Supply Chain Practices in the Petroleum Downstream

by

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MSc Economics and Management
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Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

Master of Engineering in Logistics

at the

Massachusetts Institute of Technology

May 2005

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Abstract

This thesis studies current supply chain practices in the petroleum downstream industry, using ExxonMobil as a case study. Based on the analysis of the literature and the interaction with industry experts, this work describes the main supply chain issues and challenges in the downstream sector. Moreover, supply chain strategies used by different players in the industry are studied, analyzing in particular the progressive but slow shift of the industry towards a holistic supply chain view. Finally, ExxonMobil operations are used as an illustration of several of the aspects of the previous general analysis.

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

Acknowledgements

I would like to thank all the MLOG class of 2005 and the rest of the people that made this year in Cambridge a wonderful learning experience. I would like also to thank Dr. Lawrence Lapide for his availability and especially his patient and insightful help in the development of this thesis.

Finally, I am also grateful to the persons involved in the network of the Supply Chain 2020 Project that have actively collaborated with this thesis: Bruce Logan (AspenTech), Malavika Melkote (i2 Technologies), Andy Ott (UPS Supply Chain Solutions) and Parrish Potts (Accenture).

Dedication

To my family.

Biographical Note

Fidel Santos Manzano obtained engineering degrees from Universidad Pontificia Comillas and Ecole Centrale Paris. He completed a Masters in Economics and Management at the IFP School – ENSPM and has worked during five years in the energy industry.

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1 Introduction

This thesis is part of the Phase I of the Supply Chain 2020 Project (SC2020), which analyses the supply chain in nine industries: aerospace, apparel, automotive, computers, communications equipment, consumer packaged goods, petroleum downstream, pharmaceuticals and retail. The project will identify the best current practices and also the essential factors for the successful design and operation of supply chains.

1.1 Purpose of this thesis

The first objective of this work is to perform an industry overview, covering the internal and external factors influencing the industry of petroleum downstream. The analysis will be focused on supply chain past and current practices.

Secondly, we will elaborate a case study about one of the main players in the industry, ExxonMobil. In order to do this, we will illustrate the general study with some aspects of the petroleum downstream supply chain for ExxonMobil using the analysis frameworks of the SC2020 Project (SC2020 IAC, 2004a, 2004b, 2004c).

This thesis is the first phase in the petroleum downstream analysis by the SC2020 Project and will be followed by a second phase introducing the use of scenario planning methodologies.

1.2 Research methodology

This thesis has been elaborated using bibliographic research and field work (interviews) in several steps.

Firstly, we collected information about the industry and its actual supply chain practices. Secondly, we studied the case of ExxonMobil taking as a reference the framework defined for the Phase I of the Supply Chain 2020 Project (SC2020 IAC, 2004a, 2004b, 2004c)

In both parts the information was based on the different literature sources and interactions with industry practitioners and consultants including managers from Accenture, AspenTech, i2 Technologies and UPS Supply Chain Solutions.

2 Literature Review

This literature review will cover three topics: the general Supply Chain 2020 Project, the specific area of research concerning the petroleum downstream supply chain and finally the information about ExxonMobil.

2.1 Supply Chain 2020

The general supply chain context for this work is based on the works of Fisher (1997), Hammer (2004) and Porter (1996). The work of Porter (1996) provides a general strategic framework for all the industry analysis performed in the SC2020 Project. Fisher (1997) makes a general classification of supply chains types depending on the product life cycle of the product you are dealing with (functional and innovative products). Each of them will need a different kind of supply chain. Finally, Hammer (2004) focuses on the undervalued status of the operations activities in different companies even if operational excellence is the core of many successful company strategies and essential for sustained competitive advantage.

2.2 Petroleum downstream industry

There is a wide literature covering in depth the technical and economical aspects of the petroleum downstream. However, an integrative supply chain perspective is not common in the industry or the research work. The literature is much more limited from the global supply chain perspective. As in other industries, the typical approach has been a silo-type study of the different problems, without an integrated approach. However, a more comprehensive petroleum refining supply chain body of research has being growing in the recent years.

Most of the peer-reviewed publications focus on only one of the aspects of the supply chain, i.e., process optimization or logistics planning. In particular, the literature about the application of operational research and optimization techniques to refining processes is large (Dempster et al., 2000; Ross & Droge, 2004). Moreover, some published books deal with the overall economic treatment of the refining business (Brennan, 1998; Gary, 2001; Favennec & Wauquier, 2001; Maples, 2000), covering extensively the main supply chain issues (inventory planning, logistic networks design, process units scheduling, product yield optimization, crude oil supply, etc). Most of the literature reflects the pioneering character of the industry in the utilization of the operations research developments, but the publications also reflect the traditional isolation between the different parts of the industry. As an example, the use of linear programming for refinery planning and scheduling is widely covered, but publications about a systemic approach to the downstream supply chain (covering from crude oil origin to fuel retailing) are scarce.

In addition to the peer-reviewed formal research efforts, the petroleum companies, the software and service providers (*AspenTech, SAP, Infosys*), the national and international energy organizations (*International Energy Agency, US Energy Information Administration, American Petroleum Institute, US National Petroleum Refiners Association*) and different consultancy groups (*Accenture, Cambridge Energy Research Associates, PIRA, Poten & Partners, PetroFinance Company, Wood McKenzie*) have been very active in elaborating different studies and evaluating different aspects of the downstream supply chain. As it was indicated for the peer reviewed publications, these sources highlight the lack of a well developed supply chain approach in the industry, but witness the growing interest and need for more developed supply chain awareness. The references to this holistic perspective are usually found in the work of

consultants and they are based in many cases on the analogies with other industries where more advanced supply chain paradigms have been adopted. The supply driven approach of the petroleum industry is being progressively changed into a more customer focused orientation.

Finally, the petroleum business is widely covered in the common and specialized press (i.e., financial press: *Financial Times, Wall Street Journal, The Economist*) and features a wide series of industry-recognized trade publications and business journals that offer different perspectives on the industry issues (*Oil and Gas Journal, Petroleum Economist, Petroleum Intelligence Weekly, Hydrocarbon Processing, Energy Policy*)

2.3 ExxonMobil

In the case of ExxonMobil's supply chain, the information has been mainly obtained from public sources about the company and the information provided by industry experts.

The main documents used in this part of the work have been:

- ExxonMobil investors and shareholders presentations and publications
- Security Exchange Commission fillings (e.g., 10K)
- Different articles in the financial and trade press

The literature about ExxonMobil's supply chain reflects the general state of the industry where the different parts of the downstream still lack a seamless integration. The pieces of information examined for this thesis reflect this scattered view but also reveal the current ongoing evolution of the company structures and processes towards a more integrated supply chain.

3 Industry Overview

The petroleum industry is a significant industry from different points of view (Masseron, 1990; Yergin, 1991). First, it involves significant economical flows. According to the World Trade Organization, the total value of the trade of oil crude and products in 2002 was $615 billion, representing 9.8% of the total global merchandise trade and 44.9% of the world exports of primary products. As we can see in the Figures 1 and 2, the majority of the crude oil flows (main raw material for fuels) comes from the Middle East towards the consumer countries in the more developed areas of the World.

