ Y\ value\ also\ the\ dependent\ variable$

$a = Y\ intercept$

$b_1 = Relationship\ between\ Y\ and\ X\ with\ respect\ to\ an\ increment\ of\ 1$

$b_2 = Change\ in\ Y\ with\ each\ increment\ change\ in\ X_2$

$X = Variables\ for\ which\ Y\ values\ are\ being\ predicted$

For the purpose of this research, the researchers will use Sales as the independent variable whilst population and average price of petroleum product for the past 14 years will be used to determine a forecast equation.

3.5.1 The Analytical Hierarchy Process

The AHP comes up with a weight for each of the evaluation criteria which is developed by the decision maker's pairwise comparison. The weight assigned to a criterion determines the level of importance of the corresponding criterion. Next, the decision maker assigns a score to all options according to the pairwise comparisons. The score determines the importance of the criterion. The higher the score, the better the performance.

Finally, the AHP assigns the weight of the criteria and its associated options scores. This helps to determine a global score for each option and a consequent ranking. Mathematically the global score for an option is the sum of the weighted score is obtained with respect to all the criteria. To implement the AHP three main steps are to be considered.

They are;

- Computing the vector of the criteria weight.
- Computing the matrix of option scores
- Ranking the options

To compute the vector of the criteria, weight the AHP creates a pairwise comparison matrix A. The matrix A is a matrix where n represents the number of evaluation criteria considered. Each a_{jk} of the matrix A specifies the relevance of the j^{th} criterion with respect to the k^{th}criterion. In a case where, $a_{jk} > 1$ then the j^{th} criterion is more important than the k^{th} criterion.

On the other hand, if $a_{jk} < 1$, it implies that the k^{th} criterion is more important than the j^{th}criterion. In a case where a_{jk} is 1 then the two criteria have the same level of importance as $a_{jk}$and a_{kj} should satisfy the following constraint:

$$a_{jk}.a_{kj} = 1$$

After matrix A is developed, it is now possible to come up with the normalized pairwise comparison matrix A_{norm}. This is made possible by summing all entries on each column and equating them to 1. It is mathematically represented by:

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}}$$

Finally, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging the entries on each row of A_{norm}, i.e.

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m}$$

The next step is computing the matrix of option scores. The matrix used for option scores is a nxm real matrix S. Each s_{ij} of matrix S indicates the scores of the i^{th} option compared with the j^{th} criterion. In other to make this possible a pairwise comparison matrix $B^{(j)}$will have to be built by for each m criteria where $j = 1, \dots, m$. The matrix $B^{(j)}$takes the form of a nxn real matrix, where n represents the total number of options being accessed. Each entry $b_{ih}^{(j)}$ of matrix $B^{(j)}$ compares the i^{th} option to the h^{th} option with respect to the i^{th} criterion. Should it occur that $b_{ih}^{(j)} > 1$, the i^{th} option is considered better than the h^{th} *option.* If two options have the same score, then $b_{ih}^{(j)}$ is 1. All entries for $b_{ih}^{(j)}$ and $b_{hi}^{(j)}$ should satisfy the constraint below:

$$b_{ih}^{(j)}.b_{hi}^{(j)} = 1$$

$$b_{ii}^{(j)} = 1 \quad for\ all\ i\ .$$

To obtain the score vectors $S^j, j = 1, \dots . m.$, each entry in the same column is divided by its sum and then the average on each row is found. The vector entails the scores of each accessed option with respect to the j^{th} criterion. This is represented mathematically as:

$$S = [s(1), \dots, s(m)]$$

Finally, all options are ranked. After arriving at figures for the weight vector w and the score matrix s, a vector v (global scores) is found by multiplying $s\ by\ w$.

$$v = S \cdot w$$

Inconsistencies may arrive whilst applying the AHP because we are dealing with human judgements (Experts). A consistency index can be computed using the formula:

$$CI = \frac{(Average\ of\ ratios - n)}{n-1}, where\ n\ is\ the\ total\ number\ of\ ratios.$$

After calculating CI we can computer consistency ration by using the formular below:

$$CR = \frac{CI}{RI}$$

A consistency ratio of more than 0.10 means our result are inconsistent and therefore weights assigned to the various criteria should be re considered.

3.5.2 Net Present Value

The researchers used the Net Present Value Analysis (NPV) to evaluate the investment decision of a depot that GOIL wants to undertake. NPV can be used to find the current value of cash flows in the future by a project with respect to the initial capital investment.

The researchers will come up with an estimated sum for building a depot considering factors such as:

- Number of years it takes to build the depot
- Labor cost
- Cost of land
- Material cost

The cost of labour, land, and materials will be used to determine an estimate for building a depot in the selected location. The NPV formula employed by the researchers is stated below:

$NPV(n) = -I_0 + \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} = -I_0 + R \sum_{i=1}^{n} \frac{1}{(1+r)^t}$ Where;

$NPV - Net\ Present\ Value$

$R - Savings$

$I_0 - Intial\ Investment$

$n - Payback\ time$

$r - Interest\ rate$

4.0 DATA ANALYSIS

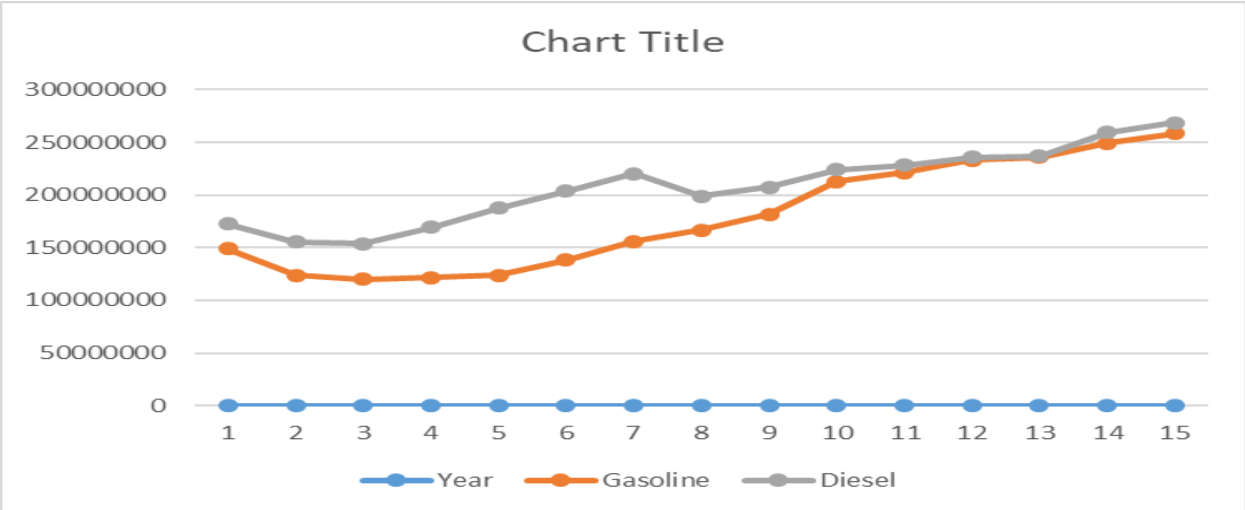
4.1 Data Presentation

In this chapter, the researchers used all the data collected during the research to perform an analysis of the study.

