Supply and Demand Planning for Crude Oil Procurement in Refineries

by

Beatrice N. Nnadili

Master of Business Administration (2005)
Lancaster University Management School, UK

Submitted to the Engineering Systems Division in partial fulfilment of the requirements for the degree of

Masters of Engineering in Logistics

at the

Massachusetts Institute of Technology

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Signature of the Author..
Engineering Systems Division
May 12, 2006

Certified by..
Dr. Larry Lapide
Research Director, Center for Transportation and Logistics
Thesis Supervisor

Accepted by ....
Dr. Yossi Sheffi
Professor, Engineering Systems Division
Professor of Civil and Environmental Engineering
Director, MIT Center for Transportation and Logistics

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ABSTRACT

The upstream petroleum supply chain is inefficient and uneconomical because of the independence of the four complex and fragmented functions which comprise it. Crude oil exploration, trading, transportation, and refining are functions which may be integrated through unified decision-making facilitated by timely information exchange. This exchange has been problematic because the four business units with their disparate activities have not been able to capture and appropriately structure the required information. How can business executives in the oil industry assemble all of the required information to achieve system-wide optimization?

To remove the silos which impede system-wide optimization, there is need to analyze people, systems and issues in the upstream section of the petroleum supply chain; as a background to understanding the current challenges faced in achieving integration. Hence, the use of secondary and primary data sources was used for this research. The secondary includes the review of relevant literature while the primary data were from two sources. The first came from an on-site interview with the heads of business units of a case study, a company which is a major player in the industry. The second is from telephone interviews with industry experts which include software providers, consultants and other major players in the industry.

The findings are that on-time information exchange will maximize shareholders' value and improve process efficiency in the supply chain. This process efficiency makes the upstream supply chain more responsive to possible changes in the environment that affects its operation. This will allow supply chain managers to achieve both a reduction in the variability in price of end product will be obtained while achieving stable profit margins.

This research concludes by advocating that the use of information systems that accurately support data exchange among the functions in the supply chain in a timely, coordinated fashion with minimal distortion is required to ensure consistency in optimal decision making. To achieve this, change management is necessary because it requires a shift to a holistic approach in making decisions. Finally, areas recommended for future research are stated.

Advisor: Dr. Lawrence Lapide (Research Director, MIT CTL)

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I dedicate this dissertation to God, for his continuous guidance and faithfulness

This dissertation is the product of the help and the encouragement of many people. I am indebted to many of you but space allows me to mention only a few of the contributors by name. I would begin by thanking my family for their prayers, encouragement and support all through the years.

Special thanks, to the MLOG program director – Dr. Chris Caplice for his support in various ways during the course of my studies at MIT and for his effort in ensuring that this chosen case study was used for this research.

I owe gratitude to the representatives of ExxonMobil, Shell, BP, Accenture, UPS Consulting, SAP, AMR Research and Aspen Technologies for the time taken from their busy schedules to discuss my research work and to those who also shared some draft of their academic papers. Their very useful advice on and valuable contributions helped to shape the structure of this thesis.

The research in this field would not have been possible without the expert guidance of my esteemed supervisor, Dr Larry Lapide, who was always available (most times at a moment's notice) through out the research process. Dr. Lapide painstakingly read the drafts of each chapter of my thesis, generously sharing his insights, opinions and candid advise that added immense value to this research. Most importantly Dr. Lapide was instrumental in reaching out to industry experts. His suggestion on pertinent references gave me priceless insight into the research topic.

Finally, I would like to thank all my buddies - the members of the MLOG class of 2006 for sharing a part of their lives with me. Finally, to all those too numerous to mention that made this year in Cambridge a wonderful living and learning experience, thank you from the bottom of my heart.

BIOGRAPHICAL NOTE

Beatrice Nne Nnadili obtained a Bachelor of Science in Accounting at the University of Uyo in Nigeria. Before obtaining a Masters in Business Administration at the Lancaster University Management School in the UK, she had worked for two years in Nigeria's oil and gas industry.

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1 OBJECTIVE, SCOPE AND METHODOLOGY OF STUDY

This is an exploratory study of the on-going tension between centralization and decentralization of information networks within the oil industry. The effect of this tension on the efficiency of information shared within the organization is examined to understand how companies in the oil sector respond to the internal forces that shape the integration, behaviour, strategy and structure of their supply chain.

The first objective of this work is to gain an industry-wide view of the upstream section of the petroleum supply chain. Secondly, an elaborate case study was conducted on one of the major players in the industry. This was done to understand current practices of information exchanged within a company and to explore how such practices affect upstream integration.

This research explores opportunities for upstream integration in the petroleum industry and the gains that could be derived from effective and timely exchange of information among its functions. Present business support systems are unable to capture information from various functions in the upstream section and present it in a structured manner that will aid unified decision-making. This shortcoming makes assembling all the data required for decision-making a difficult task for managers.

Given this situation, the major motivator for this thesis is a need for a new paradigm for the integration of processes and functions using decision support systems capable of gathering dispersed information required for effective planning of crude oil procurement in refineries.

1.1 BACKGROUND

The petroleum supply chain consists of upstream and downstream activities. The former involves the exploration, production, trading and transportation of feed stock to the refineries, while the latter deals with the distribution and the marketing activities of all the products from the refined feed stock. This research focuses on the upstream operations in the petroleum supply chain with emphasis on information exchange within the various functions in the supply chain. Each of these functions in the upstream section developed into independent departments where profit optimization is achieved within business units rather than across the entire organization, making the recent need for the integration of all functions a difficult task.

For the purpose of this thesis the upstream section of the supply chain is defined as all logistics activities occurring through feedstock exploration and movement into the refineries to refining operations. This includes transportation planning, price modelling, demand planning, crude oil trading, crude oil marketing and refinery optimization. Stefan. R (2005) described these activities as "drivers" in the upstream section of the petroleum supply chain.

The upstream section of oil companies have lagged behind in supply chain integration when compared to the downstream section. This is because of the upstream's complex structure and logistics which include crude oil exploration, marketing, trading, transportation and refining. A lot of effort is now going into technological solutions that will integrate the different departments in companies, giving them more flexibility to respond to changes in the industry. To achieve this vision, there is a need for oil companies to implement a more holistic approach to decision-making, which requires integration of people, processes and technologies.

Upstream petroleum supply chain is affected by external influences which shape its activities. These external effects could create barriers or opportunities for integration. The PESTLE (Political, Economical, Social, Technological, Legal and Environmental) framework is used to gain useful insight into the external factors that affect operations of the upstream supply chain. This is shown in Figure 1.

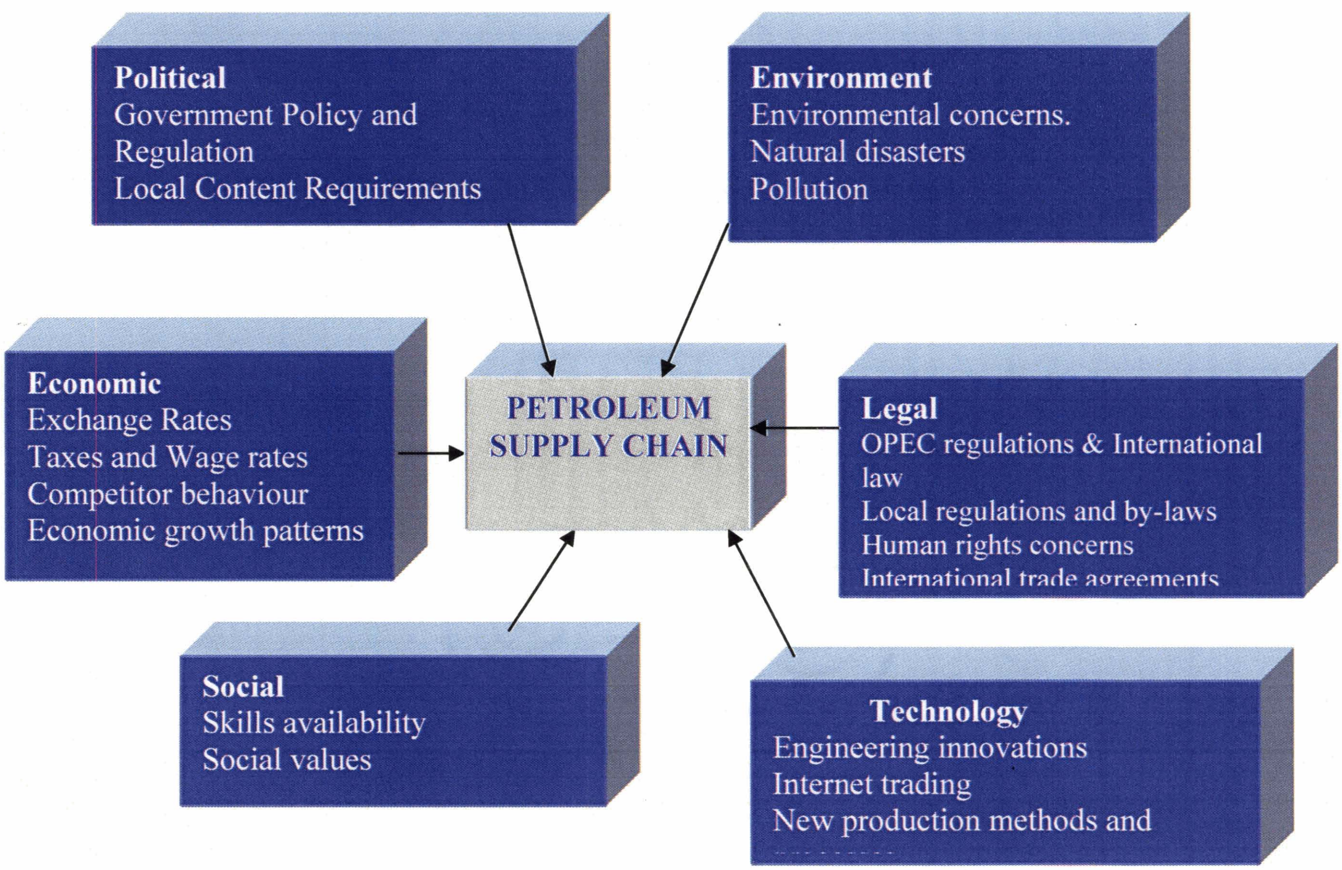

Figure 1 PESTLE factors affecting the petroleum supply chain.
Source: Strategy Survival Guide

After analysing the above framework, the importance for executives in oil companies is to constantly evaluate these PESTLE trends in the external environment cannot be overemphasized. This is because the implementation of process integration is highly dependent upon a range of economic, technological and cultural factors that affect upstream activities. In the past, these factors were responsible for the prices of crude oil as depicted in the Figure 2 below. For example, uncertainty resulting from an impending war could cause an increase in price. This is evident from, the damage in Iraq's oil fields which lead to spillage or disruption in production, and consequently an increase in the price of crude oil.

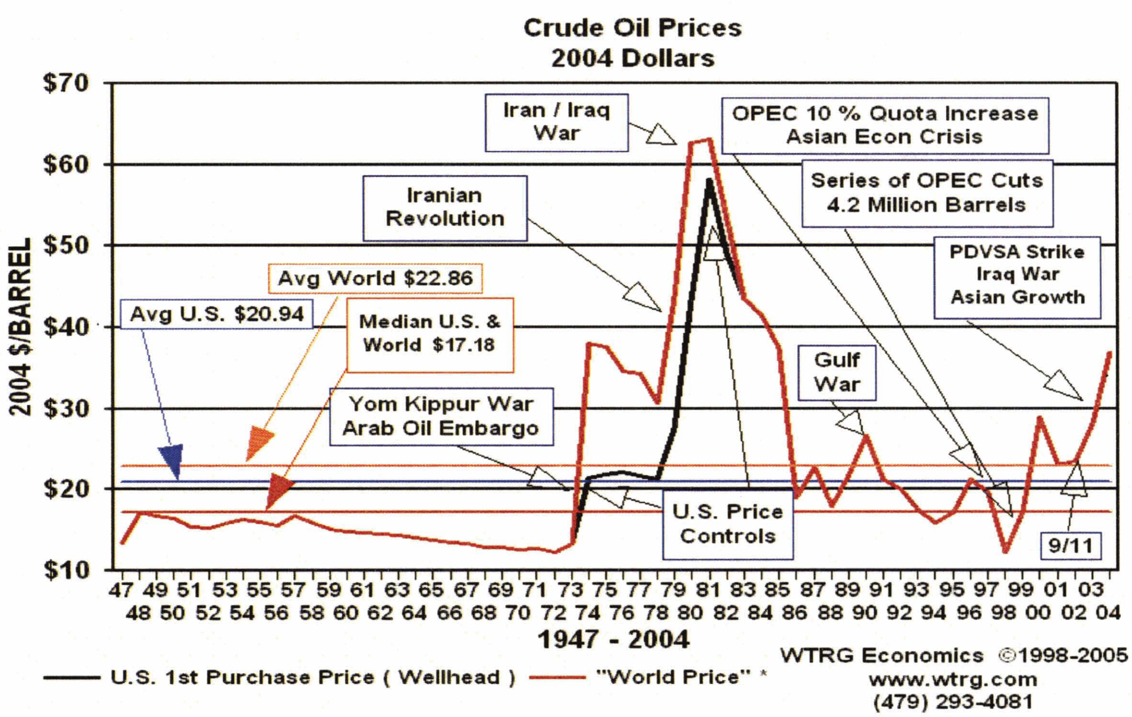

Figure 2 PESTLE effects on crude oil prices. (1947 – 2004)
Source: WRTG Economics - www.wtrg.com

Crude oil prices behave much as any other commodity, with wide price swings in times of shortage or oversupply. The crude oil price cycle may extend over several years responding to changes in demand and supply.