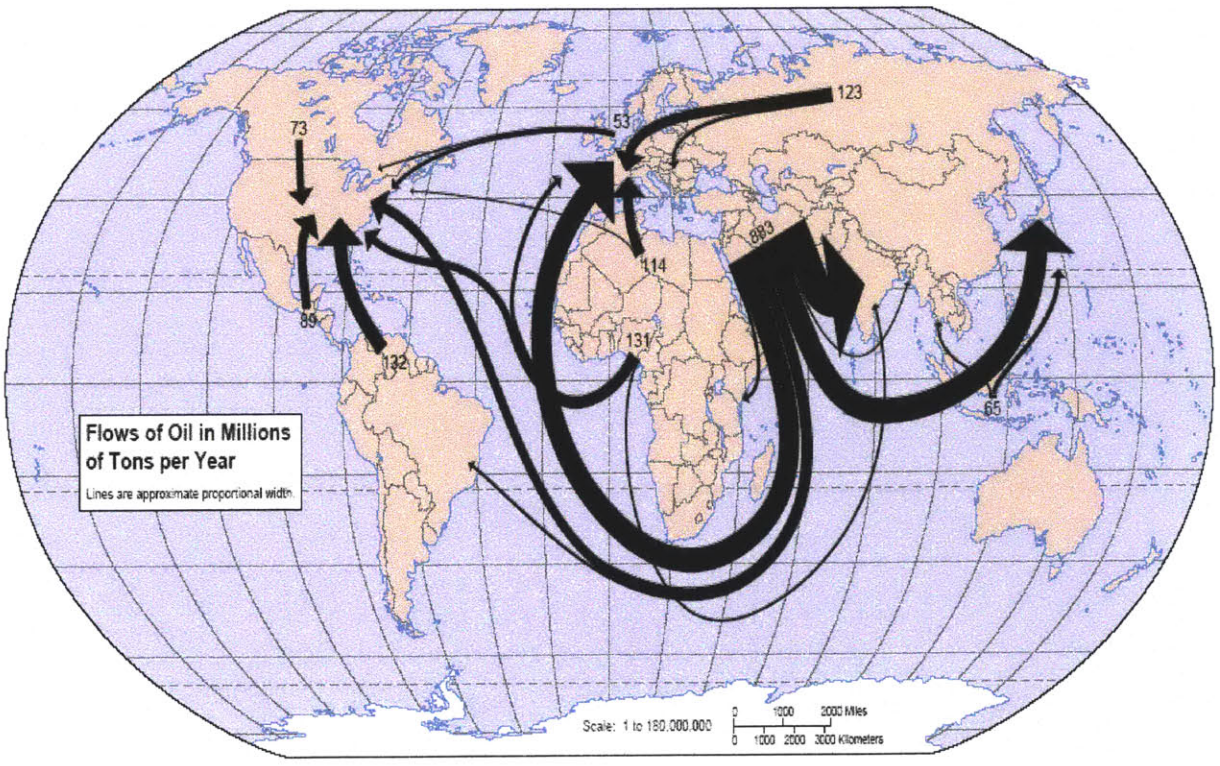

Figure 1 *– World oil flows (Source: McGraw Hill 2002)*

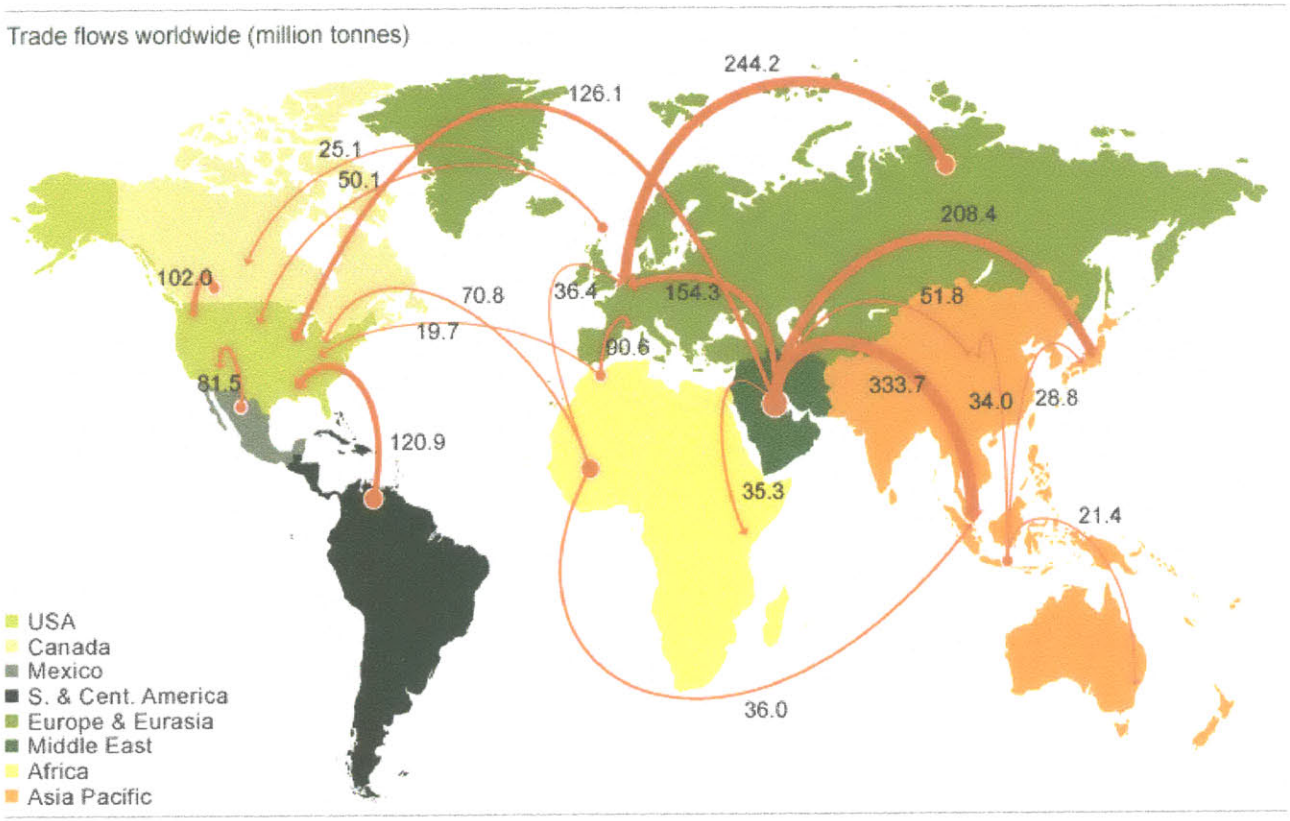

Figure 2 *– Oil trade flows (Source: BP Statistical Review of World Energy 2004)*

This industry is strategic as the base of transportation and other essential activities of the economy of any country. As a result of these strategic issues, it is in the center of the international geopolitical and macroeconomic panorama and most of the governments maintain careful control of the evolution of the industry or even directly manage the operations in their respective countries. A clear example is the behavior of the governments of the producing countries (Masseron, 1990).

The industry is usually divided between the upstream and the downstream activities. The first part covers the exploration, production and transportation of crude oil and gas to the point of transformation into final products (mainly refineries). The downstream activities deal with the processing of crude oil in refineries, the distribution and the marketing activities of all the oil derived products.

As we indicated in the introduction, in this thesis we will concentrate on the activities of the downstream, focusing on the refining and fuel marketing activities. In the case of the refining activities, some of the issues highlighted are closely related to its character as a process industry, presenting some important differentiating characteristics from the point of view of its supply chain when compared to other non-process industries (GLSCS, 2003).

3.1 Products and services

For the purpose of this thesis, we will define petroleum downstream as the *activities which take place between the purchase of crude oil and the use of the oil products by the end consumer. This covers transporting the crude oil, performing supply and trading activities, refining the crude oil, and distributing and marketing the refined products output.*

3.1.1 Products

The main products obtained from the activities of a refinery are: liquefied petroleum gases, naphtha, gasoline, kerosene, diesel, fuel oil, lubricant oils, asphalt, and petroleum coke.

Most of these products are used in every day applications (transportation, heating, etc). Moreover, petroleum products are also used in the petrochemical industry for the manufacturing of rubber, nylon, plastics and other kinds of derivatives (Favennec, 2001; Gary, 2001).