4.1.1 Relationship Between Gasoline and Diesel Demand in Ghana

First and foremost, the researcher established the relationship between the major petroleum products used in the country over the past 18 years starting from 2004 to 2018 with data received from the GOIL's annual reports using excel. From figure 9, the relation between these two products in terms of demand is almost the same. This implies that in terms of decision making these two petroleum products should be considered together by GOIL.

Figure 9. Relationship between the Demand for Gasoline and Diesel from 2004 to 201(litres).



Field Study 2019

4.1.2 Forecast for Diesel Demand in Ghana

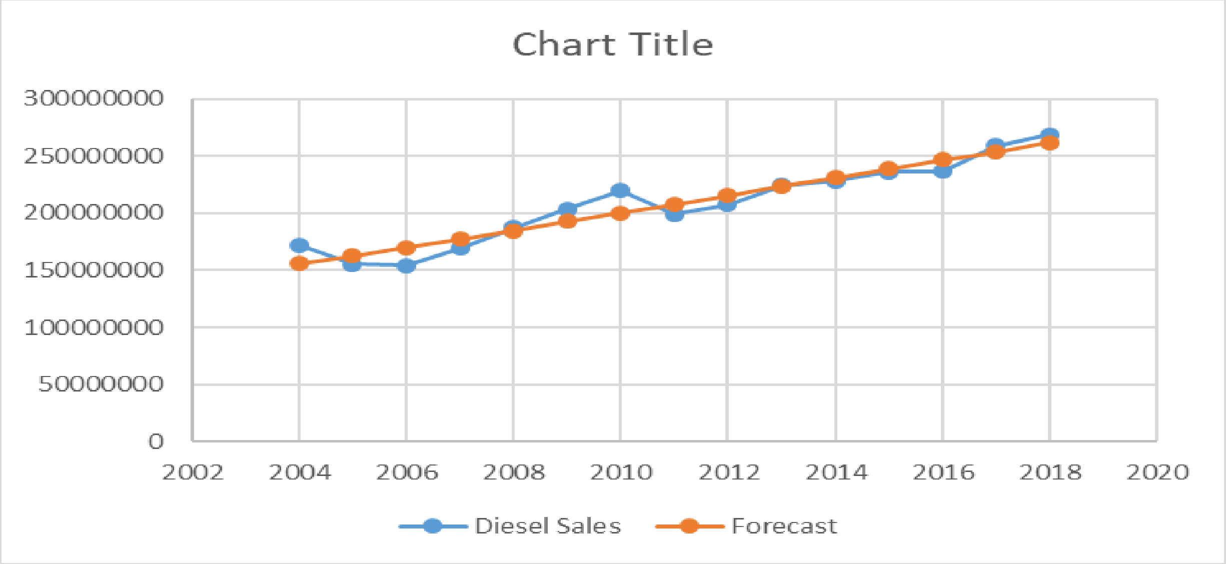
The researchers developed a demand equation for diesel using multivariate regression analysis. The equation is stated below:

$$Demand = -103092903 + 3459792(Price) + 12.26(Population)$$

Sales from 2004 to 2018 was used as the independent variable whilst factors such as price/liter and the population were used as the dependent variable. An adjusted R square of

0.9 meant that the factors considered can be highly recommended to predict the sales pattern for upcoming years. This equation can, therefore, be used to make future projections in terms of the overall demand in the country.

Figure 10. Forecasted Trend for Diesel from 2004 to 2018. (Littres)



Field Study 2019

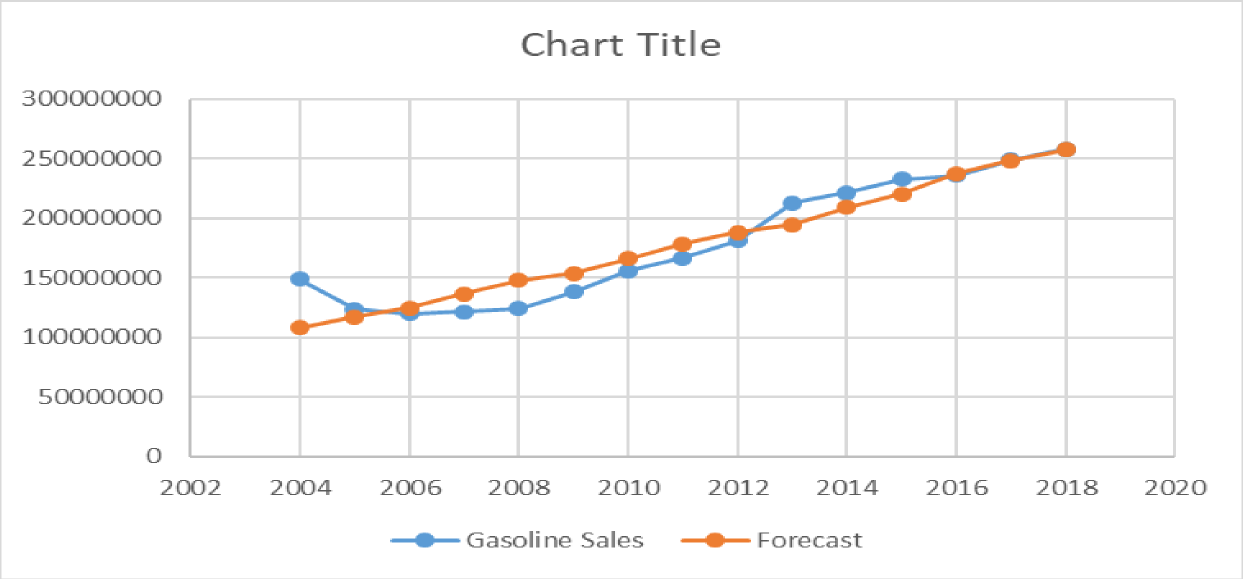
4.1.3 Forecast for Gasoline

The researchers also developed a demand equation for gasoline using multivariate regression analysis. The equation is stated below:

$$Demand = -289108121 - 25856889(Price) + 19.46(Population)$$

Sales from 2004 to 2018 was used as the independent variable whilst factors such as price/liter and population was used as the dependent variable. An adjusted R square of 0.8 meant that the factors considered can be highly recommended to predict the sales pattern for upcoming years.

Figure 11. Forecasted Trend for Gasoline from 2004 to 2018. (Litres)



Source: Field Study 2019

4.2 A Summary of the Interview with the Chief Internal Auditor.

The chief internal auditor stated that GOIL is an Oil Marketing Company (OMC). As a result, GOIL does not import petroleum. They just like many other OMC's purchase petroleum products from Bulk Distribution Companies (BDC's) on behalf of their dealers or service stations. According to him, GOIL boasts of about 250 service stations nationwide.

GOIL is the only OMC owned by the government in charge of downstream activities in Ghana. Shell and Total are private oil companies whose main objective is to maximize profit on the other hand GOIL is a state-owned company whose main objective as given to it by the government, is to make oil readily available across all the 10 regions in Ghana. It is the only oil company that has outlets or distribution points in every region. The Bulk Oil Storage and Transport Company (BOST)oversees storing oil produced by the upstream sector. BOST then delivers oil to GOIL according to GOIL's nationwide demand. It is the duty of GOIL to determine how much oil is demanded so that BOST can satisfy their demand. In special cases where demand outstrips supply, the Ministry of Energy imports oil from neighbouring countries such as Nigeria (this occurrence rarely happens).