With oil prices as volatile as shown in the Figure 2, the industry should implement practices aimed at reducing the variability in price. Efficiency in supply chain integration can help control price swings. This is achieved through the implementation of processes that control disruption in product flow such as up-to-date information changes in the industry. Such information exchange will enable quick response to changes in the external environment such as price spikes, government regulations, natural disasters, and production declines. Responsiveness to these changes while optimizing upstream operations is pertinent to achieving benefits such as profitability and survival. This research work seeks to explore how upstream integration and effective information-exchange between business units in the supply chain will enable a process which yields these benefits.

1.2 RESEARCH METHODOLOGY

This thesis combines the use of theoretical and field work for its research process. An extensive literature search using library-based resources and media research (primary data) was conducted to understand the past and current level of thinking by experts in supply chain integration and information exchange. Recent reports were also investigated to identify key trends and decision criteria that lead to implemented strategies. The assembly and study of the secondary data improved the understanding of the various lines of inquiry that could be followed as well as the alternative courses of action which might be pursued. Information from the media and published articles were scrutinized for optimistic and pessimistic results from the publisher's perspective. Statistics and their reliability also change over time, consequently, for the purpose of this dissertation; the publication year of all cited sources will be disclosed.

Building on the secondary research, primary data were collected from two sources because it was vital to get varying organizational perspectives for a better understanding. The first was from industry experts, which include software providers, consultants and major players in the industry. The second was with managers at a case study company where information was collected through unstructured/open-ended interviews with industry experts. An open-ended interview allowed the respondent to talk expansively on the related subjects which provided more information useful for this research. In some cases, a telephone interview was carried out as scheduled by the respondents. In each case the interviewee also received a copy of the transcript and was asked to confirm that their interpretation of issues discussed was accurately presented. The case study required a site visit to the office location of the company where heads of relevant business units were individually interviewed. All information from industry experts and the case study was collected on the condition of strict confidentiality of the respondents.

The conclusions were not entirely drawn on the basis of the industry experts' opinion as experts from different aspects of the upstream petroleum supply chain were interviewed and vested interests were taken into consideration when evaluating responses. The response rate (based on the number of companies interviewed) is too small a sample size to draw a conclusion compared to the number of existing players in the industry. A larger sample size would have made this source of data more valid. The major focus of this thesis is the use of one of the major players in the oil industry as a case study for this research. Since this dissertation is an exploratory study, emphasis is on the use of the case study and secondary data.

1.3 STRUCTURE OF THIS THESIS

This thesis consists of the following six chapters:

1. In Chapter One, the motivation for this research and what it seeks to accomplish is stated. It goes further to discuss the thinking framework that gave an understanding to the conceptualization of this research. Thereafter, the research methodology is described in detail with reasons for the selection of the various methodologies. Finally the scope of this dissertation was defined.
2. Chapter Two explores past and current literature relevant to the research topic with emphasis on the upstream activities and the structure of the petroleum supply chain.
3. Chapter Three discusses the concept of supply chain integration viewed from the perspective of industry experts. The focus on this chapter is on information sharing and organizational structure and concludes with a series of research questions.
4. Chapter Four is a case study of one of the major players in the oil industry. The introductory part of the chapter gives an overview of the company to gain a better understanding of its competitive positioning. Thereafter, the structure and functions facilitating supply chain integration and information-sharing is evaluated for a deeper understanding of the company's strengths and weaknesses. To facilitate and structure its functions, the upstream supply chain is divided into two segments: the internal functions (fully controlled by the company) and the external functions.

5. In Chapter Five the findings derived by the use of both secondary and primary data are discussed.

6. Finally in Chapter Six, an overview of the previous chapters and lessons learned from this research is summarized to form the conclusion of this thesis; Areas recommended for future research are also explored.

2 LITERATURE REVIEW

This section of the thesis reviews past and current literature on the petroleum industry. It starts by discussing the industry trends, dynamics, and characteristics in general. It proceeds to describe the structure of the upstream petroleum supply chain. It concludes by exploring the possible challenges and opportunities in the upstream section of the petroleum supply chain as proposed by the literature reviewed.

2.1 INDUSTRY OVERVIEW

Oil has been used since early human history to keep fire ablaze but its usage has evolved over the years through innovative ways of using it as a source of energy. Wood and coal were used to heat and cook, while whale oil was used for lighting. The difficulties in processing and using these forms of energy motivated research interest to discover alternative sources of energy. This led to the discovery of crude oil. Petroleum demand has constantly increased since this discovery, leading to the beginning of the oil industry.

The importance of oil in an economy cannot be overemphasized. This is because the oil industry has often been considered the life blood of many other industries because of its use in manufacturing and as a source of energy. According to Aspen Technologies (2002), Petroleum is the second largest consumable on the planet – second only to water. To re-inforce its importance, the Department of Energy stated that, "petroleum is the single largest source of energy used in the United States." Compared to other sources of energy such as coal and natural gas, petroleum is more commonly used for a variety of purposes. The increasing dependence on petroleum as a source of energy is a huge concern to the oil industry leaders resulting in a quest for more efficient ways of exploring, trading, processing and transporting crude oil.

The location, production and consumption of crude oil are not evenly spread as depicted by Figure 3. This has led to long lead times in most cases from where it is sourced to areas of consumption. For example, the United States currently consumes 7.5 billion barrels (1.2 km3) of oil per year which accounts for 40% of the United States energy supply and a comparable percentage of the world's energy supply which is 30 billion barrels (4.8 km3) per year. Where as, 65% of production and exploration activities are carried out in the Middle East.

To ensure effective distribution of crude oil by exporting countries, OPEC (Organization of Petroleum Exporting Countries) was set up to regulate the world flows and make policies that control the operations of its members. The result is an increase in the overall world oil supply, a global trading market and an intensification of competition in the industry. Such challenges increase competitive rivalry in the industry.

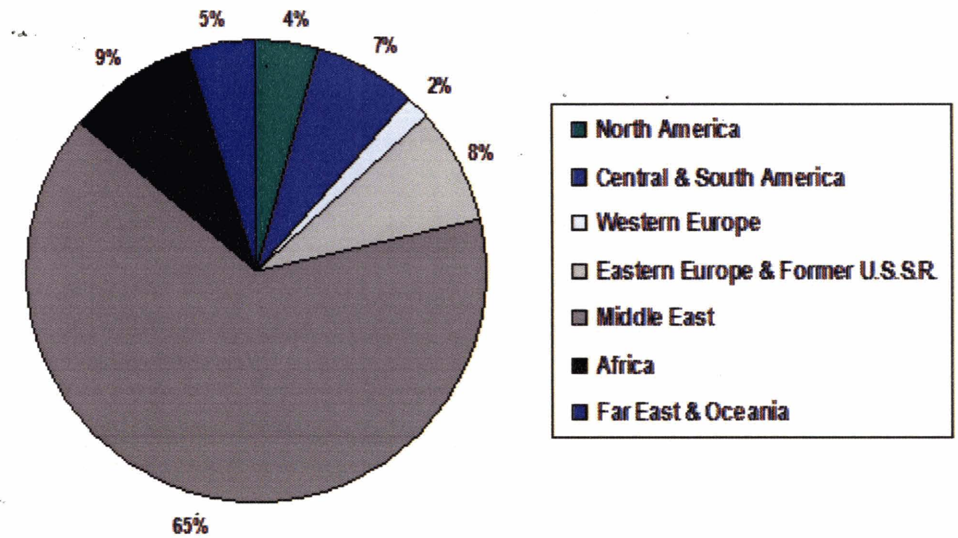

Figure 3 Oil Producing regions in the World.
Source: US Energy Information Agency, International Energy Annual Report (2004)

The trend of the competitive landscape during the last years has been towards increased rivalry and decreased barriers. The results have been a mature industry offering flat or even diminishing returns for some companies. Michael Porter's (1985) five forces model provides a useful framework for assessing and analyzing the petroleum industries competitive characteristics. Porter's framework is focused on analyzing five issues that shape the competitive environment which includes: existing competitive rivalry, threat of new market entrants, power of buyers and suppliers, and threat of substitute products.

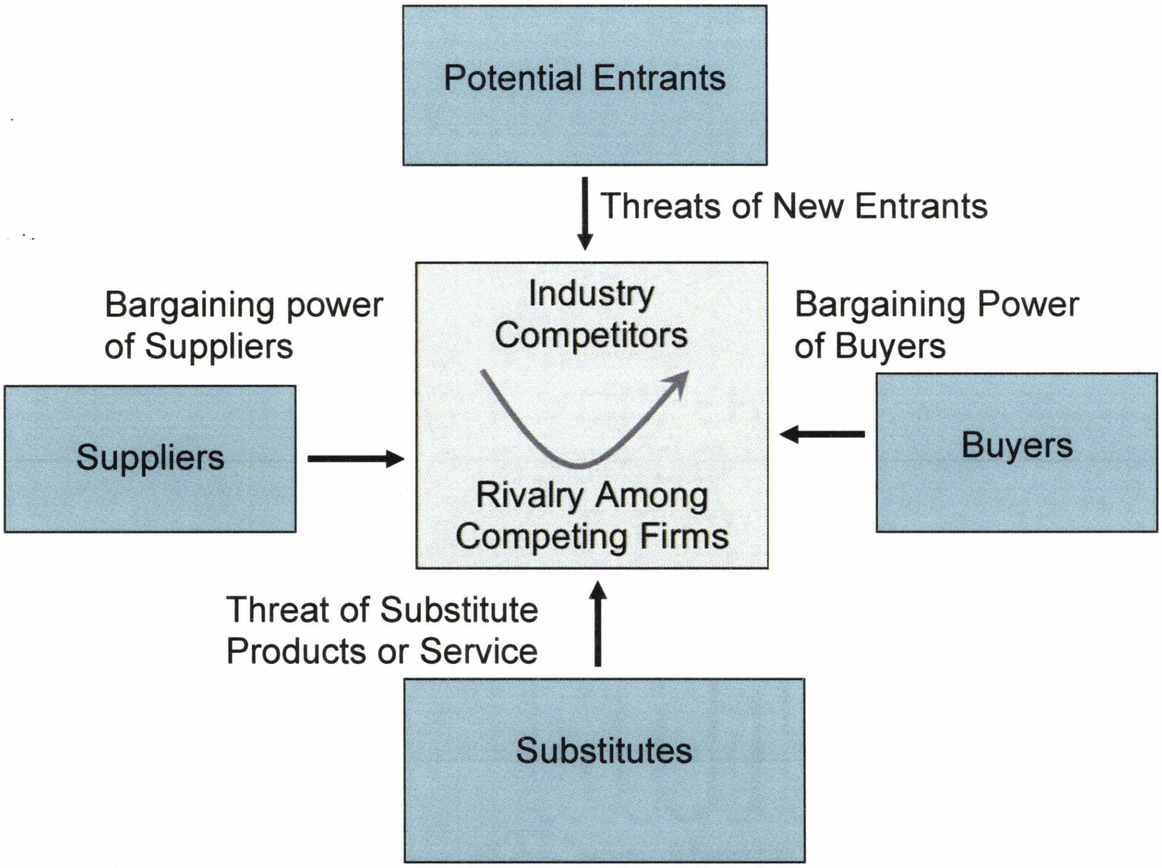

Figure 4 Porter's five forces affecting the upstream section of the oil supply chain
Source: Porter, Michael E., 1980, "Competitive Strategy: Techniques for analyzing industries and competitors", New York: Free Press

Threat of New Entrants - There are thousands of oil and oil servicing companies throughout the world. Some of the barriers to enter this industry include high capital investment, government regulations and local content requirements. Barriers can vary depending on the area of the market that the company is situated. For example, some types of pumping trucks needed at well sites could be more expensive in one location than others. While, some areas of the oil business may require highly skilled workers thereby creating higher barriers to entry, others may simply be offering fairly simple support services.