The crude oil is initially distilled and the initial product yields can be improved by using other refining units (conversion units) to chemically modify the hydrocarbons (by cracking, combining or altering the molecules). The classical way of operating the refinery takes into account the wide variation in price and the seasonality of consumption for the products. For the first one, some refineries are able to adjust quite quickly to the market value of the products and generate the optimal economical mix of products to maximize revenue. On the other hand, refiners also take into account the seasonality of consumption, usually producing more gasoline

during the summer or "driving season" in the Northern Hemisphere, and more heating oil during the winter.

The main difference among petroleum products is the length of the hydrocarbon chain. The gases are generally formed by short chains, less than 5 carbon atoms, liquids are usually up to 18 atom chains, and the hydrocarbons with more than 19 atoms are usually solid at ambiance temperature. A description of each product type is as follows:

- Petroleum gases are methane, ethane, propane and butane. They are in gas state at room temperature, they can be evaporated quite easily and their main applications are heating, cooking or petrochemical feedstock. The usual way to handle them is liquefied (liquefied petroleum gas or LPG) under pressure in bottles, through pipelines or using storage tanks.
- A second product is naphtha, a very light, liquid, clear and volatile product. Its main uses are: petrochemical feedstock in crackers (units in petrochemical facilities), solvent for paints or cleaning products, and gasoline blending.
- Gasoline is one of the main products of petroleum refining. Its main application is as a fuel for internal combustion engines. It is a quite volatile liquid. The suitability of gasoline for its main application (fuel for internal combustion engines) is measured through the octane number. This figure characterizes the ability of a substance to combust evenly and without detonation when subject to high pressures and temperatures, like inside a car engine. This is particularly important, because a low octane number produces "knocking" in the motor, which generates uncomfortable driving, extra fuel consumption, and engine damage in the long-term. Lead used to be added to gasoline to improve the octane number,

but the use of catalytic converters for exhaust gases and environmental regulations phased out its use. Nowadays, gasoline is formulated using aromatic-based and oxygen-containing compounds (oxygenates) to improve the octane number.

- Kerosene is another oil product used as a liquid fuel for jet engines and army vehicles. Less purified types of kerosene may be used as heating fuels in developing countries.
- Gas oil (also called diesel distillate) is a liquid used as internal combustion engines fuel and heating oil, as well as a blending material or feedstock for other chemical processes. In the case of gas oil, the suitability as an engine fuel is measured through the cetane number, similarly to the octane number for gasoline.
- Lubricants bases are used to manufacture motor oil, grease and other lubricants. These products are heavier than the precedent ones and do not vaporize at room temperature. They include motor oil, gear oils, vaseline and semi-solid greases.
- Fuel oil is a liquid heavy fuel used in industry for heat or power generation and as a feedstock for making other chemical products.
- Residuals are solid products such as petroleum coke, asphalt, tar and waxes. These residuals can also be used a raw material for manufacturing other products.

Figure 3 shows a summary of the main oil refining products and their applications, presenting them in increasing order of density from the bottom of the figure.

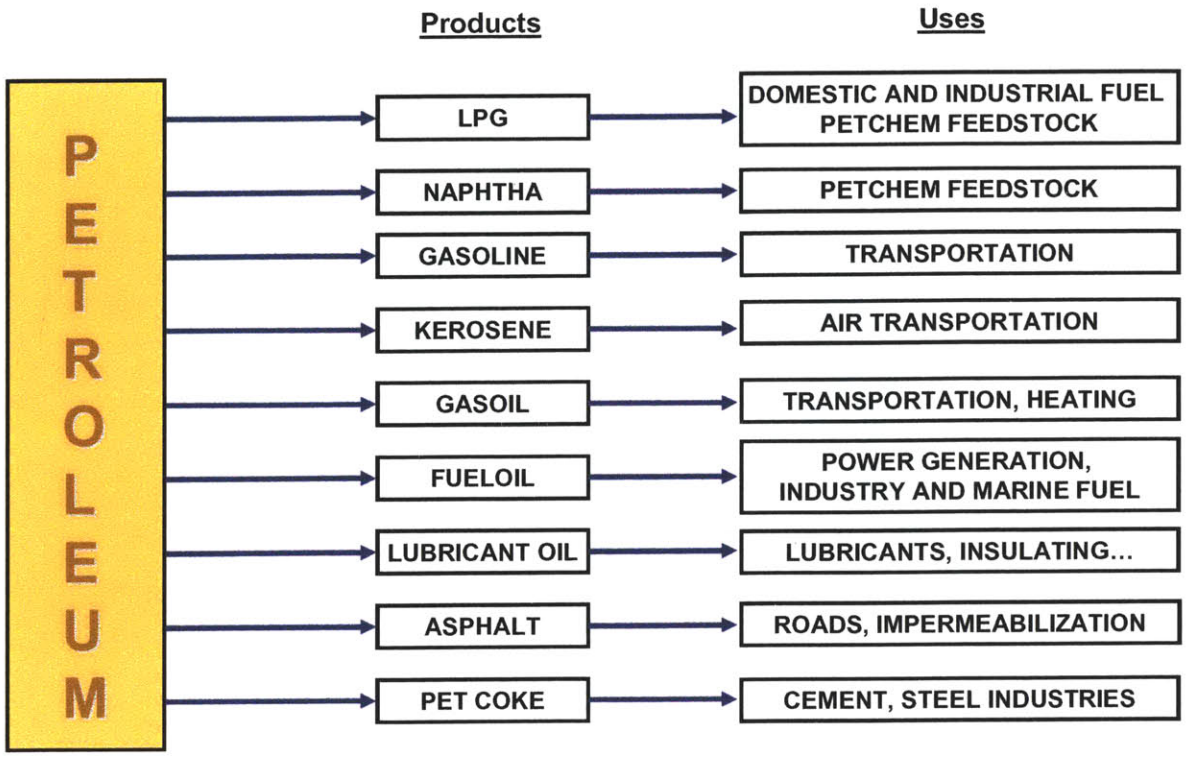

Figure 3 *– Petroleum products and applications*

3.1.2 Manufacturing processes

As explained in the previous section, the derivatives obtained from the petroleum refining are quite diverse. They take physical states ranging from gases for the smallest chains to liquids or solids in the case of the longer chains. The refining process consists in separating the different kinds of hydrocarbons mixed in the crude oil through different steps:

i. Crude oil distillation: primary separation ("topping units")

ii. Conversion: further processing of the streams coming out of the distillation tower ("conversion units")