Among all the OMC’s currently operating in Ghana, only three are considered as the major players in the industry. They include Total, Shell and GOIL. GOIL still remains the OMC with the largest market share in comparison to the other OMC’s in Ghana He further explained that the traditional way of satisfying demand was transporting straight from BOST until 2007 when the first depot was built in Accra due to variation in demand. He further stated that they wanted this depot to be close to areas where demand is increasing at an increasing rate with variations. GOIL is the only downstream distributor of oil which has its own depot(s). The depot was constructed with the help of funds given by the Government. No other oil distributor has a depot. From our research, we realized that GOIL has two (2) depots. The centralized depot in the Greater Accra Region and a relatively smaller one in the Western Region of Ghana. It is the only company with 290 service stations and 150 consumer outlets. We intend to start running interviews with service station managers of GOIL to give more information about the supply chain.

In terms of the supply chain, he said whenever a dealer (Service Stations) places an order for petroleum products, GOIL acts on behalf of the dealer and places the order for that quantity of petroleum to a BDC through Tema Oil Refinery. Once the request has been made and accepted, a truck is sent to load the quantity and deliver it to the dealer. According to him, GOIL does not need a petroleum depot(s) because the practice has been to order the products from the BDC's as and when a dealer or buyer needs petroleum products to replenish his or her stock but in spite of the current increase in demand, it is an option that should be considered. GOIL does not own the trucks used in transporting petroleum products from the BDC’s. These truck drivers are independent but act on behalf of GOIL.
Regarding sales over the past years, he believed the trend may be downward sloping. He stated that this was because of the increase in OMC’s in Ghana over the past years. However, he maintained that GOIL still controlled a significantly large share of the market. Finally, he provided as with sales data between 2004 to 2018

4.3 Supply Chain Mapping for GOIL (Based on Interviews with Regional Managers)

From the interview, we realized that all the service stations acquire petroleum products using the same procedure. The researchers realized that this procedure was established by the managers in charge of GOIL's operations in the whole country. At the beginning of every month a certain amount of petroleum product was sent to the service stations based on their sales for the previous month. It was clear that sales were used to forecast each service station's quantity every month.

The researchers also found out that there is no way GOIL monitors the inventory level at every station. It is rather the duty of the service managers at each station to make a phone call to GOIL in case they suspect any shortages within a certain month. In such a case GOIL access the situation with the service managers to determine the total amount of petroleum product they may need to curb the shortage.

The products are carried countrywide on GOIL’s distribution trucks.

It takes 24 hrs. for service stations to decide exactly how much product they need. It takes equally the same number of hours for GOIL to decide whether to satisfy that services station’s demand. GOIL then relays the order to the National Bulk Distribution Center (The National Bulk Distribution Centre is set up by the government as the main distribution center for the Ghana Oil Company Limited-GOIL). The BDC then loads the product into GOIL's tracking unit and this usually takes between 24 to 72 hrs. depending on the total amount to be loaded. The trucks then deliver to the service station by road. In case there are situations such as bad roads, bad weather or an unexpected breakdown of the truck during transportation, it takes on the average 48 hours to deliver to the service stations. It might take longer if the service station is in the northern part of Ghana because that is almost 670 kilometers from the depot. It takes 3 days (-1 or +1) depending on the service station's location to deliver products in terms of emergency.

From our respondents, the researchers were made to know that service stations in the northern part of Ghana do not encounter shortages. The simple reason being that most of its habitat are farmers who still use primitive methods of farming.

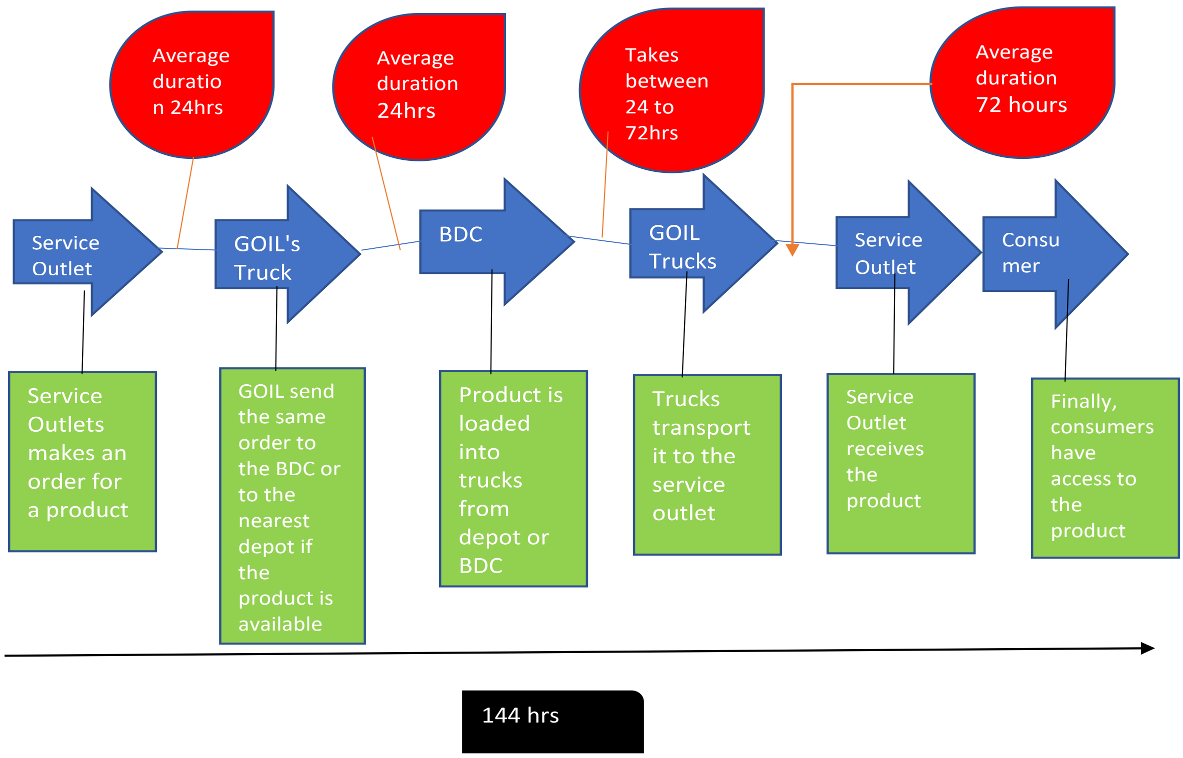
Another factor was the lack of manufacturing and industrial companies in the region. In terms of transportation, only a few numbers of the habitats used cars and other locomotives which might need petroleum as its source of energy. So, demand has been fairly predictive over the years.

Service station managers in Southern Ghana encounter a lot of shortages within some months. Demand is highly unpredictive. Demand for the past two (2) months can be very different from demand for the subsequent months. They attributed this to the enormous industrial and manufacturing growth in the southern part. We were also made to understand that, internal migration from the north to the south to seek for greener pastures has resulted in a rapid increase of the population in the south, hence increasing demand for petroleum products. Another important point was the unavailability of trucks to transport petroleum products from depot to service stations. Respondents made as understand that, sometimes in cases of an unexpected increase in demand, GOIL sometimes does not have available any truck to carry petroleum products to the service stations. Therefore, stations will have to wait until there is an available truck or trucks to carry the products to them.