Power of Suppliers - While there are numerous companies in the global oil industry, much of the business is dominated by few major players. The large amount of capital investment needed significantly reduces the number of companies and increases the power of existing players in the industry. This is because, providing expensive oil production infrastructure and support services like rigs , pipelines , drilling equipments, and refinery equipments reduces the number of suppliers.

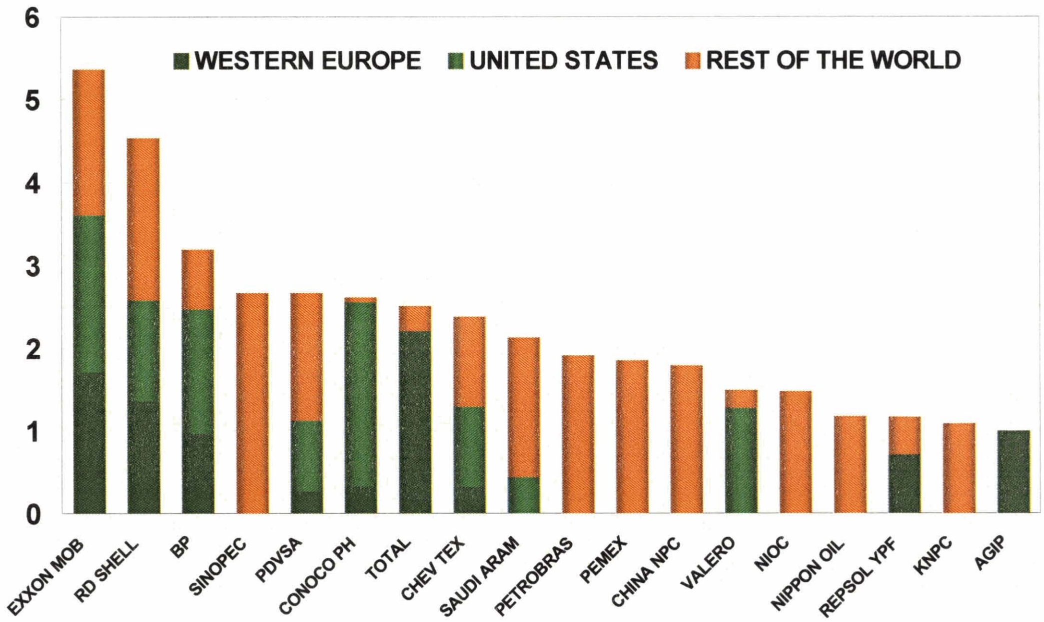

Figure 5 Major Players in Global Refining and their Regional Market Share.
Source: Oil and Gas Journal (2003)

As shown in Figure 5, capital cost has made the major players, such as ExxonMobil and Shell, have power over smaller drilling and support companies. This has resulted in a lot of mergers and acquisitions in the industry. This wave of mergers has followed a general consolidation of assets within the refining industry over the past two decades. In 1981, 189 firms owned a total of 324 refineries; by 2001, 65 firms owned a total of 155 refineries, a decrease of about 65 percent in the number of firms and a decrease of about

52 percent in the number of refineries. During this period the market share of the ten largest refiners increased from 55 percent to 62 percent. Economic principles dictate that markets in which a few firms have market power to affect overall supply will exhibit higher prices than more competitive markets. As long as suppliers can indirectly affect prices through their decisions.

Power of Buyers - The balance of power is shifting towards buyers. Oil is a commodity and so one company's oil or oil drilling services differs insignificantly from others. This translates into buyers seeking lower prices and better contract terms. According to Darrell (2002), the decreasing margins, as illustrated in the Figure 6, shows the drive for reduced prices. The plotted graph in Figure 6 is the difference between gasoline price (without road tax) and the crude price from 1918 through 1999 in constant 2000 dollars depicts a downward trend, which is the major driver for the industry.

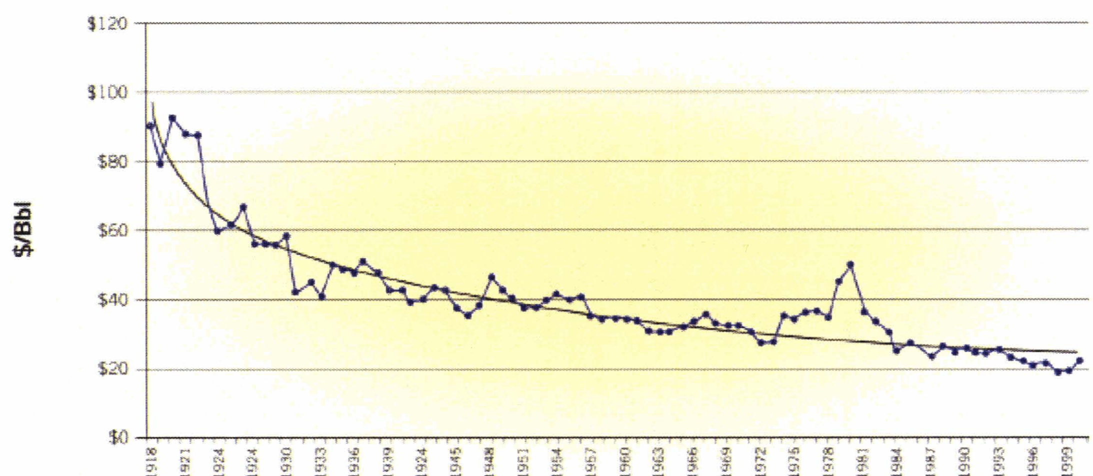

Figure 6 Retail Gasoline Pump Price Margins
Source: US Department of Energy, Energy Information Administration.

Availability of Substitutes - Substitutes for oil in general include alternative fuels such as coal, gas, solar, wind, hydro, and even nuclear energy. It is important to note that oil is used for more than just running our vehicles; it is also used in plastics and other materials. The threat of substitutes for oil-based fuels is currently low, but new technological innovations could make the substitutes a serious threat in the future.

Competitive Rivalry - Slow industry growth rates and high exit barriers are good examples of problems facing the oil industry. For a period of almost 20 years, no new refineries were built in the US. According to the Department of Energy, the US had 324 refineries in 1981 with a total capacity of 18.6 million barrels per day. The Oil and Bas Journal in 2002 reported that, there are just 132 operable U.S. oil refineries with a capacity of 16.8 million b.p.d. This signifies that, U.S. refineries declined from 324 in 1981 to 132 in 2002.

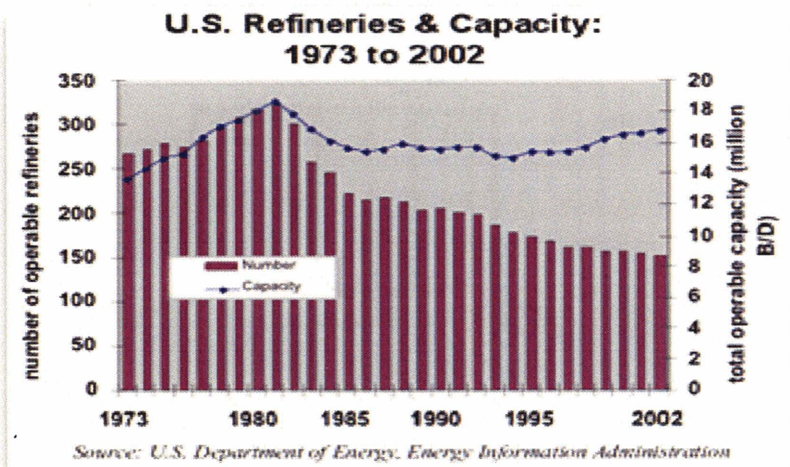

Figure 7 U.S. Oil Refinery & Capacity
Source: US Department of Energy, Energy Information Administration.

To help meet the shortfall between supply and demand, the operating rate of refineries has risen—from 86 percent of capacity to 93 percent. At peak levels of seasonal demand, utilization is over 95 percent. Even so, the U.S. is unable to meet its demand for petroleum products and is forced to import an ever-increasing share of petroleum products from abroad. Over the last ten years, gasoline imports increased from 3.5 percent to 9 percent of demand. As shown in Figure 8, refinery capacity exceeded the product demands as a result of conservation efforts following the oil shocks of the 1970s and most recently hurricane Katrina.

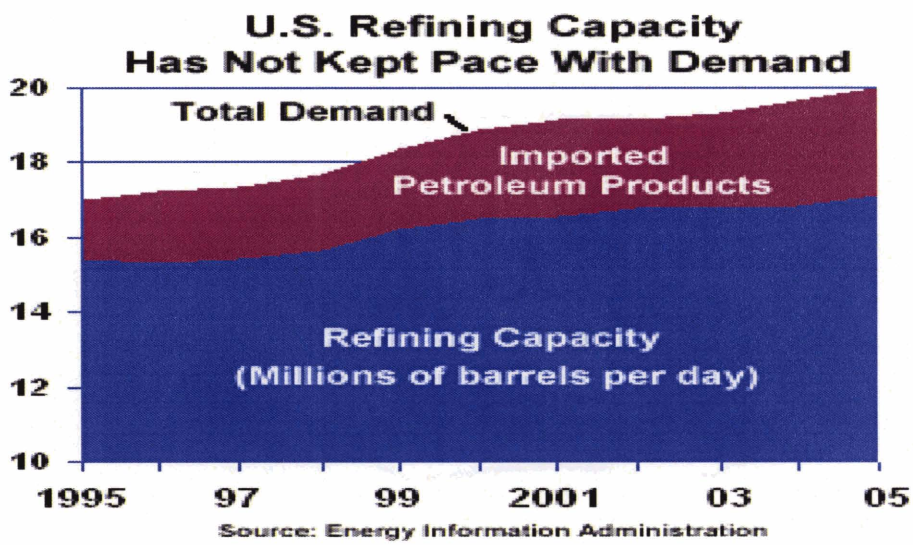

Figure 8 US Refinery Capacity & Demand
Source: Energy Information Administration

This has led to oil companies squeezing their margins and increasing the competitive rivalry in the industry. At the same time, exit barriers in the refinery business are quite high because besides the scrap value of the equipment, a refinery that does not operate has no value-adding capability.

2.1.1 LESSONS FROM PORTER'S FIVE FORCES MODEL

The rivalry in the upstream petroleum supply chain is progressively increasing as the margins are squeezed out of major players and the barriers to entry are progressively high due to the high set up and switching costs. Crude oil supply has continued to be strategic and highly political because of its regional distribution and sourcing strategies. Additionally, a government tax is an important part of the budget in many countries. All these factors provide an incentive for strong government regulations.