iii. Final treatment and blending: manufacturing of final products

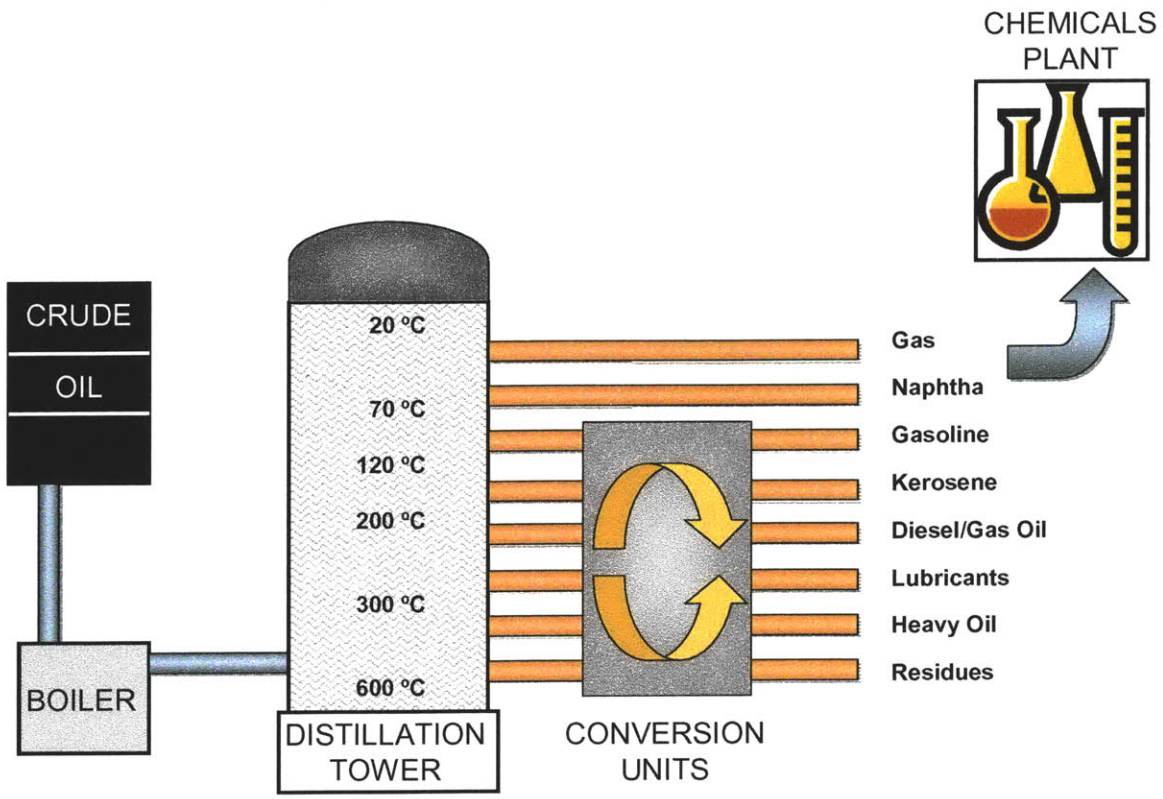

Figure 4 – *Petroleum refinery basic configuration*

3.1.2.1 Crude oil distillation

After eliminating some impurities in the crude oil (salts, sulphur, metals) and using the different boiling points of the different components of the crude oil, the atmospheric distillation process allows the refiner to separate them into different cuts. This is the first and most important process in any refinery. Additionally, a refinery may have a second distillation tower used to process some of the heavier streams coming out of the atmospheric distillation tower. This second unit (vacuum distillation tower) uses reduced pressure conditions to further the process of separation of the different components.

3.1.2.2 Conversion

After the first distillation, the available streams can be further processed to obtain other fractions. One of the possible operations is the transformation of long hydrocarbon chains in shorter ones. In fact, the first distillation barely creates any final product that could be economically sold into the market. Refiners use these additional units to improve the yield of crude oil on the most valuable products and try to match market demand.

The main conversion processes are:

i. Cracking

Cracking units break large hydrocarbons chains into smaller pieces using either heat (thermal conversion) or catalysts (catalytic conversion). The thermal cracking can be done by using steam (usually to obtain petrochemical products as ethylene and benzene), visbreaking systems (by lowering the viscosity of crude oil or topping streams) or coking techniques (by separating residuals from other refinery units into naphtha, gasoline and heavy oil and obtaining petroleum coke as a byproduct).

In the case of the catalytic process, a catalyst is used to facilitate the chemical reactions. There are two basic types of catalytic conversion plants:

- FCC units (fluid catalytic conversion), where using a hot and fluid catalyst, diesel and especially gasoline are obtained

- Hydrocracking units, in which adding hydrogen to the catalyst at lower temperatures and higher pressure, the refiner obtains middle distillates (diesel, kerosene) and gasoline.

ii. Unification

Another family of processes used in petroleum refining is the opposite of cracking, namely creating bigger molecules. The main unit in this group is the catalytic reforming, which uses a catalyst to transform light streams coming out of the distillation tower into chemicals or components for the gasoline blending pool.

iii. Treatment Processes

In this case, the unfinished products are treated to remove or separate undesirable components before formulating the final products. This can involve dissolution, absorption, or precipitation using a variety of processes including desalting, drying, hydrodesulfurizing, solvent refining, sweetening, solvent extracting, and solvent dewaxing.

3.1.2.3 Final treatment and blending

Once the different components have been distilled and processed, the final products (gasoline, kerosene and jet fuel, diesel oil, heating oil, lubricants and others) are created by combining the appropriate quantity of different streams.

Each refinery has at least one primary distillation tower and a different array of conversion units going from the simplest topping configuration (only with a distillation tower) to very complex configurations with a variety of conversion units. As a rule of thumb, the more

complex the refinery the higher the margins that can be extracted as the final products generated have higher values in the market. How to operate the refinery, what product yield to generate, and what plant configuration to build are decisions at the heart of competitive advantage in the downstream industry.

In addition to these elements intrinsic to the refinery, there is a second important component of the margin of the refinery operations linked to the geographical location of the plant. Most petroleum products are commodities widely traded. The main market references for petroleum products are located in certain geographic areas (ARA: Amsterdam-Rotterdam-Antwerp, US Gulf Coast and Singapore) and therefore the value of the products of any given refinery will be also linked to the place where it is located, as the products will be priced by reference area and transportation costs considered (Favennec, 2001).

3.1.3 Crude oil sourcing decisions

A key issue in the petroleum downstream supply chain is the procurement of raw materials for the refining units, especially crude oil. The market price of the crude oil is essentially based on two parameters: density and content of sulphur. The premiums or discounts applied to the international benchmarks (mainly Brent, West Texas Intermediate and Dubai grades) are based in those two qualities and also in the particular yield of products that can be obtained from a particular crude oil grade after processing. Refiners have to make the tradeoff between investing in more sophisticated units in the refineries or buying more expensive crude oils that do not need so much transformation to generate better margins.

i. Density

Crude oil grades may be classified as heavy or light depending on their density. Lighter crudes are usually considered of better quality as they contain a greater amount of high value final products (the value of the products is in general better for the lighter ones). Depending on supply and demand factors, refinery configurations, or the relative prices of different final products, the differential of heavy versus light crudes may vary widely.

ii. Sulphur content

This is a very important parameter in a crude oil from the point of view of processing and quality of the final products. Most countries are moving towards very low levels of sulphur in the fuels because of environmental reasons.

In addition to crude oil, other low volumes of different raw materials are introduced either in the distillation tower or during the blending process to meet final product quality specifications.

The trend has been a shift towards the use of heavier crude oils. This may seem contradictory with the better yields and the cleaner character of lighter oils. However, the increasingly attractive price of heavy oils and growing production has made them the input of choice for many refiners. This bigger discount in price when compared with lighter grades has made the tradeoff of quality versus processing costs/lighter yield increasingly attractive for heavy crude oils. In addition to this fact, the average quality of the oil produced worldwide has become heavier, adding new barrels of this type into the market, even if this fact has been

sometimes mitigated by the supply cuts of OPEC (Organization of Petroleum Exporting Countries), usually affecting the heavier and cheaper barrels.

3.1.4 Petrochemicals

In many cases, refineries are integrated with nearby petrochemicals plants. This integration allows both plants to exchange streams: the petrochemical facility receives streams of raw materials from the oil refinery and the refinery receives back streams from the petrochemical plant that can be used again for petroleum products (e.g., gasoline blending). The petrochemicals plants produce high value products like ethylene, propylene, styrene, butadiene and benzene. Furthermore, these so-called base petrochemicals can be transformed again into other products like high density polymers (plastics, PVC, polystyrene, polyethylene, polypropylene), elastomers and aromatics-based products.

3.1.5 Distribution and marketing

This part of the petroleum supply chain comprises the transport of finished fuels from the door of the refinery to consumers and the sale of the products either in bulk or in small quantities in gas stations.

The distribution of finished products is made by pipeline, tanker, truck, rail or barge. The quantities transported are smaller (typically 10 to 50,000 tons) than in the case of crude oil (generally over 100,000 tons) and therefore the economies of scale are less important than in the case of bigger crude oil tankers.