From the interview, the researchers were able to come up with a graphical representation of GOIL's supply chain below;

chain below;

Figure 12. GOIL's Supply Chain



Source: Field Study 2019

4.4 Challenges Facing GOIL

From our field study below are the challenges facing GOIL in their operations:

- The number of days it takes for GOIL to fulfill orders made at service stations during stock out is long. This leads to high lead time hence shortages at service stations during an unexpected increase in demand.
- Unavailability of trucks for transportation during an unexpected increase demand.
- GOIL has over **280** customer retail outlets (Filling Stations) across the country. Monitoring of inventory level at all the filling stations by GOIL is very difficult.
- There is no alternative mode of transport apart from roads.

- Demand variation in the southern part of Ghana is projected to increase due to industrialization, population growth and internal migration from the north to the south. The persistence of such variations will increase forecasting error.

4.5 Building of a Depot and its Effects on the Supply Chain of GOIL

According to Noche (2012), the process of streamlining activities from depots to filling station is the second most important aspect in the oil and gas supply chain. The researchers, therefore, discussed the effect of a new depot on GOIL's supply chain. These effects are stated below:

- Shorter lead time

Building a depot will draw products closer to the customers. This will imply that, the distance travelled from depot to consumer outlets will decrease. This will reduce lead time.

- Reduces transportation cost

Once the depot is built closer to the customer, the distance travelled by GOIL’s truck to satisfy service station’s demand will decrease, hence money spent to fuel delivery trucks and maintenance of trucks will decrease. This will reduce the overall cost of transportation to service stations.

- Trucks will not have to travel long distances which will reduce the risk of losses because of accidents.

The poor infrastructure of road networks in Ghana has also been a major issue to GOIL. Delivery trucks sometimes stand a risk of being engaged in road accidents. Whenever there is an accident, GOIL losses a lot of revenue. Building a depot will reduce the risk of delivery trucks being engaged in road accidents because they will not have to travel long distances to make deliveries at service stations.

- Increase customer satisfaction.

Once the time between re-ordering and replenishment is reduced, service stations stand a minimal probability of running out of stock. This will reduce the rate of shortage and loss of revenue, hence, increase in customer satisfaction.

- Increase in inventory cost

On the other hand, building a depot can increase inventory holding cost of GOIL. This can be a major set back considering the impact it can have on the overall supply chain cost.

- The initial set up cost of the depot can be high.

The set-up cost involved in building a depot such as labor cost, cost of land and material cost can be very high. It is therefore important for GOIL to consider the financial burden involved in undertaken such a project.

4.5.1 Site Location Strategy (AHP)

The AHP analysis was used by the researchers to find a suitable location for a depot for GOIL. The processes involved in applying AHP have already been explained in the previous chapter.

4.5.2 Steps Involved in Building the AHP

1. The first step in an AHP analysis is to build a hierarchy for the decision. For our decision, the goal is to find a suggested location for a depot whilst considering factors such as cost of land, number of service stations in a region, distance from the central depot and the cost of labor. These factors are the major factors considered by GOIL before setting up a depot according to the internal auditor. After identifying these factors, a pairwise comparison scale is developed which determines the level of importance attached to every factor being considered. Expects are usually needed to come up with these pairwise comparisons and in our case, we were fortunate to have the internal auditor come up with a scale based on their previous built depot.

2. The second step involves assigning a weight for each of the criteria. Each criterion (factor) considered before building a depot is compared to each other. Saaty, who came up with the AHP model designed a scale from 1 to 9 which is used to measure importance.

Table.3 Scale for Measuring Importance in AHP

LEVEL OF IMPORTANCE	DEFINITION	MEANING
1	Equally important	Two factors on the same level of importance
3	Slightly more important	One criterion is slightly preferred over the other.
5	Much more important	One criterion is strongly favored over the other.
7	Very much more important	One criterion is very strongly favored over the other.
9	Absolutely more important	One is preferred more over the other. This is the highest ratio
2,4,6,8	Intermediate values	Used when compromises arise.

3. The next step involves coming up with the normalization of the comparison matrix. First, add the values in each column and then divide each cell by the total of each column. This step is indicated with the color yellow.
4. The next step is to find the final priorities from the normalized matrix. This is done by calculating the average value of each row. This is highlighted with color ash in our work. This step helps us identify the level of priority assigned to each criterion.
5. Finally, we compare our priority weight of each suggested location to the weight assigned to the factors considered by GOIL before setting up a depot. The model indicated that the suggested location or region of the depot should be in the Greater Accra Region (G.A.R).

In order, for our solution to be considered valid we needed to check for consistency. Since the numeric values are derived from the subjective preference of individuals, it is impossible to avoid inconsistencies in the final matrix of judgment since we are dealing with human judgment. A comparison matrix is consistent if;

$$a_{ij}.a_{jk} = a_{ik}\ , for\ all\ i, j, k$$

The question is how much inconsistency is acceptable. For this purpose, AHP calculates a consistency ratio (CR) comparing the consistency index of a random like matrix (RI) A random matrix is one where judgment have been entered randomly and therefore it is expected to be highly inconsistent. More specifically, RI is the average CI of 500 randomly filled in matrices. Saaty (Professor who came up with AHP) in 2012 provides the calculated RI value for matrices of different sizes.

In AHP the consistency index is defined as CR where:

$$CR = \frac{CI}{RI}.$$

Saaty also has shown that consistency ratio (CR) should not be more than 0.10 or less is acceptable to continue the AHP analysis. If CR is greater than 0.10 it is necessary to revise the judgment to locate the cause of the inconsistency and correct it. Steps involved in checking consistency are as follows:

1. Create a new weight (shown in green in appendix). This is created by multiplying each value in the pairwise comparison by its corresponding final priority weight. Example in our work, numbers in each cell from B6 to B9 were individually multiplied by L6. The same process was done for all other cells to get the new weights.
2. Column product was derived from summing up horizontally weights from cells N10 to Q 10.
3. Column ratio is determined by dividing the product by final priority
4. Consistency index is then developed by:

$$CI = \frac{(Average\ of\ ratios - n)}{n-1},$$

$where\ n\ is\ the\ total\ number\ of\ ratios.$

5. After calculating CI we calculate consistency ratio by:

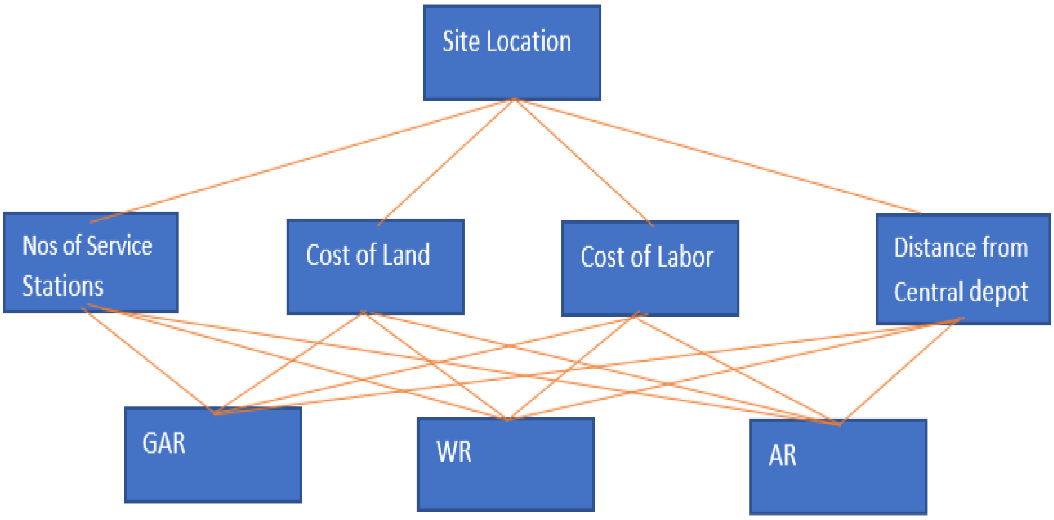
$$CR = \frac{CI}{RI}$$

Since all our CR in our calculation is less than 0.10 we can say our results are consistent and therefore solution from AHP can be considered.

4.5.3 Application of AHP to the Research

Figure 12 below is a graphical representation of how the AHP will be applied in making a facility location. The objective is determining a location for a deport considering factors such as the number of service stations available in each region, the cost of land in each region, the cost of labor in each region and distance from central depot.

Figure 13. Hierarchical Structure of the AHP Model



Source: Field Study 2019

Where ;

GAR- Greater Accra Region

WR- Western Region

AR- Ashanti Region

These regions were chosen because they are highly populated as suppose to other regions such as Central Region, Volta Region, Eastern Regions. Population was considered because has been the main factor affecting the demand for petroleum and petrochemical products in Ghana over the years according to our demand forecast.

Table 4. Comparison Pairwise Matrix of Criteria with Factors

CRITERIA	NOS OF SERVICE STATIONS	COST OF LAND	COST OF LABOR	DISTANCE FROM CENTRAL DEPOT
NSS	1	5	7	3
COST OF LAND	1/5	1	3	1/3
COST OF LABOR	1/7	1/3	1	1/5
DFCD	1/3	3	5	1
TOTAL	1.6761905	9.333333	16.0	4.533333

Source: Field Study 2019

Where:

NSS- Number of Service Stations

DFCD- Distance from Central Depot

Table 5. Normalized Matrix from Factors

0.596591	**0.535714**	**0.437500**	**0.661765**
0.119318	0.107143	0.187500	0.073529
0.085227	0.035714	0.062500	0.044118
0.198864	0.321429	0.312500	0.220588

Source: Field Study 2019

Table 6. Weight from Normalization Matrix Compared with Factors

0.557892
0.121873
0.56890
0.263345

Source: Field Study

Table 7. Comparison of Criteria with the Suggested Location in Terms of Cost

NOS OF SERVICE STATIONS	**GAR**	**AR**	**WR**
GAR	1	2	3
AR	½	1	2
WR	1/3	½	1
TOTAL	1.833333	3.5	6.0

Source: Field Study 2019

Table 8. Normalized Matrix from Comparison with Suggested Location

NOS OF SERVICE STATIONS	GAR	AR	WR
GAR	0.545455	0.571429	0.5
AR	0.272727	0.285715	0.333333
WR	0.181818	0.142857	0.166667

Source: Field Study 2019

Table 9. Weight for Cost

0.538961
0.297258
0.163781

Source: Field Study 2019

Table 10. Comparison of Criteria with the Suggested Location in Terms of Distance

DISTANCE FROM CENTRAL DEPOT	GAR	AR	WR
GAR	1	3	2
AR	1/3	1	½
WR	½	2	1
TOTAL	1.833333	6.0	3.5

Table 11. Normalized Matrix for Distance from Central Depot

NOS OF SERVICE STATIONS	GAR	AR	WR
GAR	0.545455	0.5	0.571429
AR	0.181818	0.166667	0.142857
WR	0.272727	0.333333	0.285714

Source: Field Study

Table 12. Weight for Distance from Central Depot

0.538961
0.163781
0.297258

Source: Field Study 2019

Table 13. Comparison of Weight for Cost with the Suggested Location

COST OF LAND	GAR	AR	WR
GAR	1	1/3	½
AR	3	1	2
WR	2	½	1
TOTAL	6	1.833333	3.5

Source: Field Study

Table 14. Normalized Matrix for Cost of Land

COST OF LAND	GAR	AR	WR
GAR	0.166667	0.181818	0.142857
AR	0.5	0.545455	0.571429
WR	0.333333	0.272727	0.285714

Source: Field Study

Table 15. Weight for Cost of Land

0.163781
0.538961
0.297258

Source: Field Study 2019

Table 16. Comparison of Cost of Labor with Suggested Locations

COST OF LABOR	GAR	AR	WR
GAR	1	¼	½
AR	4	1	3
WR	2	1/3	1
TOTAL	7	1.583333	4.5

Source: Field Study 2019

Table 17. Normalized Weight for Cost of Labor

COST OF LAND	GAR	AR	WR
GAR	0.142857	0.157895	0.111111
AR	0.571429	0.631579	0.666667
WR	0.285714	0.210526	0.222222

Source: Field Study 2019

Table 18. Weight for Cost of Labor

0.137288
0.623225
0.239488

Source: Field Study 2019

In other to find the most suitable location from the options we multiply accumulated score with the weights for each suggested location.

$$\begin{bmatrix} GAR \\ AR \\ WR \end{bmatrix} = \begin{bmatrix} 0.470386 * \\ 0.310109 \\ 0.219506 \end{bmatrix}$$

From the analysis, GAR scored the highest point amongst the other alternatives

4.6 Cost Saving Analysis (Greater Accra Region)

The researchers calculated an estimated sum for building a depot using NPV. Factors such as:

- Number of years it takes to build the depot
- Labor cost
- Cost of land
- Material cost

The cost of labor, land, and materials will be used to determine an estimate for an initial investment building a depot in the selected location.

For annual net saving (R_t) the researchers used the savings estimations arising from:

- Cost of transportation
- Cost of maintenance (Trucks)
- Cost arising from shortages

Notations:

Assuming $R = R_t$ is constant.

$$NPV(n) = -I_0 + \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} = -I_0 + R \sum_{i=1}^{n} \frac{1}{(1+r)^t}$$

The partial sum above, is equal to

$$\sum_{i=1}^{n} \frac{1}{(1+r)^t} = \frac{1}{r}(1 - \left(\frac{1}{1+r}\right)^n)$$

So, we can make an excel table, where I_0, R, n, r are inputs, and the NPV is the output in each cell. The formula we need to implement is

$$NPV = -I_0 + \frac{R}{r}(1 - \left(\frac{1}{1+r}\right)^n)$$

Where;

$NPV - Net\ Present\ Value$

$R - Savings$

$I_0 - Intial\ Investment\ n - Payback\ time$

$r - Interest\ rate$

Apart from the real case scenario, the researchers considered multiple case scenarios because of uncertainties that can arise as a result of economic factors that can affect interest rate, savings and the initial investment.