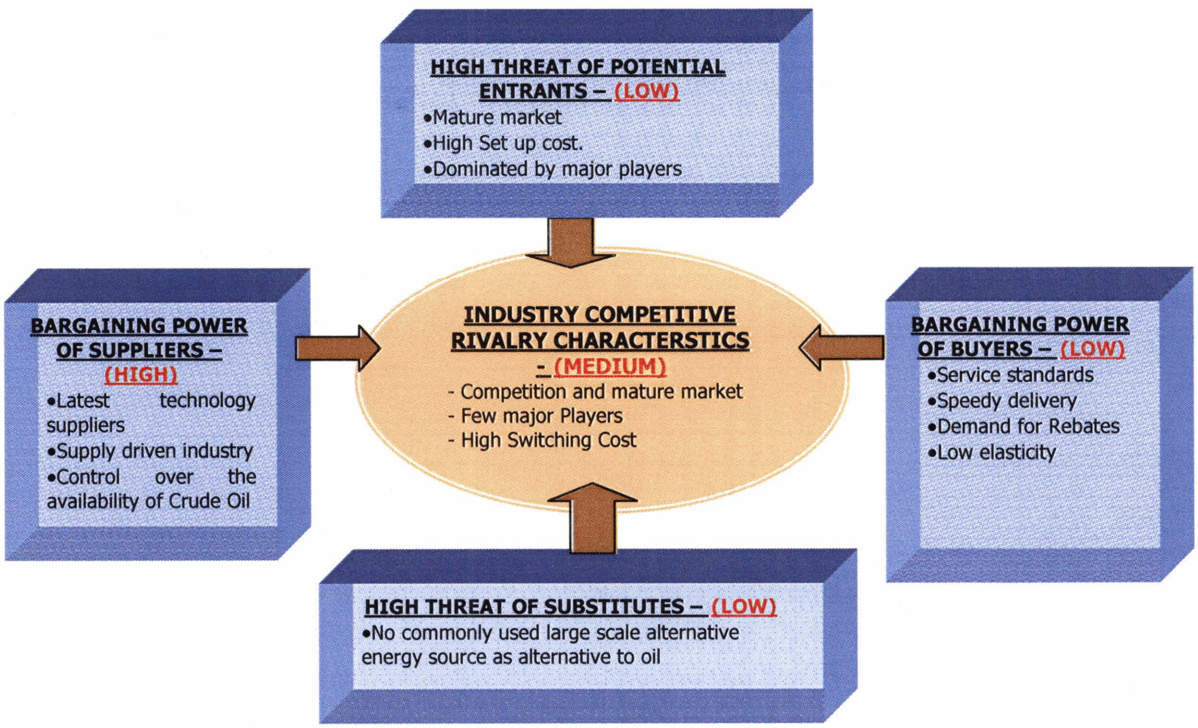

Figure 9 Effects of Porter's Five Forces on the Upstream Petroleum Supply Chain.

Hence, the trend of the competitive landscape during the last years has been towards increased rivalry and increased barriers. The results have been a mature industry offering flat or even diminishing returns for some companies resulting in increasing prices of its end products.

2.2 UPSTREAM SUPPLY CHAIN ACTIVITIES

The structure of the petroleum upstream supply chain is more discrete than the supply chains of other industries because it involves many independent operations starting with exploration and logistics involved in trading and extending to variable modes of transportation, which depend on sources, to the complex refining process, which in most companies requires the use of very large-scale optimization models. Figure 10 depicts the activities of the supply chain which are discussed under the following sub-headings:

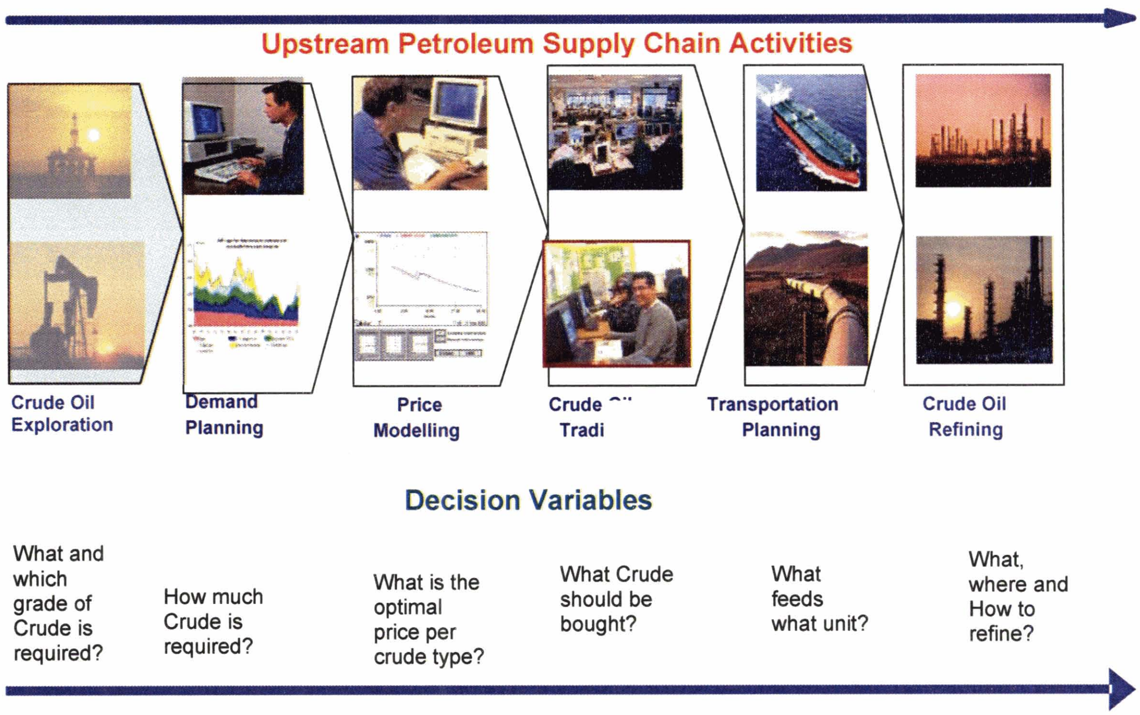

Figure 10 Feedstock inflow to the refinery (Activities of the upstream petroleum supply chain)

2.2.1 CRUDE OIL EXPLORATION AND PRODUCTION

The first oil well structures to be built in open waters were in the Gulf of Mexico. They were in water depths of up to 100m and constructed of a piled jacket formation, in which a framed template has piles driven through it to pin the structure to the sea bed. To this, a support frame was added to the working parts of the rig such as the deck and accommodation. These structures were the fore-runners for the massive platforms that now stand in very deep water and in many locations around the world.

There have been land oil wells in Europe since the 1920s. It wasn't until the 1960s that exploration in the North Sea really began, without success in the early years. They finally struck oil in 1969 and have been discovering new fields ever since. The subsequent development of the North Sea is one of the greatest investment projects in the world.

Exploration activities are undertaken in oil wells. These activities, such as drilling and oil well analysis, require high investment cost for its operations. The market price of crude will determine the economic incentives for exploration. The higher the price the higher is the in-ground value of crude. A high in-ground value of crude implies greater incentives to find new oil.

2.2.2 CRUDE OIL TRADING

Crude oil is the most heavily traded commodity on the New York Mercantile Exchange (NYMEX). Crude trading involves large capital investments and operating cash flows with highly volatile prices and margins. Price volatility places a huge financial risk on energy companies. In order to manage and mitigate this risk, upstream oil and gas companies need accurate and up-to-date views of their financial and physical positions every minute of every day. They need to quickly identify and instantly respond to price spikes, credit downgrades, production declines and weather events. These factors make commercial excellence and, in particular, optimization of trading and risk management activities, key to profitability and survival.

2.3.3 CRUDE OIL TRANSPORTATION

There are several ways of transporting crude from one region to another: ocean shipping, barges, railways, or pipelines. These enable oil producers to place crude in the local or the international market. Crude transportation also requires costs. Transportation costs vary depending on the situation and the quantity of crude. This cost can be borne by the producer or the buyer, depending on the purchase terms.

The bulk of the oil is transported (62%) using maritime transportation. The network must be designed in an optimal way and set up. Moreover, the transportation of fuels throughout the network needs focused planning and scheduling.

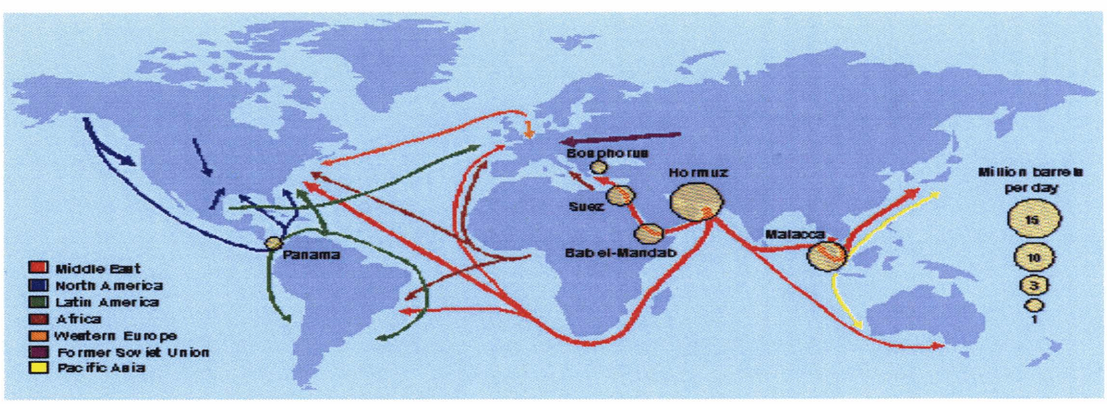

Figure 11 The Geography of transport systems
Source: Dr. Jean-Paul Rodriguez (2006), Dept. of Economics & Geography, Hofstra University

Major continental movements involve the Russian and former Soviet Republics' petroleum shipped to Western Europe by pipeline, and Alaskan and Canadian petroleum shipped to the United States, also by pipeline. Other important oil shipments are from

Africa to North America and Europe, from the North Sea to Europe, and from South America to North America.

Since the first oil tanker began shipping oil in 1878 in the Caspian Sea, the capacity of the world's maritime tanker fleet has grown substantially. Each year, about 1.9 billion tons of petroleum is shipped by maritime transportation, which is roughly 62% of all the petroleum produced. The remaining 38% is using pipelines (dominantly), trains or trucks. The dominant modes of petroleum transportation are complementary, notably when the origins or destinations are landlocked or when the distance can be reduced by the use of land routes. The maritime circulation of petroleum follows a set of maritime routes between regions where it has been extracted and regions where it is been refined and consumed. More than 100 million tons of oil is shipped each day by tankers. About half the petroleum shipped is loaded in the Middle East and then shipped to Japan, the United States and Europe. Tankers bound to Japan use the Strait of Malacca while tankers bound to Europe and the United States will either use the Suez Canal or the Cape of Good Hope, depending on the tanker's size and the destination. International oil trade is often correlated with oil prices, as it is the case for the United States.

2.2.4 CRUDE OIL REFINING

Crude oil usually consists of a mixture of hydrocarbons having varying molecular weights and differing from one another in structure and properties. These various species are separated into groups, or fractions under different boiling temperatures, by a process of distillation called refining. The distillation column which then coverts the crude, depending on its distillation curve, to the final products.

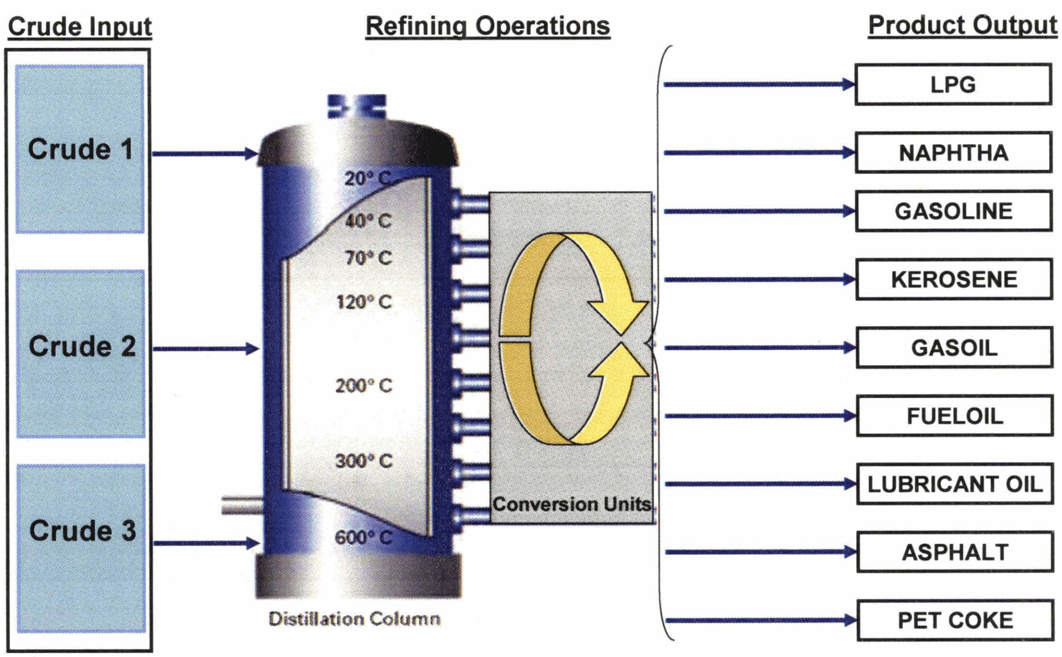

Figure 12 Crude oil Refining Process
Source: Modified from Original Work by Stefan Rothlisberger (2005)

The basic refining processes take place in the crude distillation unit (CDU) of the Fuels Zone. Here, crude oil is taken into the atmospheric distillation tower where it is separated into its different fractions. The hydrocarbons in crude oil have different boiling points according to the number of carbon atoms in each molecule and how they are arranged. The oil is heated and the resultant vapours rise up the tower. The distilling column consists of set of trays which permit vapour to rise at different temperature while allowing the denser liquid to condense toward the bottom. The heat in this column causes the vapour (Hydrocarbons) to change to liquid state as the temperature reduces. This process could be repeated as required until the required output is derived from each tray. Crude oil compositions vary widely depending on the type or grade of crude oil. The light crude oil tends to have more gasoline, naphtha and kerosene; the heavy crude has more gas oil and residue.