Sales may target the direct delivery to big consumers (e.g., heating oil, heavy oil for power plants) or the retail selling through a network of service stations. In the case of the

network of service stations, fuel retailing is a well differentiated part of the business where marketing strategies are critical. Fuel retailing is similar in some aspects to the consumer products goods industry. Therefore, this part of the business presents rather different challenges in supply chain than the refining or upstream activities, less focused on final consumer needs.

3.2 Historical revenues, operating margins, and employees

The petroleum industry has been growing recently as a result of different factors, like the increasing demand of products, particularly in the case of China and India (NPC, 2004). The following tables and charts show the evolution of different magnitudes for the major non-public companies in the US.

In the Table 1, we can see the 2004 revenues for the biggest US petroleum companies and the evolution from 2003 to 2004.

Million US$	Revenues	% 04-03
EXXON MOBIL	291,252	27%
CHEVRONTEXACO	147,967	29%
CONOCOPHILLIPS	121,663	22%
VALERO ENERGY	53,919	45%
MARATHON OIL	45,444	22%
SUNOCO	23,226	46%
AMERADA HESS	17,126	18%
PREMCOR	15,335	74%
TESORO PETROLEUM	12,139	39%
MURPHY OIL	8,634	62%
FRONTIER OIL	2,862	32%
GIANT INDUSTRIES	2,513	37%
HOLLY	2,246	60%
US PETROLEUM INDUSTRY	**744,326**	

Table 1 *– Annual revenues (Source: Fortune 2005 and ExxonMobil Annual Report)*

In Table 2, we have the net income for the same list of companies.

Million US$	Net Income	% 04-03
EXXON MOBIL	25,330	18%
CHEVRONTEXACO	13,328	84%
CONOCOPHILLIPS	8,129	72%
VALERO ENERGY	1,804	190%
MARATHON OIL	1,261	-5%
SUNOCO	605	94%
AMERADA HESS	977	52%
PREMCOR	478	310%
TESORO PETROLEUM	328	331%
MURPHY OIL	701	138%
FRONTIER OIL	70	2059%
GIANT INDUSTRIES	16	45%
HOLLY	84	82%
US PETROLEUM INDUSTRY	**53,111**	

Table 2 *– Annual net income (Source: Fortune 2005)*

Finally, in Table 3, we have the number of employees and we can note a movement in the industry towards the reduction of the working force as part of efficiency gains.

Million US$	Employees	% 04-03
EXXON MOBIL	85,900	-3%
CHEVRONTEXACO	56,000	-9%
CONOCOPHILLIPS	35,800	-8%
VALERO ENERGY	19,797	1%
MARATHON OIL	25,804	-4%
SUNOCO	14,200	-5%
AMERADA HESS	11,119	-3%
PREMCOR	2,300	30%
TESORO PETROLEUM	3,640	2%
MURPHY OIL	3,982	16%
FRONTIER OIL	731	-2%
GIANT INDUSTRIES	2,235	-1%
HOLLY	845	15%
US PETROLEUM INDUSTRY	**262,353**	

Table 3 *– Number of employees (Source: Fortune 2005)*

3.3 Evolution of top 5 companies in it

The industry has seen a wave of consolidation in the last ten years and has led to the current panorama of big oil majors, mainly ExxonMobil, BP, Royal Dutch Shell,

ChevronTexaco, Total, and ConocoPhillips. Further consolidation is still possible and will probably be centered around the acquisitions of smaller companies by the big majors or the combination of medium-size regional players to compete in the global arena (DB, 2004).

In Table 4 we offer the world ranking of refiners by installed capacity in 2003. This capacity had small variations over the last few years in the OECD countries, and the main expansions have been centered in the Asia Pacific region.

Total Ranking	Non-NOC Ranking	Company	Topping Capacity Mill. bbl/d (2003)	% Total
1	1	EXXONMOBIL	5.4	7%
2	2	RD SHELL	4.5	6%
3	3	BP	3.2	4%
4		SINOPEC	2.7	3%
5		PDVSA	2.7	3%
6	4	CONOCOPHILLIPS	2.6	3%
7	5	TOTAL	2.5	3%
8	6	CHEVRON TEXACO	2.4	3%
9		SAUDI ARAMCO	2.1	3%
10		PETROBRAS	1.9	2%

NOC: National oil companies; bbl/d: barrels per day

Table 4 *– Worldwide refining capacity (Source: Oil & Gas Journal 2004)*

3.4 Customer segments and sales channels

As stated before, the petroleum downstream industry serves basically two types of customers:

- Wholesale customers, composed by petrochemical facilities, power plants, big fuel consumers (airlines, shipping companies) and other industrial customers.
- Retail customers, who use the fuels essentially for transportation and domestic heating.

In the case of fuel retailing, the main channel is the network of service stations. A first categorization for different types of gas stations is branded or non-branded, depending on

whether the gas station is using the brand image of one of the major integrated oil companies or not. Additionally, we could classify the types of branded gas stations in five categories depending on the different combinations of the ownership of the physical assets and the management of the actual operations:

- CoCo – Company Owned Company Operated. These are the gas stations where the oil company (usually a major oil company) owns the assets and controls the operations through its own employees.
- CoDo – Company Owned Dealer Operated. In this case, the oil company is the owner of the gas station assets, but the operations are delegated to another entity through some kind of contract.
- DoDo – Dealer Owned Dealer Operated. Here the oil company may just decide to offer the brand and operate the gas stations through franchises.
- DoCo – Dealer Owner Company Operated. Similarly, the owner may ask an oil company to run the operations of its assets.
- Independent – The owner of the gas station has no link with any oil company.

The oil companies try to differentiate their gas stations by offering mainly two kinds of focuses:

- Service-focused: offering premium services (e.g., high quality convenience stores, mechanical repairing) or products (e.g., gasoline with high performance additives) and loyalty programs

- Price-competitive (e.g., hypermarkets): in this case the main competitive advantage is low price in the fuel and the focus is on maintaining operating costs as reduced as possible.

3.5 Industry & supply chain structure

The downstream petroleum supply chain can be characterized as a global supply-driven structure with the main following actors:

- Suppliers of crude oil: as a natural resource the crude oil is located in certain areas of the World that usually are far from the main consuming countries, mostly the OECD (Organisation for Economic Co-operation and Development) members. An important part of the crude oil supply and reserves is concentrated in the hands of a cartel: OPEC (Organization of Petroleum Exporting Countries).