Table 19. NPV Scenario 1(Real Case Scenario with Forecasted Savings)

	Interest					Years	Initial Investment	
Saving	**0.13**	**0.15**	**0.17**	**0.18**				
490000	-833434	-1134789	-1391148	-1505127		15	4000000	
590000	-187196	-550052	-858730	-995969				
690000	459041	34685	-326311	-486811				
790000	1105279	619422	206108	22346				
890000	1751517	1204159	738527	531504				

Source: Field Study 2019

So, with 15% interest, 690 000$ in annual cash flow and an initial investment of 4000000 the NPV is positive, $34685 that is. under this scenario the depot is profitable.

Table 20. NPV Scenario 2(Forecasted Savings)

	Interest					Years	Initial Investment	
Saving	**0.13**	**0.15**	**0.17**	**0.18**				
490000	-333434	-634789	-891148	-1005127		15	3500000	
590000	312804	-50052	-358730	-495969				
690000	959041	534685	173689	13189				
790000	1605279	1119422	706108	522346				
890000	2251517	1704159	1238527	1031504				

Source: Field Study 2019

Under scenario 2, with 15% interest, 690 000$ in annual cash flow and initial investment of $3500000 the NPV is positive, $534685 that is, under this scenario the depot is profitable.

Table.21 NPV Scenario 3 (Forecasted Savings)

	Interest					Years	Initial Investment	
Saving	**0.13**	**0.15**	**0.17**	**0.18**				
490000	-1833434	-2134789	-2391148	-2505127		15	5000000	
590000	-1187196	-1550052	-1858730	-1995969				
690000	-540959	-965315	-1326311	-1486811				
790000	105279	-380578	-793892	-977654				
890000	751517	204159	-261473	-468496				

Source: Field Study 2019

Under scenario 3, with 15% interest, 690 000$ in annual cash flow and initial investment of $5000000 the NPV is negative $965315, that is, under this scenario the depot is not profitable.

Table 22. NPV Scenario 4 (Forecasted Savings)

	Interest					Years	Initial Investment	
Saving	**0.13**	**0.15**	**0.17**	**0.18**				
490000	-1333434	-1634789	-1891148	-2005127		15	4500000	
590000	-687196	-1050052	-1358730	-1495969				
690000	-40959	-465315	-826311	-986811				
790000	605279	119422	-293892	-477654				
890000	1251517	704159	238527	31504				

Source: Field Study 2019

Under scenario 4, with 15% interest, $690000 in annual cash flow and initial investment of 4500000 the NPV is positive, $534685 that is, under this scenario the depot is profitable.

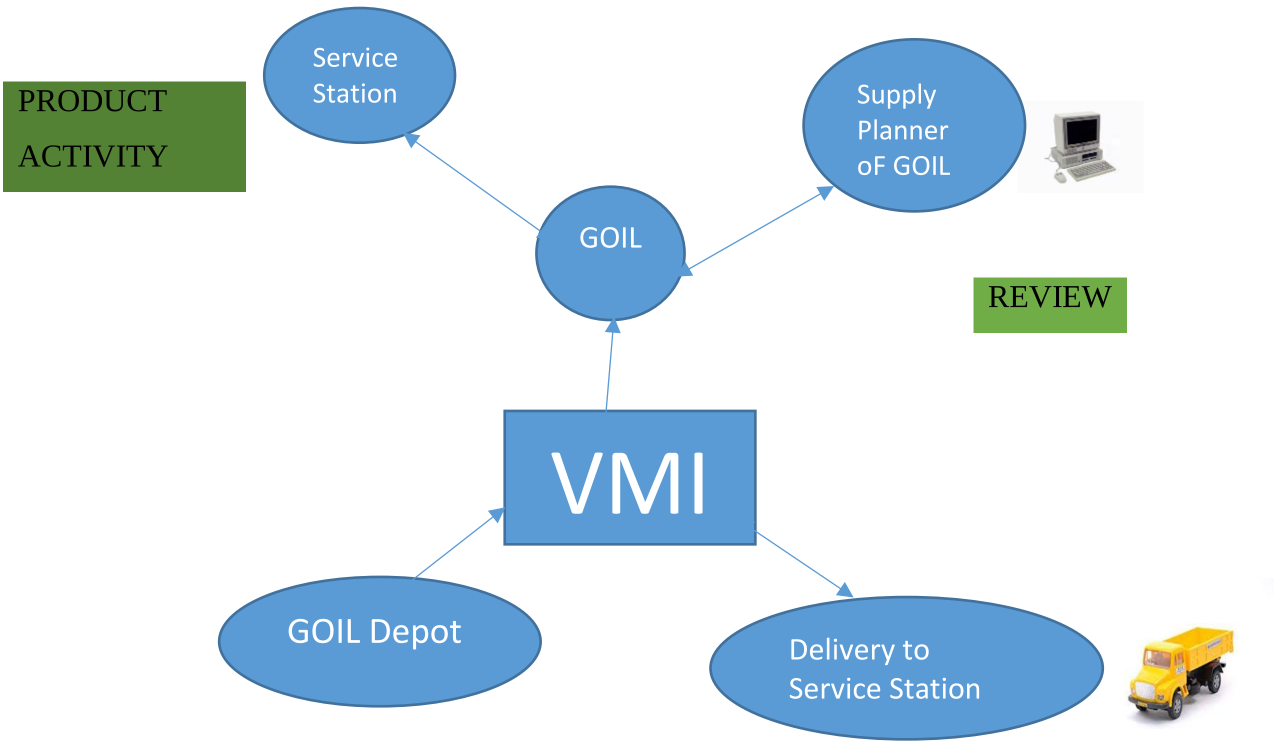
4.7 Alternative Logistics Solutions for GOIL

As part of the researcher's field study, the following alternative logistics solution was proposed:

4.7.1 Vendor Management Inventory

Vendor Management Inventory is a streamlined approach to manage inventory and order fulfilment. It involves a partnership between suppliers and their customers such as distributors and retailers.

Figure 14. Suggested VMI Network for GOIL



Source: Field Study 2019

Figure 14 above is used to demonstrate how a VMI software can improve GOIL supply chain. The VMI process begins with the service stations of GOIL sending a product activity report. The information included in this report can be sales and inventory information.

The VMI software analyses the data and makes suggestions on when to make order replenishments. The analysis is based on factors such as frequency of sales and forecasts.

GOIL's Supply Planner analyses the recommendations made by the VMI software. The supply planner sends a replenishment order to the depot(s). Finally, an acknowledgement of order fulfilment is sent to the service station(s).

If this system is implemented, there will be reduction in stock out at GOIL's service stations. GOIL will be able to see when service stations are about to exhaust its inventory. It can prepare to replenish the service station by scheduling distribution. Service outlets will reduce stockouts because they will not have to order products at the last minute without having information on whether GOIL can restock. Part of VMI's objective is to reduce uncertainty that can arise when GOIL has no information on service station inventory status.

4.7.2 Alternative Mode of Transport

GOIL should look for other alternative modes of transportation apart from road. The current railway system being rehabilitated by the government can be a good start up point. Petroleum products from the central depot can be transported straight to Ashanti and Brong-Ahafo regions using this railway line.

In the future GOIL can also consider transportation of petroleum products through pipelines. Pipelines can be used to transport products directly from central depot to regional depot. This will help to reduce transportation and inventory holding cost. The disadvantage of setting up a pipeline will be high set up cost.