According to Leffler (2001), there are two types of crude namely, the sweet and sour crude. Sweet crude typically have 0.5% sulphur content and sour crude have 1.5% or more. Sulphur is chemically bonded to the molecules required to convert to final products. Hence, requires separation which is a complicated process that requires heating before the hydrocarbons are ready for use. Sulphur and other strong smelling compounds are removed because when the products are used the sulphur compounds emitted would smell of rotten eggs and dissolve in rain to form sulphuric acid which would contribute to the problem of acid rain.

The final product (oil) then undergoes further processing prior to distribution. Heavy residue is taken off at the base of the tower and reprocessed. In the fluid catalytic cracker (FCC) the heavy oil is distilled again, using a chemical catalyst this time, to produce gasoline and diesel. The heaviest sticky residue is re-distilled in the vacuum distillation unit then taken to the Lubricants Zone where it is processed to make bitumen, lubricating oils and wax.

2.3 CRUDE OIL PROCUREMENT

According to Shigeki K (2001), oil companies formulate optimal refinery production plans, based on anticipated demand for oil products and product sales volumes.

Information required to make this plan is gotten from price modeling and demand planning. This plan is compared with actual crude oil inventories to determine in aggregate volumes, price ranges, and grades of crude oil to be purchased. Other types of information required to evaluate the economic viability of crude include:

- Ratios (or yields) of individual products obtained from processing a given crude oil
- The purchase cost of that crude
- The volume of crude that can be physically purchased.

Today, many oil companies formulate optimal refinery production plans, using LP (linear programming) models. This plan is used by other business units such as crude oil trading and transportation planning in making strategic decisions.

2.4 SUPPLY CHAIN MODELING

This thesis focuses on the informational aspect of supply chain modelling. The vision for the appropriate model of supply chain integration is one which ensures that all sets of data that need to be exchanged between members of the supply chain are communicated effectively in a timely and unbiased manner.

The upstream supply chain functions are managed by using mathematical models which can evaluate crude, model price, forecast demand, schedule cargoes, and blend streams to give products. In manufacturing, models and yield accounting packages optimize the performance of different conversion units. Integration of systems with trading and tracking software is a challenge which companies in the industry are faced with. Hence the disconnect between the supply chain models, accounting packages, trading software and scheduling tools used renders their individual benefit of reaching an optimal decision for an organization inconsistent. Thereby, leaving room for optimization and making the supply chain more responsive and headed in a single focused direction. Generally, most of the modelling approaches used by the upstream function in the petroleum supply chain can be categorized into following classes:

2.4.1 LINEAR PROGRAMMING (LP): This is a mathematical technique for finding the maximum value of some linear equation objective function subject to stated linear constraints. It is commonly used in refinery planning to identify with confidence the most profitable refinery-wide operating strategy. LP has been around since the 1940s and has now reached a very high level of advancement with the meteoric rise in computing power. The "linear" in LP stands for the algebraic aspect, i.e. all the constraints and objective functions are linear and satisfy two fundamental properties: proportionality and additivity. The "programming" in LP actually means "planning" only. The implementation of LP involves the development of an integrated LP model representing the refinery operations with all constraints and flexibilities and then solving it to determine the optimum plan. A refinery LP model contains modelling capabilities like Successive Linear Programming (SLP), mixed integer programming (MIP), Implicit and Explicit Pooling, Multi-period modelling, Distributive property recursion, attribute error tracking, rigorous sulphur distribution, etc. Compared to an approach based on average values, these techniques provide very accurate estimates of yields and qualities of finished goods, all the while keeping short computation times. The refinery-wide optimization using an LP model has been proven to bring economic gains far higher than unit-specific simulation models or advanced process control techniques. Below provides are some example of the multiple objectives of refinery optimization:

- Minimize crude landed cost at refinery
- Optimize refinery crude mix
- Minimize quality giveaway
- Optimize fuel consumption, minimize losses
- Optimize utilization of the assets
- Optimize inventory management
- Optimize capacity utilization and shutdown planning

These objective functions are subject to the various constraints and parameters defined in the model, including the inventory value and carrying cost parameters. All of the objectives mentioned above present a refinery with a challenging problem and an opportunity to maximize the overall profitability.

MIP Optimization Modelling: Many important supply chain models fall into the MIP (Mixed-Integer Programming) class. This includes most models for vehicle routing and scheduling, facility location and sizing, shipment routing and scheduling, freight consolidation and transportation mode selection. Mixed-integer models are often difficult to optimize, as there can be an exponential number of possible decision alternatives. Some problems are nonlinear MIP.

2.4.2 STOCHASTIC PROGRAMMING AND ROBUST OPTIMIZATION METHODS: Stochastic programming deals with a class of optimization models and algorithms in which some of the data may be subject to significant uncertainty. Uncertainty is usually characterized by a probability distribution on the parameters. Such models are appropriate when data evolve over time and decisions need to be made prior to observing the entire data stream. Stochastic programming formulations for the optimal midterm production planning of a refinery addresses three major sources of uncertainties, namely prices of crude oil and saleable products, product demands, and product yields. A systematic and explicit stochastic optimization technique is employed by utilizing compensating slack variables to account for violations of constraints in order to increase model tractability.

2.4.3 HEURISTIC METHODS: Heuristic is another important class of methods for generating supply chain alternatives and decisions. The heuristic's effectiveness is illustrated by its application to an oil-refinery's crude-oil blendshop scheduling problem. A heuristic is simply any intelligent approach that attempts to find good or plausible solutions. Generally, mathematical programming methods are used to solve strategic and higher levels of tactical supply chain planning. This method generally works only for solving linear- and some integer-based models, commonly used in strategic levels of planning. Heuristic methods used in supply chain planning and scheduling include the general random search approaches such as simulations and genetic algorithms.

2.4.4 SIMULATION BASED METHODS: This is a method by which a comprehensive supply chain model can be analyzed by considering both its strategic and operational elements. This method can evaluate the effectiveness of a pre-specified policy before developing new ones.

According to US Department of Energy, a refinery study conducted near a Salt Lake facility in Utah by Chevron used process simulation models of its light ends distillation columns and associated re-boilers and condensers to predict the performance of potential equipment configuration changes and process modifications. It found that, more than 25,000 million British thermal units (MMBtu) in natural gas could be saved annually if a debutanizer upgrade project and a new saturated gas plant project were completed. Together, these projects would save $4.4 million annually.

2.4.5 LIMITATIONS:

Despite the benefits derived from the use of these models, limitations to their use exist because providing all the possible processing options and data is impossible without decision support systems capable of capturing all required data. Information exchange is required to pool the data required for optimization. It also important to note that models are just as good as the data put in and the assumptions used to create them. Models should not replace good and sound engineering judgment. For example, the nature of the refining processes is mainly non-linear whereas linear programming - as the name already suggests - assumes that a linear combination of the provided options is valid. Hence an information pool that considers variables related to all aspects of the upstream supply chain is required to overcome these limitations and achieve optimal decision making.

2.5 UPSTREAM INTEGRATION – CHALLENGES AND OPPORTUNITIES

Lee H.L et al (1993) has the view that the concept of a supply-chain is about managing coordinated information and material flows, plant operations, and logistics through a common set of principles, strategies, policies, and performance metrics throughout its developmental life cycle. This provides flexibility and agility in responding to consumer demand shifts at minimum cost. The fundamental premise of this philosophy is synchronization among multiple autonomous entities represented in it. That is, improved coordination within and between various supply-chain members.

According to White W. J (2004), firms engaged in supply-chain relationships, as customers, suppliers, or providers of services, need to share a great deal of information in the course of their interactions. Over the years, companies have managed these information flows in a number of ways, including telephone calls, letters, telex, faxes, and electronic data interchange (EDI). More recently, firms have begun using the power of the Internet to create more effective and open transmission protocols for machine-to-machine communication of the same high-frequency data now handled by traditional EDI (It is the implementation of these Internet-based information systems that is most often referred to as supply chain integration (SCI), even though EDI, telephone/fax and information technology systems, such as enterprise resource planning (ERP) are also ways of integrating supply chains).

The upstream sections of oil companies have lagged behind in supply chain integration when compared to the downstream sections. This is because of their complex structure and logistics. A lot of effort is now going into technological solutions to integrate the different parts of the companies to give them more flexibility, responsiveness and enhance better decision-making.

Crude oil trading has increased as a result of insufficient refining capacity in the main consuming areas. This creates a pressure on margins in regions with a deficit, because finished products start flowing from the regions with a surplus (such as with the imports of gasoline from Europe to the US). On the other hand, this situation creates new markets in other countries for local refiners and opportunities for increased efficiency in the overall supply chain.

Present business support systems usually do not have the capability to capture the information from varied sources and represent it in a structured manner that would aid unified decision-making. Thus, they are unable to accommodate all the alternatives that the decision-maker has in front of him. Given this reality, the need for a new paradigm for decision support systems, which are capable of gathering the dispersed information required for the normal function of an enterprise and that provide a structured way to make decisions, is obvious. While decision support systems are available for many of these tasks they are inadequate and disjoint. Some issues currently faced by oil companies are as follows:

- Planning-Scheduling integration requires multiple sources of information
- Scheduling-Operations integration
- Planning is not integrated with scheduling
- Scheduling is done in a reactive mode
- Modelling technology is used poorly
- Evaluation requires long turn-around time, thus resulting in ad-hoc decision making
- Integrity of process models are questionable
- Little or no cross-checking between actual operations and planned

The environmental regulations and compliance rules (greenhouse effect, gas emissions, soil pollution, etc) is very crucial, making the operation of the existing facilities or the construction of new ones even more expensive and intricate. Moreover, the liabilities in the case of environmental damage and public image vulnerabilities are major concerns for refinery operations.

Finally, the geopolitical factors surrounding crude oil production and the mentioned high volatility of petroleum prices in the international markets introduce additional components of complexity and variability in the operations of the downstream supply chains. However, the volatility creates opportunities for profit as the companies can use the forward and futures markets to capture additional value in their downstream activities (e.g., by freezing the refining margin using oil futures).

Moreover, the transition to a more holistic supply chain view will need a paradigmatic change (Byrnes, 2004) and a modification of the incentives and metrics used to measure the success of supply chains. The industry's progress will be based on the creation of more efficient business processes, the use of more relevant and efficient information systems, and a large investment in human capital to perform the activities that make supply chains successful. Finally, we would like to highlight that some estimations by supply chain management consultants quantify the potential additional savings through supply chain improvements as an average margin gain of fifty cents per barrel (Lewin, 2003).

3 INDUSTRY EXPERTS' PERSPECTIVE

Three categories of industry experts were interviewed for this research. They include the following;

- Representatives of oil producing and trading companies
- Software providers to the energy sector
- Consultants to the energy sector.

The choice of industry experts was based on the impact of their operations and services on the petroleum supply chain. The following areas discussed below were seen as very important factors to be considered in order to achieve upstream integration in the petroleum supply chain.

3.1 LEADERSHIP

Most Industry experts believe that oil executives are convinced about the concept of upstream integration "on paper". However they remain sceptical about the effects of its implementation and change process. Questions normally asked by oil executives include; where and how is value gained? What transformational change is required?

According to an energy consultant, executives in the oil industry will be able to maximize margins across the enterprise by adopting best and emerging business practices if they drive the change process. Such a leader should have a long-term vision of the integration initiative and the management skills required for the change process necessary for buy-in from all business units. These competencies will facilitate visibility across applications to ensure proper execution.