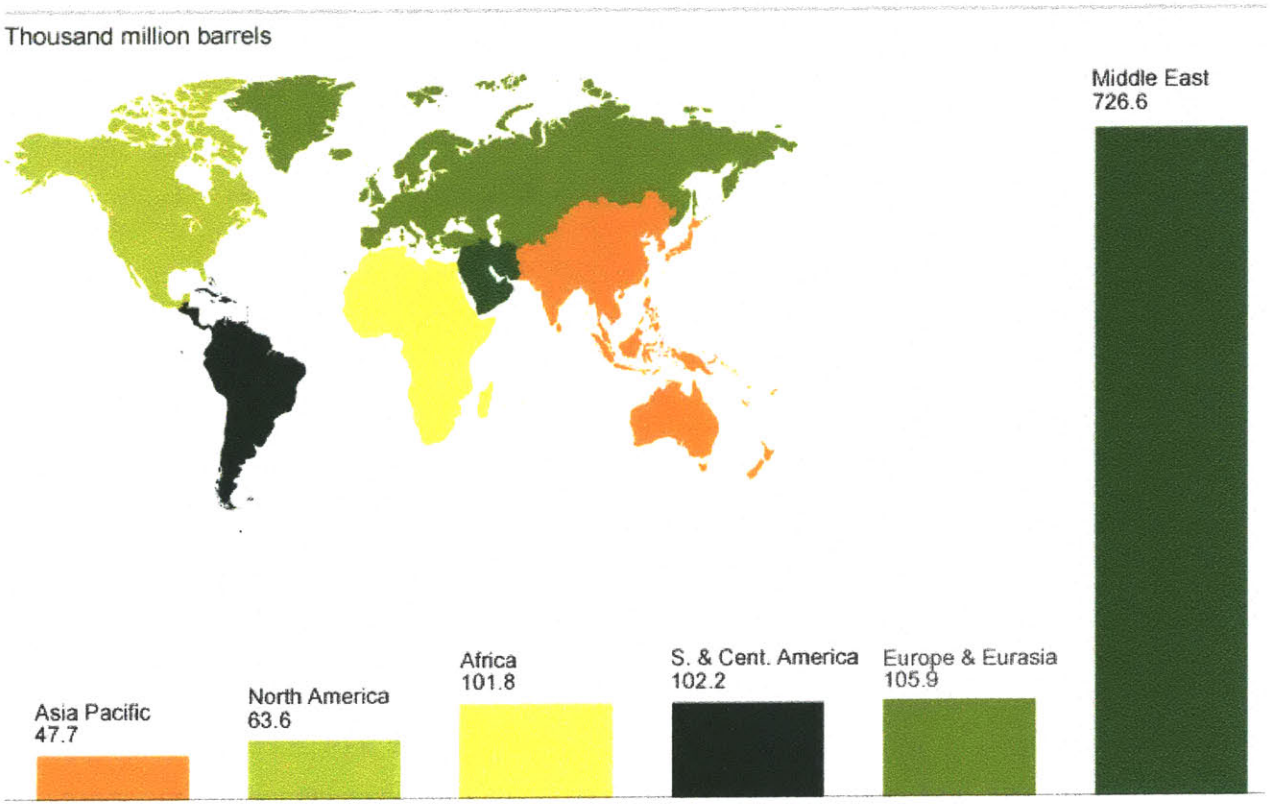

***Figure 5** - Proven oil reserves (Source: BP Statistical Review of World Energy 2004)*

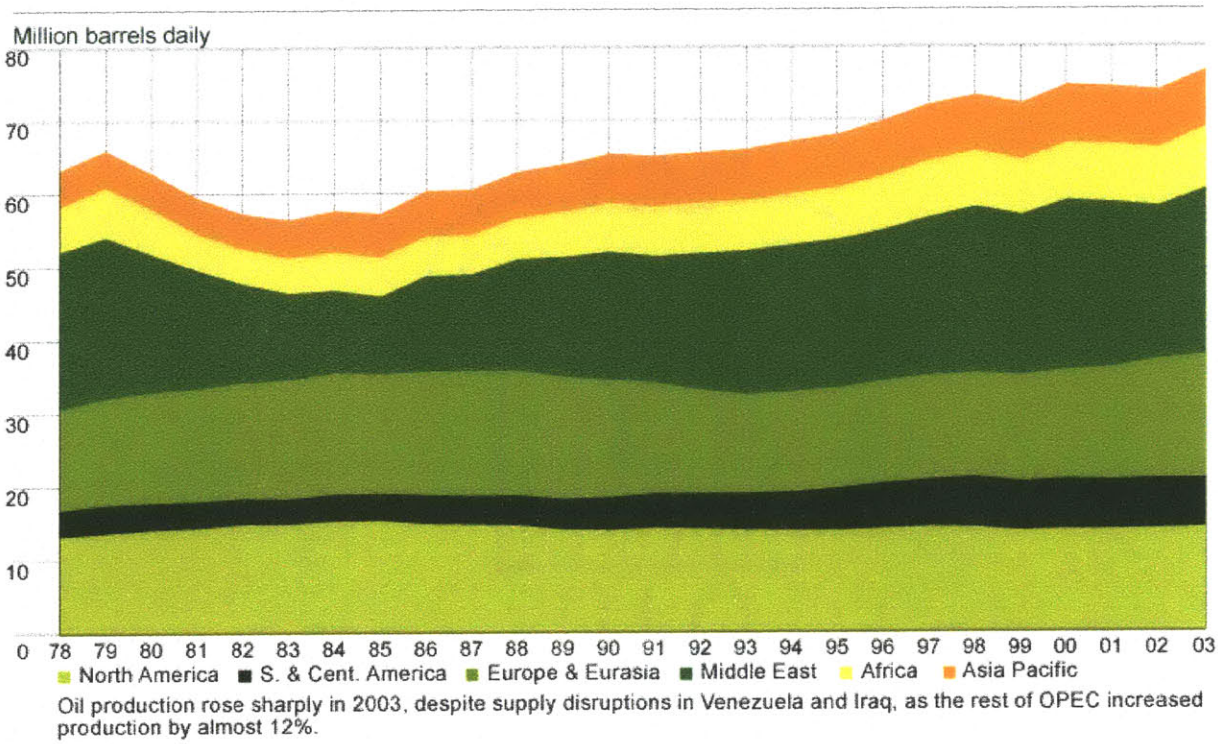

Figure 6 *- Oil production by area (Source: BP Statistical Review of World Energy 2004)*

- Refiners: with plants located all over the world and closer to final consumers. The main reason for this fact is the economies of scale of transporting crude oil in big supertankers versus transporting the final product in smaller lots, and the strategic value of the refining assets. This latter fact makes governments prefer having some of the refinery operations in their territories.
- Consumers: as stated before they are divided into small consumers (e.g., car owners buying gasoline) and wholesale consumers (e.g., power stations using heavy oil, petrochemicals plants receiving feedstock).

These actors are involved in the main activities that configure the downstream supply chain:

- Oil Supply & Trading: these activities deal with the procurement of raw materials and bulk sales of products in commodity markets. In the case of crude oils, for each of the available grades, it is necessary to assess the price, quality, timing, and distance to the refinery in order to decide the optimal acquisition. Additionally, the refiner has to carefully monitor the price risk and manage the inventory.
- Manufacturing: the procedure of designing and building the appropriate technical configuration is vital. Moreover, the refiner needs to plan and schedule production levels, and finally manage the efficiency and safety of all operations.
- Distribution: similar to the refinery case, 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 (either by truck, tanker, rail, pipeline or barge).
- Sales & Marketing: in the last step of the supply chain, managers are confronted with pricing decisions, the use of efficient tools for demand management, and the seizure of market opportunities in an increasingly competitive environment.

3.6 Trends and industry drivers

The downstream industry is usually characterized as a mature, rather competitive, and complex industry (Hackworth, 2004; Roeber 1994)

In particular, a part of this supply chain, petroleum refining, is at the center of value creation and has presented the biggest challenges and drawn most of the attention of managers in the downstream supply chain:

- As stated previously, the prices of the raw materials and the final products are highly volatile when compared to other commodities.
- The industry is highly capital intensive (a medium-sized refinery may cost up to $3 billion) and is usually subject to cycles of profitability, yielding frequently lower returns on investment than other petroleum businesses. This creates periods of unbalanced investment.
- The supply chain decisions are conditioned by some industry-specific factors:
    - frequent "make versus buy" decisions that change continuously as a function of prices and transportation costs (commoditized market)
    - a supplier base (mainly crude oil producing countries) with extensive negotiation power
    - complex inventory decision-making given the volatility in prices

There are some additional factors that make refining operations particularly challenging:

- The necessity for scheduled maintenance and overhauls in refineries, and the occurrence of unscheduled breakdowns
- The competition from new fuels in the long term such as natural gas, biodiesel, or fuel cells
- The increases in productivity are incremental and most low-hanging fruit has been harvested, making further improvement more difficult and requering significant investment in existing refinery equipment, processes, and practices.