5.0 Findings, Conclusion and Recommendation

In this chapter, the whole research is reviewed. The revision will be based on the methods and models used by the researchers. Finally, conclusions, recommendations are made based on the findings and results from chapter 4.

5.1 Findings

The aim of the research was to analyse the supply chain design of GOIL whilst deducing the causes of shortages in service stations over the past few years in Ghana. The researchers also gave a general overview of the oil industry in Ghana.

In chapter 4.1, research question 1, that is, the relationship between the major petroleum product namely diesel and gasoline were established. A multivariate forecasting method was used to determine the demand equation of the two major petroleum products in Ghana. From the equation, it was realized that population plays a major role in the demand of products. This means that, with population growth ascending over the years and years to come, demand for petroleum products is subject to increase.

In chapter 4.4 answers to research question 2 was provided. The researchers were able to identify the major challenges faced by GOIL's supply chain through the various interviews conducted. The challenges are:

- Long lead times resulting to shortages in most service stations.
- Managing of inventory by GOIL and service station outlet is challenging.
- Inadequate trucks for distribution in times of unexpected increase in demand.
- No alternative mode of transport apart from road.
- Demand variation in the southern part of Ghana is projected to increase due to industrialization, population growth and internal migration from the north to the south. The persistence of such variations will increase forecasting error.

To solve the problems above, the researchers considered the effect of building a new depot on GOIL's supply chain in chapter 4.5 as part of research question 3. These effects are:

- Shorter lead time.

- Reduces transportation cost because trucks will not have to travel long distances which will reduce the risk of losses because of accidents
- Increase customer satisfaction.
- Increase in inventory cost.
- The initial set up cost of the depot can be high.

The AHP model was used as an answer to research question 4 to suggest a suitable location for in chapter 4.5.3. The Greater Accra Region was chosen as a suitable location for the depot.

In chapter 4.6, research question 5 was answered. The researchers conducted an analysis using NPV to determine the profitability of building a new depot under different scenarios apart from the estimated real scenario. Four different initial investment figures were used for each scenario. The analysis indicated that it will be profitable to build a depot under the current conditions estimated by GOIL.

In chapter 4.7 answers to research question 6 was discussed. The researchers considered other alternatives that can improve GOIL's supply chain. Vendor Management Inventory system will enable GOIL to have an idea of the inventory level at every at all service stations. This system will therefore help GOIL anticipate any shortages that could possibly occur at any service station so that they can plan their distribution ahead of time. GOIL should consider using the newly build railway line from the Brong Ahafo Region to the Greater Accra region for its distribution the mid parts of the country. This will reduce the over reliance on trucks and roads as their only mode and means of transportation. In the long run GOIL can also decide to build pipelines straight from the central depot directly to regional depots. This factor will help reduce transportation cost even though initial setup cost can be high,

5.2 Conclusion

The main objective of the research was channelled towards improving the distribution of petroleum products in order to increase customer satisfaction. The time periods between order placement until the delivery of petroleum products can be significantly reduced. This practice will help to reduce lead time and decrease the probability of shortages in service outlets. This will make petroleum products readily available to consumers across the country.

5.3 Recommendation

The following recommendations have been made based on the research:

- GOIL should consider practicing Vendor Management Inventory system
- GOIL should consider building a depot in the Greater Accra Region to serve all the other regions such as the central, eastern and Volta regions.
- GOIL should consider building additional storage areas in service stations to keep buffer stocks.
- GOIL should consider taking advantage of the newly constructed railway system from the Eastern to the Greater Accra Region which was constructed by the government. This will give them an option to either use road or rail depending on the conditions available.
- GOIL should consider using an effective forecasting technique to make projections of demand in the up and coming years so that they can foresee problems before they arise.
- GOIL should consider building a pipeline as an alternative mode of transport in the long run.

5.4 Suggestion for Future Research

There is certainly more work to be done on the supply chain downstream. The NPV analysis is very simple and has the potential for a more thorough investigation.
The upstream industry in Ghana is still considered an infant industry. Last year companies such as Aker Energy, Exon mobile and Tullow oil have been given the opportunity by the government of Ghana to undertake oil and gas Deepwater exploration in the Gulf of Guinea and Cape three Point. There has not been enough research on the upstream sector. Transportation of crude oil from exploration rigs to BDC's can be an important area to consider for future research.

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APPENDIX 1

Questions Asked During Interview with Chief Internal Auditor of Goil .

1. How does GOIL acquire petroleum products?
2. Where does GOIL acquire petroleum products?
3. Does the company purchase petroleum products on a monthly basis?
4. How are petroleum products distributed to the various service stations across the country?
5. Does GOIL have any depot(s) across the country?
6. How many service stations are registered under GOIL in Ghana?
7. What factors do you consider in building a new service station for GOIL?
8. Which regions have the highest number of GOIL service stations?
9. How large is GOIL's market share?
10. What is the company's sales in gasoil and gasoline for the past ten years?

APPENDIX 2

Questions Asked During Interview with Selected Service Stations in Ghana

1. How do you acquire petroleum products?
2. How do you place orders for petroleum?
3. How long does it take to receive products after order has been made (Lead time).
4. Do you experience shortages?
5. What do you think causes these shortages?
6. What will you suggest will help improve the distribution between GOIL and its service stations?

APPENDIX 3

Demand for Gasoline and Diesel

Year	Gasoline	Diesel
2004	148787701	172343400
2005	123723691	155206400
2006	119809050	154006105
2007	121489900	169528400
2008	124019250	187317650
2009	138199400	203467630
2010	156167600	220085773
2011	166709650	198851400
2012	181470800	207597600
2013	212927839	224241376
2014	221490350	228311350
2015	232873783	235869032
2016	235909301	236849233
2017	248937478	259304743
2018	258384903	268348938

APPENDIX 4

Demand forecast for Diesel Using Multi variate Regression

Years	Diesel Sales	Forecast	Price	Population
2004	172343400	155604783.6	0.42	20986536
2005	155206400	162690333.1	0.5	21542009
2006	154006105	170144295.2	0.63	22113425
2007	169528400	177302297.9	0.62	22700212
2008	187317650	184637589.3	0.62	23298640
2009	203467630	192851531.1	0.85	23903831
2010	220085773	200238302.6	0.83	24512104
2011	198851400	207642467.7	0.81	25121796
2012	207597600	215446344.1	0.9	25733049
2013	224241376	223689359.3	1.11	26346257
2014	228311350	230897812.7	1.01	26962563
2015	235869032	238639079.2	1.05	27582821
2016	236849233	246468571.1	0.89	28266728
2017	259304743	253452015	0.9	28833629
2018	268348938	261624248	1.03	29463643

APPENDIX 5

Multi Variate Regression Forecast of Gasoline

Year	Gasoline Sales	Forecast	Populatior	Price
2004	148787701	108354025.5	20986536	0.42
2005	123723691	117092968.7	21542009	0.5
2006	119809050	124849260.5	22113425	0.63
2007	121489900	136524580.8	22700212	0.62
2008	124019250	148167824	23298640	0.62
2009	138199400	153995566.2	23903831	0.85
2010	156167600	166347495.2	24512104	0.83
2011	166709650	178727032.9	25121796	0.81
2012	181470800	188292684.1	25733049	0.9
2013	212927839	194793545.9	26346257	1.11
2014	221490350	209370319.1	26962563	1.01
2015	232873783	220404019.5	27582821	1.05
2016	235909301	237847476.9	28266728	0.89
2017	248937478	248618749.9	28833629	0.9
2018	258384903	257515146.7	29463643	1.03