The software providers are of the view that company executives are only receptive to "process changes and system changes" but are not receptive to 'transformational change." The transformational change in their opinion should be a multiyear change process and pre-requisite for integration.

Effective supply chain integration process requires a leader capable of aligning strategic and tactical objectives as a back bone for supply chain strategy. It's a very challenging task to achieve in the upstream supply chain given that the business processes are on vastly different time frames. The order fulfillment process may take as much as six months to account for turnaround planning, but is focused more on the following one to two weeks. However, the strategic decisions, going out to five or ten years, will set the constraints on the order fulfillment process. The figure below shows the complexity of integrating tactical and strategic activities.

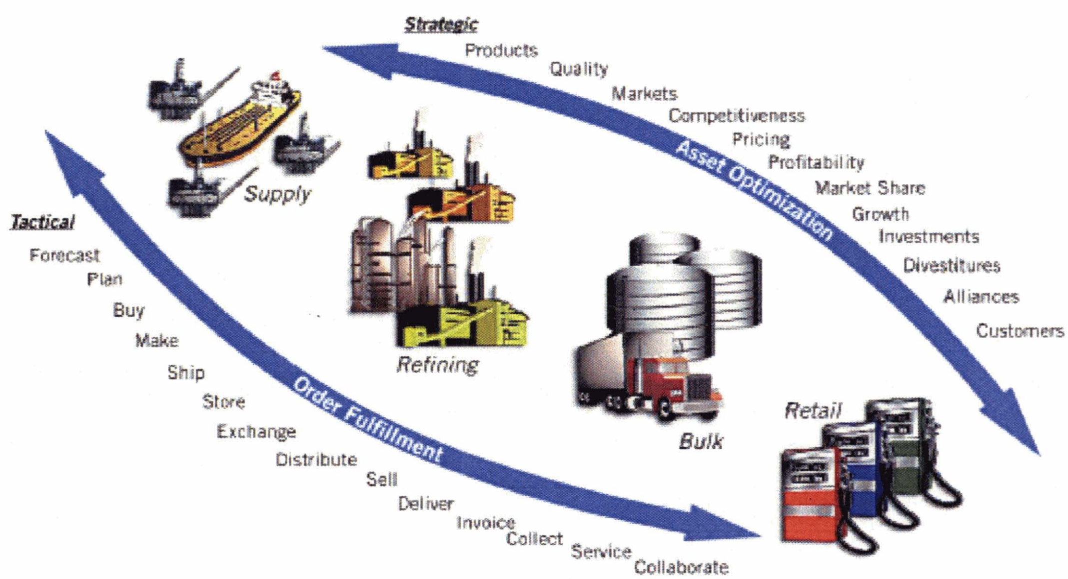

Figure 13 Integrating Strategic and Tactical Decision Making
Source: Darrell Rangnow and Jack Davis (2002), Aspen Technologies Corporation.

3.2 INFORMATION TECHNOLOGY

The upstream functions require decision support systems to aid quick processing of information. However their independent functions impede the use of a common system. Questions also exist regarding to quality of the software-assisted solutions which still depend on many decisions which have to be taken beforehand and exogenously, and in which human judgment is critical. According to AMR Research (2002)[1], effective support systems must be able to:

- Monitor events across the entire enterprise
- Notify present stakeholders based on event type and triggers
- Simulate current operations and future results
- Control supply chain decisions and subsequent events
- Measure actual results against key performance indicators (KPI).

The objective is to get visibility into the supply chain, better understanding of product movements and constraints. This can be tied into how it affects crude selection and refining utilization decisions in order to create "an information-driven supply chain",[2] which aligns upstream functions.

Most industry experts believe that it's time for executives in the industry to commit to an IT investment that will fully automate processes, streamline operations and improve the integrity of financial reports. Energy consultants are however concerned about the

[1] Source: Darrell Rangnow and Jack Davis (2002), Aspen Technologies Corporation.

[2] Ken Cottrill (2003), Oil on Troubled waters – Severe oil price renews pressure to more effectively tie supply to demand. The Journal of Commerce – traffic World Inc.

various support systems which do not work together and their effect in achieving upstream supply chain integration. A consultant to the energy sector was of the opinion that only the software providers should seek ways of pooling their strategic competences for long term benefits through collaboration or providing mechanisms through which different systems could communicate with each other. The main technology barriers to overcome to make upstream integration a reality are interoperability between systems used by the various business units, through integrated planning and scheduling tools, and the visibility needed for collaboration across the enterprise.

Software providers are however focused on providing applications in their respective niche markets and although viewing integration as the major trend in the industry, are concerned on the effect of collaboration in their market positioning.

3.3 PEOPLE

Decisions to explore, buy, transport or schedule crude oil can be made with confidence, in less time and with minimal business risks through a better understanding of the supply chain. All industry experts believed that the key to profitability is having employees skilled at making prompt and efficient decisions. Additionally, such employees should be able to respond proactively to unanticipated market, operational, or logistical changes that impact the profitability of the overall supply chain. These competencies could further be enhanced by providing systems which provide data required for optimal decision-making. This is crucial for the upstream section of the supply chain because most business units require action to be taken in only a few minutes, especially when it is related to a competitive landscape such as crude oil trading.

Furthermore, energy consultants are of the view that the trend in the industry is moving toward the use of employees with multiple skill sets as a source of competitive advantage. This is because of the high skill sets needed for upstream activities such as linear programming, simulations and price modelling.

It is cost-effective for the company if the same employee who runs the optimization models used in the refinery also carries out crude oil trading. This is because running the models and obtaining the real time data required to make pertinent oil trading decisions is key to maximizing profits. However, questions as to whether this scenario affects employee job satisfaction and specialization remains unanswered? According to a software provider, supply chain integration and information-sharing using a common system will go a long way towards ensuring prompt access to information. Consequently, one can infer that prompt access to the data required for decision-making will significantly reduce operational downtime and improve employee efficiency, which may lead to job satisfaction.

Finally, executing the change process into an integrated supply chain cannot be achieved without a change in the fundamental values of employees. This requires acknowledging the impact of feeding in data promptly and sharing information required across business units.

3.4 INDUSTRY STANDARDS

According to an energy consultant, the need to get streamlined data is required to facilitate the integration process. This is because difficulties exist when each silo has a different way of representing data.

One of the software providers stated that, "*there is need for a planning and transactional backbone for effective use of master data to integrate and work around the silos*". The master data here refers to sales information, inventory data, and product codes etc. This can only be achieved, if the oil executives are willing to come together and develop common standards for reporting.

3.5 3PL COLLABORATION

The upstream supply chain has disparate business units which relate to different logistics providers either as suppliers, customers or service providers. Therefore, the need for 'buy-in' from these providers cannot be over- emphasized. Some of the 3PLs and the need for collaborations are briefly discussed below:

- **Software Providers**: Collaboration among software providers such as SAP and Aspen Technologies is important in order to merge efficiencies derived from their applications, so as to generate industry-wide value.
- **Carriers (Transportation Modes):** Carriers who own fleets of ships or trucks used for transportation should also have systems compatible to those used by the contracting oil company so that benefits accrue to the extended enterprise through visibility and on-time information exchange.

- **Crude Oil Marketers**: The system used for crude oil trading by marketers should be accessible to all functional units in the upstream supply chain so that information regarding the current status of crude oil prices is available for profit maximizing decisions.

3.6 MODELLING APPROACH

According to Darrell Rangnow and Jack Davis (2002), one of the most difficult problems in real-time supply chain optimization, requires the integration of planning and scheduling tools for upstream integration. The present disconnect among an organization's supply chain models, accounting packages, trading software and scheduling tools causes inconsistencies resulting from difficulties in reaching optimal decisions.

Furthermore, information exchange is important because the models are continuously interacting with inside constraints and outside changes (price and product demands), making them dynamic in nature. All of these factors imply that the maintenance of these models should be carried out as regularly as possible in a timely manner. The type of updates needed include: reduction in the yield of a unit, change in price, and change in schedule. To address both the economic optimization and feasible path constraints the following is required;

- Model representation of the problem consistent across planning, scheduling, and process engineering tools.
- Use of the optimizer that the problem requires.

This requires information on aspects of the supply chain that may possibly affect the optimal solution in order to ensure that modeling takes into consideration all the variables and external factors affecting the decision being made. To achieve this vision, the price models, demand models, and linear optimization models used should be working with the same data, and should also have good knowledge of the changes in the external market. One of the major oil players has been able to achieve huge savings by using different models as the problem requires. This approach not only ensures that Crude oil traders are aware of the risks and benefits inherent in refinery optimization decisions, but it also creates real-time data exchange between oil traders and optimizers. The result is competitive advantage acquired through maximizing profit margins.

Overall, the view was that although the above points are very vital, it's not totally sufficient to tackle integration challenges facing the upstream petroleum supply chain. Companies will need to develop an organizational structure, culture and capabilities that transcend the supply chain in order to achieve the required change. This according to energy consultants requires change in processes and metrics to simultaneously drive yield and margin maximization.

4 CASE STUDY

The case study is on one of the major players in the global oil industry. The company primarily explores, produces, transports, refines, stores, markets and retails petroleum products. The company was considered in this work because it represents a real-world example of supply chain functions in the upstream section of the petroleum supply chain. The company's functions which make up different business units in the upstream section of the supply chain are described below:

4.1 UPSTREAM FUNCTIONS

4.1.1 CRUDE OIL TRADING: This function acts as a liaison between the commercial trader and the supply organization (Refinery). It finds the most economical crude oil to fill requirements and makes decisions on which is the best crude to procure, at the best price. It is important for oil traders to keep to the price range provided by the refinery optimization runs without compromising on the crude oil characteristics. Crude oil is traded at futures exchanges, such as the New York Mercantile Exchange. A futures contract is a promise to deliver a given quantity of a standardized commodity at a specified place, price and time in the future. The exchange records the pairings of buyers and sellers, and reports the transaction prices. Electronic services then report these prices with minimal lag. Prices are also available throughout the day from the exchanges via the Internet, specialty trade publications and daily newspapers. Additionally, prices are reported on a weekly basis by the Energy Information Administration. The ready availability of the reported prices has enhanced "price transparency" and the ability of the oil traders to assess the prevailing price level, based on the crude oil grade required at the right time by the refineries; criteria for assessing successful trading.

4.1.2 PRICE MODELLING: Ensures that refineries produce and set the appropriate price for the right product through information provided by price drivers. Also, through analysis of the market price, various crude oil traders share the current market demands, availabilities, and price levels using a spreadsheet model. This information is then pulled into the LP Models of the various plants to help assess the most attractive crude oil given the prices of feedstock and the capabilities/constraints of the various locations

4.1.3 DEMAND MODELLING: Involves running the models from refinery to the olefin plant with the updated price file. Demand modelling also determines the set of values to provide to decision-making tools for refining operations. Running these models with the updated price file then allows the team to look into the feedstock market place and judge what will be the most profitable set of feedstocks in the coming months.

4.1.4 REFINERY OPTIMIZATION: Is the interface between systems in trading and refinery optimization. It runs optimization using "LP models" to make decisions regarding the right crude oil to purchase. Running the models on a weekly basis (making a four -month projection) in the short term on current capabilities and in the long-term provides inputs to the supply chain strategy. These inputs highlight the changes required to adapt to fluctuations in the market such as crude oil availability. The LP models are mathematical representations of the entire petrochemical location. These models include all the various units at the location and their economics including variable costs. These models have all the plant's capabilities and constraints (e.g. olefins plant can run a maximum of 2 butane furnaces, light liquid feed to a plant must be a minimum of 15 mb/d, and more complex equations). Refinery planning forms the foundation for the business decisions that have the biggest impact on refinery profitability. A refinery typically prepares the following types of plans:

- Annual plans for annual budgeting, term crude contracts and maintenance shutdown planning
- Monthly rolling plans for spot crude purchases and conducting refinery operations in line with product demands
- Weekly plans for developing operating strategies for units at the weekly level, i.e. the refinery knows precisely which crude it has and must decide which crude cocktails to run, how long to do so, and how it is going to meet any particularly large or difficult product demands
- Strategic plans for future years and expansion projects
- Profitability improvement plans for plant -level modifications and revamp projects

The preparation of any of the above types of plans requires a set of standard procedures and an LP model customized for the refinery configuration.

4.1.5 TRANSPORTATION PLANNING: This function schedules the transportation of crude oil to the olefins plants through large cargos of crude oil, and co-ordinates the 20% of owned and 80% of outsourced carriers. It exchanges information with refinery managers on the present inventory level at the refinery in order to schedule shipment transportation and expedition. It also shares information with carriers on shipment status for feedback to the refinery managers to reduce the risk of costly downtimes.