Moreover, other parts of the downstream supply chain add to the overall complexity. For example, other factors include the operation of an extensive logistical infrastructure and compliance with constantly changing product quality specifications.

3.7 Supply chain challenges and opportunities

Due to the complexities and issues described in the previous sections, the downstream oil business as a whole faces a series of challenges that surfaced through different interviews with industry experts and are widely cited in the literature.

In many of the geographical areas, fuel demand growth is weak. However, product 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.

The quality issues are becoming especially constraining as the new fuels specifications demand more complex processing and expensive investment in new equipment. These investments do not always provide an attractive return but are in many cases required to keep the refinery operating. In the case of the US, for example, the varying state-by-state standards have led to a "boutique" market (more than 140 different standards in 2001 according to ExxonMobil). Nevertheless, the quality compliance complexity offers an opportunity for differentiation, and even brand building around some of the chemical characteristics of the fuels.

The environmental regulations and compliance rules (greenhouse effect gases emissions, soil pollution, etc) are also becoming increasingly severe, making the operation of the existing facilities or the construction of new ones even more expensive and intricate. Moreover, the liabilities in case of environmental damage and public image vulnerabilities are becoming big hurdles for the industry.

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).

If we consider the cost structure of the industry, the oil downstream has been significantly reducing operating costs for the last 25 years as can be observed in Figure 7. However, this cost reduction has not been reflected in better net margins as there has been a continuous and nearly parallel pressure also in gross margins. As a result, the net margins have remained consistently below $2 per barrel in the US until 2001, even during periods of high oil prices (EIA, 2003).

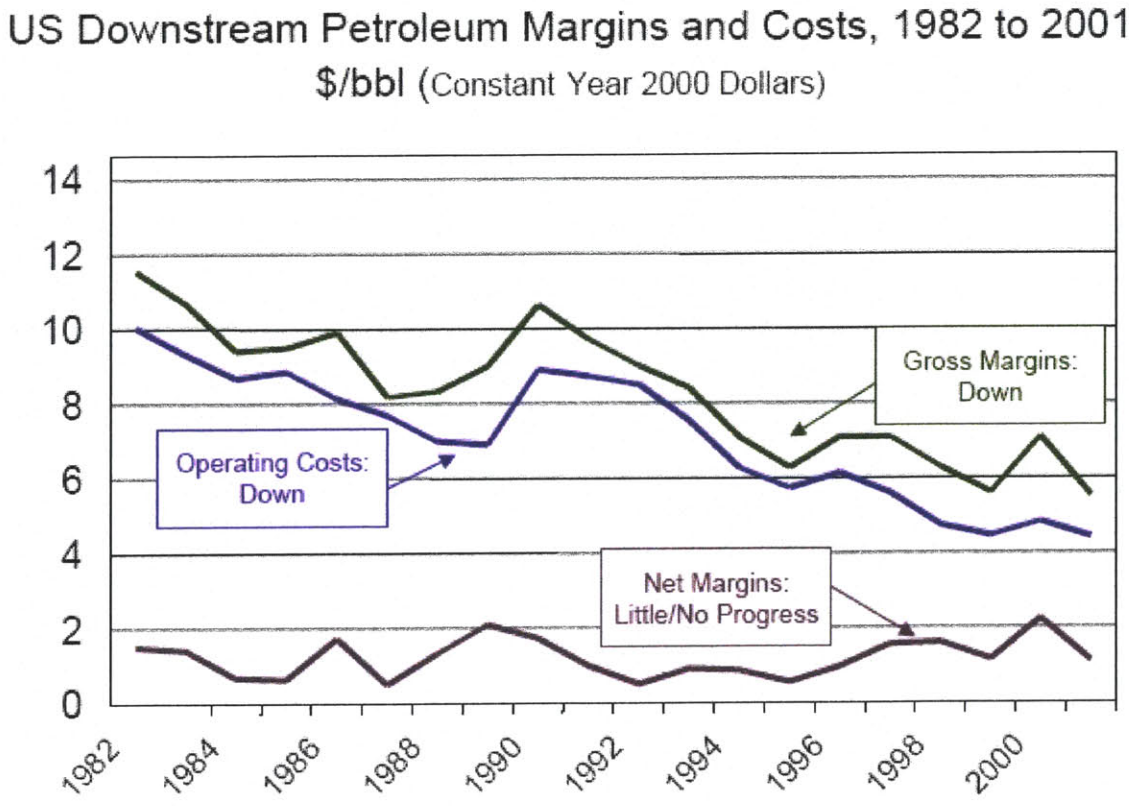

***Figure** 7 – US downstream costs evolution (Source: Energy Information Administration 2003)*

The industry had continued efforts in cost reduction and increased efficiency but has been limited until now by some characteristics of downstream supply chain operations:

1. Limited flexibility as (for example) the raw materials lead times are long (typically a crude oil cargo will take several weeks to arrive to the refinery) and the planning process spreads over several months.

2. The integration of the complete supply chain from crude oil supply to marketing at the pump is still missing as a result of a long-established silos approach. Generally, the optimization tasks (typically using linear programming tools) are focused around refinery scheduling as an island.

3. The stock decisions are rarely based on a global supply chain optimization, but dictated by constraints of storage, and the minimization of the huge working capital and risk involved.

In order to improve the profitability of the industry and go into a new era of significant efficiency improvements, a more integrative supply chain is essential (Mowat, 2004). Moreover, the transition to a more holistic supply chain view will need 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).

4 ExxonMobil position in the industry

ExxonMobil is currently the world's largest non-public oil company in terms of sales ($291.3 billion in 2004), profits ($25.3 billion in 2004) and market capitalization ($380 billion in February 2005). The company is the result of the merger of Exxon and Mobil in 1999 and counted 85,900 employees at the end of 2004 (ExxonMobil Annual Report 2004).

ExxonMobil is a vertically integrated oil company present in the entire oil supply chain, including the upstream and the downstream. Its main strategy focus is on the segment of the business offering the highest returns, upstream, basically formed by the activities of geological exploration and production of hydrocarbons. On the other hand, the downstream activities are seen as valuable cash generators and as instruments to control the full value chain of oil from production to the final consumer.

As stated in its strategic statements and presentations, after the merger of Exxon and Mobil the preference of the company is centered on organic growth, and the main strategic objectives of the company are:

- Growing by focusing on the upstream and gas & power business units
- Pursuing a higher integration and enhancing the efficiency of the downstream activities
- Increasing its business presence in Asia and particularly in China

The merger of Exxon and Mobil in 1999 took place in a context of consolidation in the industry in the late 1990s (Cibin & Grant, 1996; Davies, 2000). Low oil prices at that time

increased the need for cost reductions that could be achieved through economies of scale and resource sharing.

The oil industry is characterized by its global scope and the international dimension is unavoidable as a result of the locations of reserves and the globalization of commodity markets. The traditional vertically integrated structure of the industry has evolved during the last few years and intermediate echelons in the supply chain have appeared (Stevens, 1998; Elgar, 2003). However, the development of intermediate echelons has coexisted with the consolidation of a reduced number of large oil companies ("majors").

The nature of the pricing of the crude oil and products has moved progressively towards a more financial approach (forward and futures markets) versus the traditional spot or OTC (over the counter) physical markets. The volume of oil futures trading has been steadily increasing and it is several times higher than the physical transactions (New York Mercantile Exchange data, 2003).

As indicated previously, the important variation of the prices generates an instable environment for the activities of oil companies. In the case of a steep rise in prices, the upstream usually gets better returns, but the downstream may suffer a margin squeeze as the increase in raw materials price might not be transferred easily to the fuel retail price.

Moreover, the petroleum industry is heavily influenced by the general level of economic growth. As an example, the Asian financial crisis of the late 1990s created an overall depressed market that made oil prices go down to levels of $10 per barrel (Elgar, 2003).