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.956773405
R Square	0.915415348
Adjusted R	0.901317906
Standard E	11167036.48
Observatic	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regressior	2	1.61951E+16	8.09755E+15	64.93485	3.66226E-07
Residual	12	1.49643E+15	1.24703E+14		
Total	14	1.76915E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-103092903.1	37309081.02	-2.763212072	0.017177	-184382407.5	-21803398.68	-184382407.5	-21803398.68
X Variable	3459792.672	28765193.32	0.120277053	0.906254	-59214179.58	66133764.93	-59214179.58	66133764.93
X Variable	12.25760048	2.210926315	5.544101763	0.000127	7.44040586	17.0747951	7.44040586	17.0747951

RESIDUAL OUTPUT

Observatior	*Predicted Y*	*Residuals*
1	155604783.6	16738616.38
2	162690333.1	-7483933.141
3	170144295.2	-16138190.22
4	177302297.9	-7773897.912
5	184637589.3	2680060.748
6	192851531.1	10616098.94
7	200238302.6	19847470.38
8	207642467.7	-8791067.722
9	215446344.1	-7848744.129
10	223689359.3	552016.7337
11	230897812.7	-2586462.721
12	238639079.2	-2770047.187
13	246468571.1	-9619338.132
14	253452015	5852727.971
15	261624248	6724690.015

APPENDIX 6

Multivariate Forecasting for Diesel

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.947959234
R Square	0.89862671
Adjusted R	0.881731161
Standard E	17543777.68
Observatio	15

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regressior	2	3.27403E+16	1.64E+16	53.18719	1.09E-06
Residual	12	3.69341E+15	3.08E+14		
Total	14	3.64338E+16			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*	*pper 95.0%*
Intercept	-289108121.2	58613780.31	-4.93243	0.000346	-4.2E+08	-1.6E+08	-4.2E+08	-1.6E+08	-1.6E+08
X Variable	19.45638099	3.473437183	5.601478	0.000116	11.88841	27.02435	11.88841	27.02435	27.02435
X Variable	-25856888.89	45191054.72	-0.57217	0.57777	-1.2E+08	72605961	-1.2E+08	72605961	72605961

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*
1	108354025.5	40433675.52
2	117092968.7	6630722.316
3	124849260.5	-5040210.525
4	136524580.8	-15034680.84
5	148167824	-24148574.01
6	153995566.2	-15796166.23
7	166347495.2	-10179895.24
8	178727032.9	-12017382.85
9	188292684.1	-6821884.098
10	194793545.9	18134293.1
11	209370319.1	12120030.87
12	220404019.5	12469763.47
13	237847476.9	-1938175.909
14	248618749.9	318728.1416
15	257515146.7	869756.2867

APPENDIX 7

AHP Anaysis Using Excel

Pairwise Comparison of Objectives

	No. S|S	Cost land	Cost of Labor	Distance from Depot	Normalized Matrix				Final Priority	New Weight				Product	Ratio
No.of Service Stations	1	5	7	3	0.596591	0.535714	0.437500	0.661765	0.557892	0.557892	0.609363	0.398229	0.790035	2.355519	4.222175
Cost of Land	1/5	1	3	1/3	0.119318	0.107143	0.187500	0.073529	0.121873	0.111578	0.121873	0.170669	0.087782	0.491902	4.036200
Cost of Labor	1/7	1/3	1	1/5	0.085227	0.035714	0.062500	0.044118	0.056890	0.079699	0.040624	0.056890	0.052669	0.229882	4.040829
Distance from Central Depot	1/3	3	5	1	0.198864	0.321429	0.312500	0.220588	0.263345	0.185964	0.365618	0.284449	0.263345	1.099376	4.174659
	1.6761905	9.333333	16.00	4.533333										Consistency Index	0.039489
														CI/RI	0.043876

Pairwise Comparison Among Regions on Number of Service Station

	G.A.R	A.R	W.R	Normalized Matrix			Final Priority	New Weight			Product	Ratio
G.A.R	1	2	3	0.545455	0.571429	0.500000	0.538961	0.538961	0.594517	0.491342	1.624820	3.014726
A.R	1/2	1	2	0.272727	0.285714	0.333333	0.297258	0.269481	0.297258	0.327561	0.894300	3.008495
W.R	1/3	1/2	1	0.181818	0.142857	0.166667	0.163781	0.179654	0.148629	0.163781	0.492063	3.004405
	1.833333	3.500000	6.000000								Consistency Index	0.004604
											CI/RI	0.007938

Pairwise Comparison Among Region on Distance from Central Depot

	G.A.R	A.R	W.R	Normalized Matrix			Final Priority	New Weight			Product	Ratio
G.A.R	1	3	2	0.545455	0.500000	0.571429	0.538961	0.538961	0.491342	0.594517	1.624820	3.014726
A.R	1/3	1	1/2	0.181818	0.166667	0.142857	0.163781	0.179654	0.163781	0.148629	0.492063	3.004405
W.R	1/2	2	1	0.272727	0.333333	0.285714	0.297258	0.269481	0.327561	0.297258	0.894300	3.008495
	1.833333	6.000000	3.500000								Consistency Index	0.004604
											CI/RI	0.007938

Pairwise Comparison Among Regions on Cost of Land

	G.A.R	A.R	W.R	Normalized Matrix			Final Priority	New Weight			Product	Ratio
G.A.R	1	1/3	1/2	0.166667	0.181818	0.142857	0.163781	0.163781	0.179654	0.148629	0.492063	3.004405
A.R	3	1	2	0.500000	0.545455	0.571429	0.538961	0.491342	0.538961	0.594517	1.624820	3.014726
W.R	2	1/2	1	0.333333	0.272727	0.285714	0.297258	0.327561	0.269481	0.297258	0.894300	3.008495
	6	1.833333	3.500000								Consistency Index	0.004604
											CI/RI	0.007938

Pairwise Comparison Among Regions on Cost of Labor

	G.A.R	A.R	W.R	Normalized Matrix			Final Priority	New Weight			Product	Ratio
G.A.R	1	1/4	1/2	0.142857	0.157895	0.111111	0.137288	0.137288	0.155806	0.119744	0.412838	3.007099
A.R	4	1	3	0.571429	0.631579	0.666667	0.623225	0.549151	0.623225	0.718463	1.890838	3.033959
W.R	2	1/3	1	0.285714	0.210526	0.222222	0.239488	0.274575	0.207742	0.239488	0.721805	3.013953
	7	1.583333	4.500000								Consistency Index	0.009617
											CI/RI	0.015808

Determining Best Site (Region)

Scores from Matrix

	No. s/s	Cost Land	Cost of Labor	Distance	Weighted Scores
G.A.R	0.538961	0.163781	0.137288	0.538961	0.470386
A.R	0.297258	0.538961	0.623225	0.163781	0.310109
W.R	0.163781	0.297258	0.239488	0.297258	0.219506

G.A.R has the highest score and therefore the suggested region for the depot.