4.1.6 CRUDE OIL MARKETING: This function is not related to the crude oil trading function. The oil marketing function works with exploration and production to market its products to the general public which includes the crude oil trading business unit. Crude oil marketers also carry out the duties of the oil traders, but unlike oil trading any other company capable of bidding the appropriate price is eligible to purchase the crude oil via a website.

To set a market price , crude oil marketing requires information on type and quantity of crude oil produced, total cost of the crude oil exploration and production activities, and its availability in the long and short term. The marketer's also communicate discount status and type/quantity of crude oil available to its customers.

4.2 EXTERNAL FUNCTIONS

4.2.1 COMMODITY MARKET: Spot market for crude oil trading. Oil is sold under a variety of contract arrangements and in spot transactions. Oil is also traded in futures markets, a mechanism designed to distribute risk among participants on different sides (or with different expectations) of the market, but not generally to supply physical volumes of oil. Both spot markets and futures markets provide critical price information for contract markets. They are also used by the company to balance supply and demand.

4.2.2 COMPETITORS: Other oil producing and trading companies. While everyone in the market wishes to buy at a low price and sell at a high price, buyers and sellers are on opposite sides of the transaction and their risks are inherently different. Other players in the oil industry could also have varying appetite for risk, and speculators may wish to gamble that the price will move one way or the other. The futures market, a zero-sum game where there is a buyer for every seller, distributes the risk among market participants according to their positions and appetites. The ability of a company to procure the right crude it requires at the appropriate time and at a reduced cost is very vital.

4.2.3 CARRIERS: 80% of outsourced carriers (Ocean shipments & Trucks). These companies provide third party logistics services for their client companies which involve handling cargo and trucking operations. They also provide manning services for all the shipments. The relationship between the external and internal functions discussed above is illustrated in Figure 14.

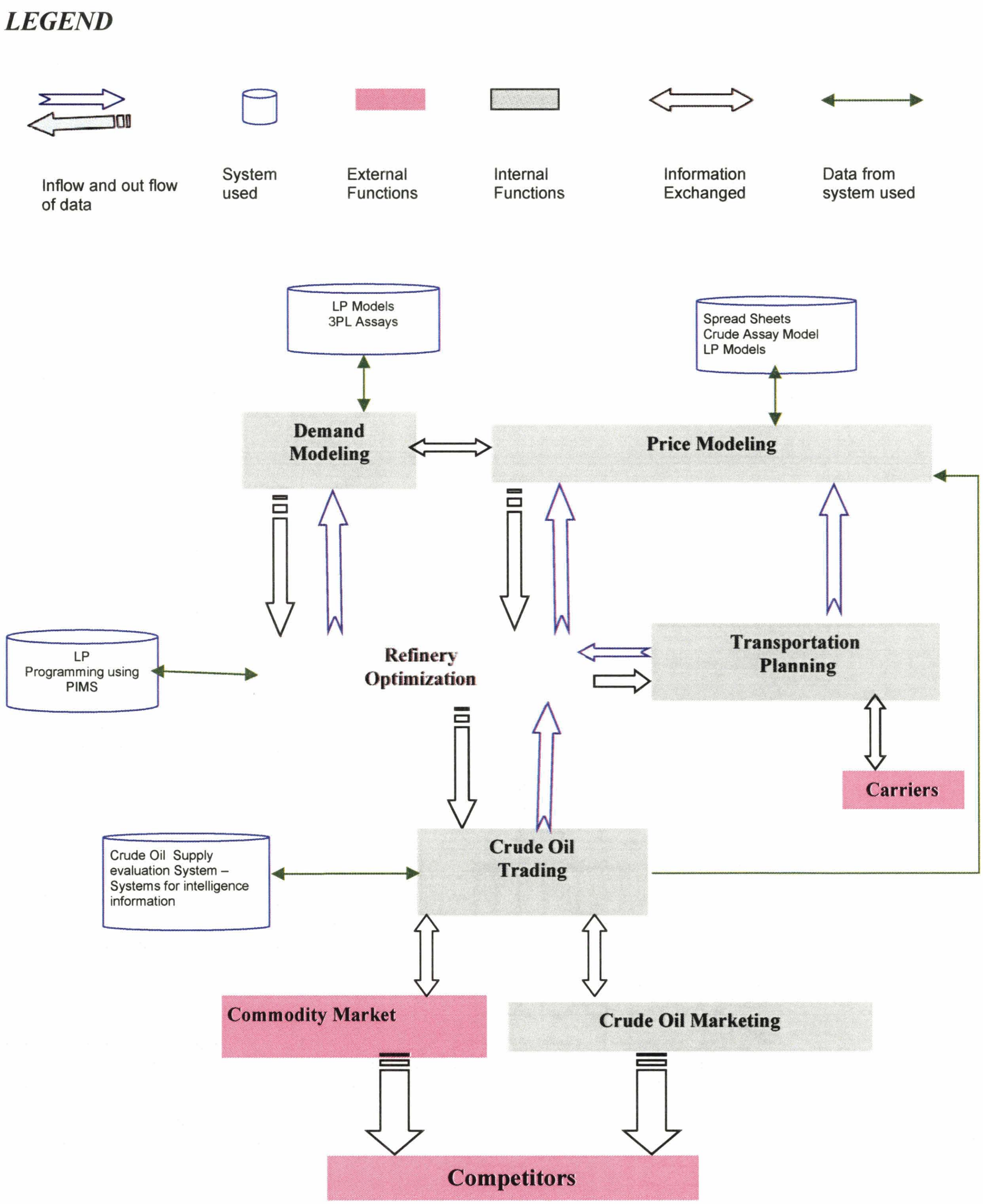

Figure 14 Structure of Case Study Upstream Functions

4.3 AREAS FOR IMPROVEMENT

TO / FROM	CRUDE OIL TRADING	TRANSPORTATION PLANNING	DEMAND PLANNING	PRICE MODELLING	CRUDE OIL MARKETING	REFINERY OPERATION
CRUDE OIL TRADING				Discount status Premium Status Market Price Crude oil type & quality	Price Crude Oil yield Quality Availability	Oil loss information Logistics Cost Purchase Risk Crude Quality & Type
TRANSPORTATION PLANNING				Freight Cost		Schedule Plans Fleet Status, Supplier's data
DEMAND PLANNING				Market Data Price forecast		Quantity of feedstock required Strategic fit Cost decisions
PRICE MODELLING			Market Data Price forecast			Price-forecast & Budgets
CRUDE OIL MARKETING	Price Crude Oil yield Quality Availability			Discount status Premium Status Market Price Crude oil type & quality		
REFINERY OPERATION	Price Quality & Type	Inventory Status	Crude Oil, Flow Rate and Feed-Rate	Refining Production Plan	Price Quality & Type	

Figure 15 Information Exchanged and Silos existing in Case Study Upstream Information Network.

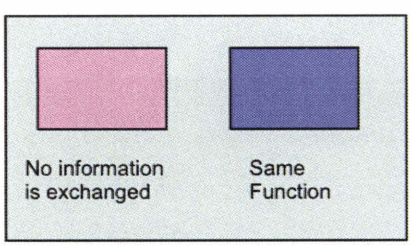

Figure 15 shows the current state of information exchange among functional units in the petroleum supply chain. Looking at the diagram, it is immediately obvious that silos exist in this information exchange framework. Removing these silos by instituting complete cross functional information exchange can yield significant operational and economic benefits.

Maximizing profit can only be achieved by minimizing the costs of crude sourcing, trading, transportation and refining. But the silos that exist would prohibit accurate estimate of production and sourcing needs. The following are areas in which improved information exchange could yield immense benefits;

- **Crude Oil Trading - Refinery Optimization – Price Modeling**

Given the volatility in the prices of crude oil traded in the spot market, crude oil traders could maximize profit margins by using real time information obtained from refinery optimization and price models. As a result, rather than make decisions based on the range of suitable prices, the crude oil traders can establish a "price point" through on time data exchange between the three functions. This "price point" represents the optimum decision derived from the given price range. Given these silos, they are less likely to be able to negotiate long-term contracts for cost efficient supplies. This results to an imbalance between the supply chain needs and expensive spot trades.

- **Price Modeling – Demand Modeling – Refinery Optimization**

These three functions should be carried out simultaneously with the same numbers using compatible or common systems to enhance visibility for each crude type rather than a cascaded approach using different systems. However, care should be taken to ensure that the system used is capable of processing separately, the modeling approach required for each business unit. However, visibility into data is required to ensure that common variables are used across these functions.

- **Transportation Planning - Refinery Operations:**

In this arrangement, a company informs refineries about forecasts regarding possible scheduling disruptions, at the same time it gives information to transportation regarding which crude oil shipment to expedite when necessary. This is because actual conditions in terms of crude oil cargo loading capacity and the number of cargo tanks of the tanker in question may require adjustments to the volume and the grade of crude oil to be lifted. Moreover, when the tanker enters into two or more ports during one voyage, it may be necessary to adjust the rotation schedule for the tanker in advance. With information sharing, the refinery manager can determine the most suitable timing of crude oil unloading at a receiving port taking into account factors such as:

- Good vessel management system, safety in transportation, safety in loading/unloading
- Latest conditions of the carrier's shipment
- Facility capacity (loading/unloading capacity, sailing speed, etc.) of the carrier.
- Adaptability to constraints on entry into loading/unloading ports such as size, draft, age, etc. of the shipment

- Movements in crude oil inventories in tanks at the receiving port
- Desired timing for lifting crude at a shipping port which is estimated by considering the transportation lead-time and inventory level at the refinery.

This information exchange will eliminate possibilities of downtime in the refinery and also increase asset utilization. Sharing information regarding its future refining needs with carriers will also aid in negotiating better contract terms that will permit the carriers to give the refinery priority scheduling and committed capacity.

The proposed structure for the case study which ensures effective information-sharing is shown in the Figure 16 below. This structure requires effective collaboration from software providers, employees, executives and logistics providers. With an integrated upstream supply chain structure which ensures on-time information exchange, changes in global supply can be addressed in minutes. This rapid response to market changes, while making effective decisions, will reduce the variability in the price of the end products. This step toward process improvement using on-time information exchange will go a long way towards achieving competitive advantage through improvements in operational efficiency.

FROM \ TO	CRUDE OIL TRADING	TRANSPORTATION PLANNING	DEMAND PLANNING	PRICE MODELLING	CRUDE OIL MARKETING	REFINERY OPERATION
CRUDE OIL TRADING		Carrier Shipment locations and Cost structure	Crude oil Purchase Cost and spot market price	Discount status Premium Status Market Price Crude oil type & quality	Price Crude Oil yield Quality Availability	Oil loss information Logistics Cost Purchase Risk Crude Quality & Type
TRANSPORTATION PLANNING	Carrier Shipment locations and Cost structure		Fore cast data of quantity of crude for shipment cost negotiation	Freight Cost	Quantiy and type of crude oilavailable	Schedule Plans Fleet Status, Supplier's data
DEMAND PLANNING	Crude oil Purchase Cost and spot market price	Fore cast data of quantity of crude for shipment cost negotiation		Market Data Price forecast	Quantity, Cost and Crude oil Type	Quantity of feedstock required Strategic fit Cost decisions
PRICE MODELLING	Discount status Premium Status Market Price Crude oil type	Freight Cost	Market Data Price forecast		Price and discount status	Price-forecast & Budgets
CRUDE OIL MARKETING	Price Crude Oil yield Quality Availability	Quantiy and type of crude oil available	Quantity, Cost and Crude oil Type	Discount status Premium Status Market Price Crude oil type & quality		Quantity of Crude oil type, price and discount status
REFINERY OPERATION	Price Quality & Type	Inventory Status	Crude Oil Flow Rate and Feed-Rate	Refinery Production Plans	Price Quality & Type	

Figure 16 Proposed Information Exchange Network for Case Study

With the network shown in Figure 16, business process transparency is maximised. The case study will have more timely information available, better communication and coordination of functions, and reduce processes that lead to cost inefficiencies.

5 FINDINGS

The three major findings of this research are as follows:

- ***No common system currently exists for use by all business units in the upstream section of the petroleum supply chain***
- ***No standard process of information is carried out. Information exchanged between upstream functions is carried out mostly through emails or telephone calls***
- ***Difficulties exist in accessing information when required.***

5.1 CHALLENGES AND THREATS OF UPSTREAM INTEGRATION

The large number of mergers and acquisitions in the oil industry in recent years has led to a significant consolidation of refining assets. For example,

- In 1998, Marathon and Ashland Oil merged their downstream assets.
- In 1998, British Petroleum (BP) merged with Amoco
- In 1999, Exxon Corporation merged with Mobil Corporation.
- In 2000, BP/Amoco acquired ARCO.

Within the past year –

- Shell acquired Texaco's domestic downstream assets;
- Chevron, which had acquired Gulf Oil in 1994, acquired Texaco (other than downstream assets)
- Phillips acquired Tosco
- Phillips announced a merger with Conoco.

Following these mergers and acquisitions, executives of the merged/acquired oil companies have struggled to integrate the separate systems and processes used by the individual "pre-merger" companies. This inevitable integration unearthed significant cultural differences among the employees of the merged company. Integrating the different cultures with a view to creating synergies, rather than inefficiencies has been a challenge to oil executives because of the effect of this integration on their' employees. However, the biggest barriers are the transformational changes required of all stakeholders in order to achieve upstream integration. These transformational changes according to the literature, industry experts, and case study include the following;

- Incentive schemes
- Information exchange
- Employee skills
- Investment cost
- Change management
- Industry standards and collaboration

5.1.1 INCENTIVE SCHEME

An incentive scheme is crucial to motivate all stake holders to be engaged in the change towards achieving an integrated supply chain. Most companies still have incentive tied to the performance of business units rather than to corporate performance. Aligning incentives with corporate objectives can be achieved through forcing a paradigmatic change. This is achieved when an explicit set of performance goals is linked to financial objectives.

The alignment of incentive with corporate objectives combines the analytic benefits of channel mapping with the strategic aspects of corporate performance goals. This creates the shift from "silo-thinking" towards seeking ways to achieve system wide profitability.

5.1.2 INFORMATION TECHNOLOGY

The use of different systems which are not compatible reduces visibility into the whole supply chain, as independent functions use disparate systems with different numbers at different times, making the benefits accrued to investing in a system unattainable. For example, the impetus that refinery and crude oil traders work with same numbers given by the demand planners is critical for visibility, accurate forecasting and data integration.

5.1.3 EMPLOYEE SKILLS

Highly skilled workers required for the intensely analytical positions (optimization modeling and linear programming) demanded by upstream functions, according to a consultant, are "few and far between". This has led to more training requirements for employees who do not have expertise in this field.

Companies who invest in their employees to ensure deep understanding of every function in the upstream supply chain will be most efficient. The knowledge of each function would stimulate the need and importance of information-exchange to ensure that profits are maximized by verification of data required for decision making

This cross-functional skill set is more important to the upstream supply chain than specialization. For instance, given the volatility of the crude market, the most efficient crude oil traders are those who execute a crude oil with the knowledge of the volatility of crude slate in the refinery.

With effective information exchange, the demand for advanced skill sets will be reduced because employees would be able to access and process data when required.

5.1.4 INVESTMENT COST

Tremendous amounts of investments have been made by oil companies in the past for information technology systems, such as transactional trading system, trade capture, and open link. The major players in the oil industry have active projects in these areas.

Executives are skeptical about investing in new technology because of the seemingly endless stream of initiatives previously promised by technologies in the past. Some company executives tend to look at the short term benefits on their profit and loss account, rather than the long term benefits and capabilities that will be accrued.

According to an energy consultant, "*Integration can only be achieved if the oil companies force the change process so that the market can drive change towards integration*". This can be done through ensuring that the software providers sell systems which resolve problem faced by a company versus that which is most suitable for a software company. Another industry expert confirmed this fact by stating that, "*It is now left for the executive to insist on investing on systems that meet the needs of on-time information exchange across all functions in the supply chain*". Software providers are now prepared to work toward more customized and sophisticated decision support systems that enable integration.

5.1.5 CHANGE MANAGEMENT

Companies should be willing to re-organize their processes for supply chain improvements. This requires a transformational change in process. Some companies have acknowledged this view by having all functions working together within the same location. However, this change has to go beyond the structural change to a psychological change towards "system-wide thinking".

The barrier faced in managing the change process is the willingness to come together to achieve a common objective. It could be internal, within business units or externally with the 3PLs. According to Jonathan L. Byrnes (1991), "Resistance to integration typically stems from a lack of understanding of how jobs can change for the better when the routine aspects are removed". The resistance to change is because it may lead to the elimination of some activities, the reconfiguration of others, and significant changes to long-established procedures and prerogatives. Hence, there is concern about how information sharing will benefit them individually. It is important that executives communicate the benefits of the change process to all parties involved to ensure effective buy-in.

5.1.6 INDUSTRY STANDARDS AND COLLABORATION

This process requires collaboration between legislative bodies, software providers and major players in the industry in order to pool their competitive strengths together to formulate industry standards and solutions. There is need for oil companies (particularly the major players in the industry) to drive and support this collaboration financially. Finally, it also requires all logistics providers to collaborate by adapting to the new process to make it more effective. These cannot be achieved if each stakeholder does not have the same vision of system-wide benefit sharing.

5.2 BENEFITS FROM UPSTREAM INTEGRATION

An integrated supply chain is able to continually and promptly respond to changes in market conditions. In contrast, for a stand-alone operation to have some flexibility, it must establish and manage a variety of separate supply contracts, incur the cost and time delay of inbound logistics, and manage the inventory for each of the feedstocks they have the flexibility to use. The three major benefits identified as proceeds of integrated upstream petroleum supply chain are a reduction in operation cost, asset utilization and customer responsiveness. These benefits are discussed below.

5.2.1 **OPERATING COST**

The operating cost refers to the total operating cost incurred by the whole supply chain. This cost is reduced through the following ways:

- Transport Cost: Transportation cost efficiency is gained through economies of scale by aggregating products purchased if information regarding forecasted demand is shared by the transportation planners. Cost can also be reduced by providing information concerning variability in freight cost under different conditions' such as distance, quantity and schedule, to implement current and continuous optimal decisions on a regular basis.

- Refining Operating Cost: Information sharing with feed stock scheduling would increase the efficiency of the refining process. This efficiency is achieved when information regarding crude oil composition and yield from transportation planning is shared seamlessly with the refinery for feedstock blending control and scheduling. The refinery uses this information to configure its operation and capacity conversions giving it optimum utilization of refining resources.

5.2.2 ASSET UTILIZATION

- Inventory Cost: The upstream petroleum supply chain requires long lead times for its planning and scheduling activities. Consequently, on-time access to historical and current inventory data would enable crude oil traders, demand planners and price modellers to accurately forecast the purchase of feed stock required for refining and highly accurate exploration planning, thus reducing inventory holding costs.

- Plant Utilization: Information on lead times required for feedstock arrival at the refinery will help co-ordinate processes such as crude slate optimization. This would aid effective process flow through the distillation column, leading to improved inventory utilization through scheduling the crude oil quality that maximizes asset utilization. This implies that effective plant utilization also minimizes the occurrence of costly downtimes in the refinery resulting from lapses in information regarding the quality of the expected feedstock.

According to a software provider, many companies do not maintain accurate information on the volatile value of their assets. As a result, some companies may wait too long to replace underperforming assets, or may act too soon in upgrading fully functional assets – either situation creates cost inefficiencies. Given this situation, difficulties exist in maintaining assets in the most efficient manner.

5.2.3 **CUSTOMER RESPONSIVENESS**

- Fill Rate: On-time information-exchange will make the supply chain more responsive to possible shortages and fluctuations. Consequently, fill rate increases because the variability in demand and supply of end products reduces.

6 RECOMMENDATIONS FOR FUTURE RESEARCH

Despite the huge benefits from integrating the upstream supply chain, the oil industry has to overcome the barriers that prohibit on-time data exchange that have caused the silos in the upstream section.

According to (Lewin, 2003), successful supply chain strategy development will need to carefully establish plans for process re-engineering, change management, and information technology design and implementation. Technology improvements on its own would only aid the industry achieve integration, but the basic structure and process have to be re-organized to support supply chain integration. The success depends on all stakeholders' collaboration and support towards achieving industry-wide value creation in the supply chain.

Finally, the following are suggested areas for further research:

- A detailed analysis of how the different software providers could collaborate to deliver the applications that support integration in such away that their competitive positioning is insured.
- How would oil companies develop standards that could be used for communication across all upstream functions so as to develop a "common language" and a "common vision"?
- How would Executives in the oil industry drive the change process? What change management skills are required to achieve the cultural and structural change required for on- time information sharing?

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APPENDIX

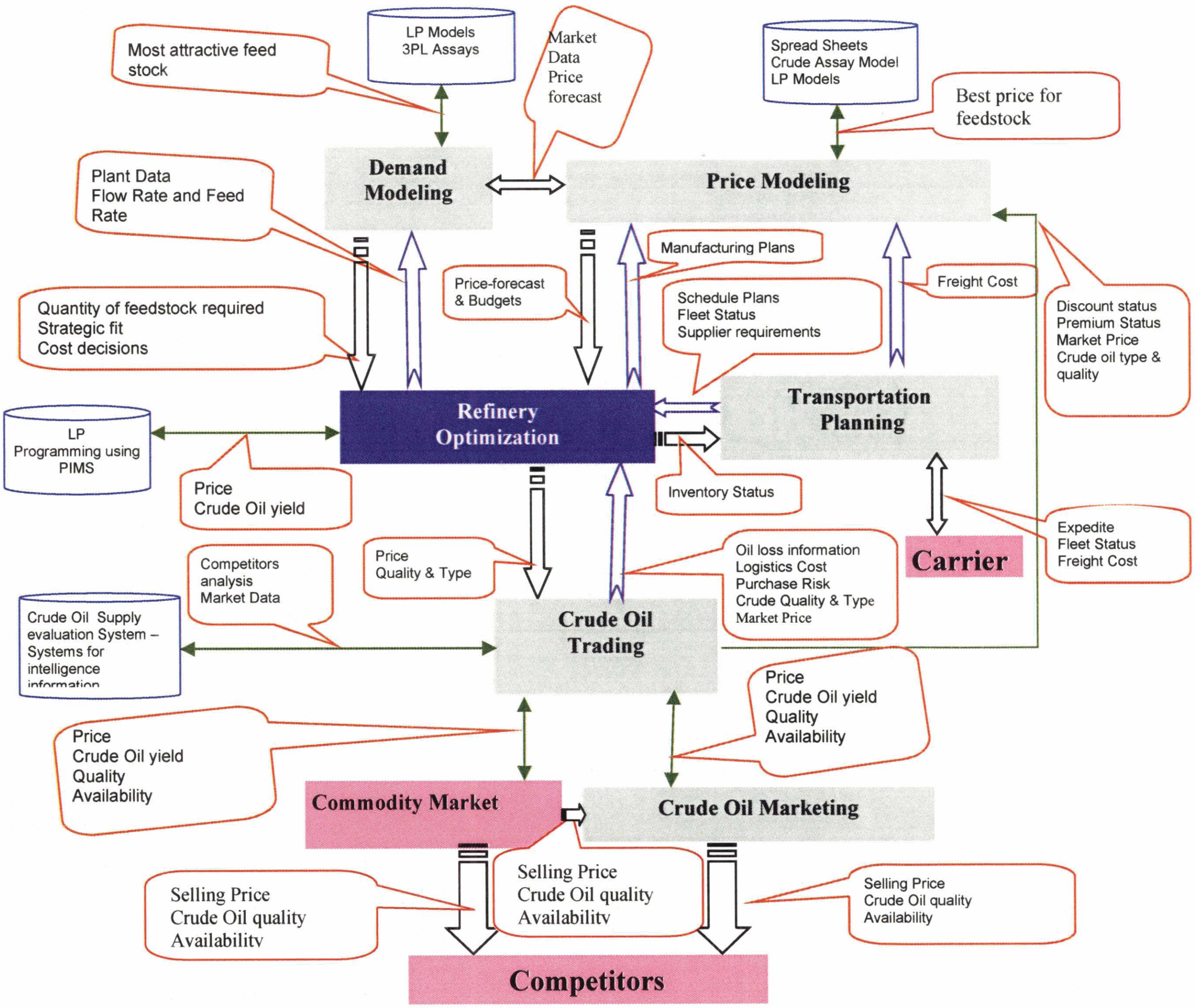

Figure 17 Case Study Structure of Information Flows in Upstream activities