In this context, other significant mergers of petroleum companies trying to gain size were the unions of BP, Amoco and Arco; Total, PetroFina and Elf; Chevron and Texaco; and Conoco and Phillips Petroleum. Additionally, the market has seen the emergence of efficient and agile

small refining and marketing companies in the US and Europe (e.g., Petroplus in the Netherlands). In this environment, ExxonMobil became a world-class reference in the oil business and epitomized the search for integration, scale and efficiency (Davies, 2000).

The merger of Exxon and Mobil allowed the further development of the combined upstream portfolio with new projects in both oil and gas, especially in offshore and Middle East locations (ExxonMobil, 2005). As for the downstream, and consistently with the acknowledged company strategy, the focus was centered on the increase of the operational efficiency and discipline in new investments. As an example of actual developments after the merger, the fuel marketing strategy became more customer-focused aiming at leadership in the industry.

4.1 Historical company revenues, operating margins and employees

ExxonMobil financial results during the last five years are reflected in Table 5:

US$ million	2000	2001	2002	2003	2004
Revenues	232,737	212,785	204,506	246,738	291,252
Net Income	17,720	15,320	11,460	21,510	25,330

Table 5 *– Financial results (Source: ExxonMobil)*

As we can see, the last three years have followed a path of increasing revenues and benefits after a global industry downturn in 2001 and 2002.

The number of employees at the end of 2004 was 85,900 and has followed an overall decreasing pattern over the last several years, especially after the merger in 1999.

4.2 Business units

ExxonMobil operates functional businesses and service organizations on a global basis. Figure 8 depicts the structure of the company.

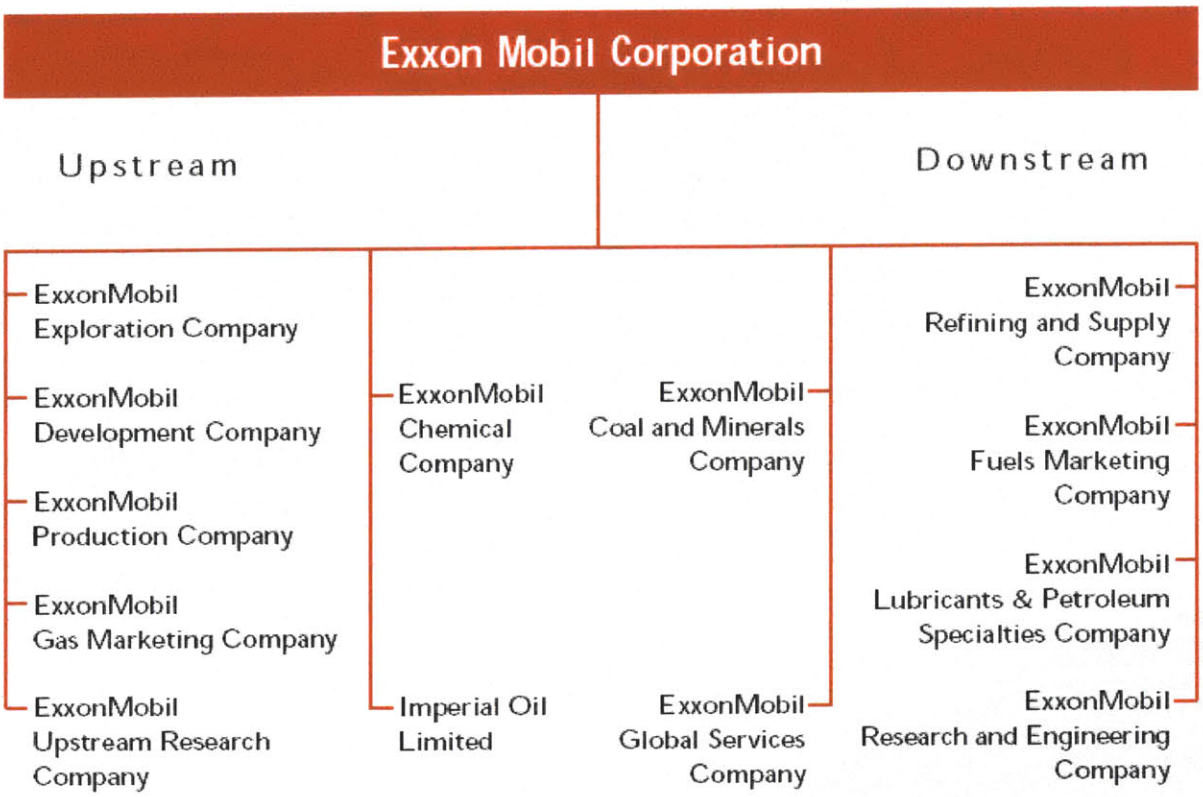

Figure 8 – *ExxonMobil Organizational Structure in 2004 (Source: ExxonMobil)*

4.3 Products and services

ExxonMobil's downstream business units focus on providing finished products and feedstocks to their customers, mainly through its distribution and marketing organizations. The refining is done using an asset base that includes an ownership interest in 45 refineries, located in 25 countries, with distillation capacity of over six million barrels per day and lubricant base stock manufacturing capacity of 145,000 barrels per day. (ExxonMobil, 2003).

A global supply organization coordinates and optimizes the supply of crude and feedstock to the refineries, the mix of products manufactured, and the working inventory levels. The supply organization also manages a global logistics system that includes an ownership

interest in 32 crude oil and petroleum product tankers, more than 25 thousand miles of pipelines, and over 300 major petroleum product terminals (ExxonMobil 10K, 2003).

ExxonMobil's fuel marketing business portfolio tries to meet the needs of local consumers over the world through the execution of globally common, consistently applied business processes, marketing programs, and best practices. With operations in over 100 countries on six continents, fuel marketing serves a globally diverse customer base.

Table 6 summarizes the main physical magnitudes of ExxonMobil's activities in thousands of barrels of oil per day, covering the upstream net liquids production, and the downstream refining throughput and final product sales:

kbbl/day	2003	2002
Net liquids production		
United States	610	681
Non-U.S.	1,906	1,815
Total	2,516	2,496
Refinery throughput		
United States	1,806	1,834
Non-U.S.	3,704	3,609
Total	5,510	5,443
Petroleum product sales		
United States	2,729	2,731
Non-U.S.	5,228	5,026
Total	7,957	7,757

Table 6 *– Physical volumes of ExxonMobil operations (Source: ExxonMobil 10K)*

4.4 Sales channels and customers segments

As we indicated before, the main types of customers in the industry are wholesale and retail clients. In the case of Exxon Mobil retail, the network of gas stations has been reduced from 48,000 pre-merger sites to 38,800 in 2003. The underlying strategy of this move is trying to eliminate non-performing points of sale and increase the sales of the remaining (ExxonMobil, 2004).

The Exxon, Mobil, and Esso brands are used in the service stations around the world and also provide over one million industrial and wholesale customers with branded fuel products. In addition, fuel products and services are provided to aviation customers at more than 700 airports and to marine customers at more than 300 marine ports globally.

4.5 Top competitors and positioning against them over time

The main competitors of ExxonMobil in the downstream are the big major integrated petroleum companies: BP, Royal Dutch Shell, ChevronTexaco, Total and ConocoPhillips. Additionally, there are other significant competitors of regional scale or playing only in the downstream part of the business: Valero Energy, Sunoco, Marathon Ashland, Amerada Hess or Citgo

The ExxonMobil vision of downstream as a secondary activity or cash generator more than a primary growth area, motivates its focus on:

- Using best in class operating systems
- Maintaining a strict investment discipline
- Clearly focusing on cost improvements in both refining and retailing
- Evaluating profitability for each retail site and not only for the global network

- Pursuing an effort of constant reduction in logistical assets and inventory levels

The actual organization of the activities tries to serve this philosophy using a structure where activities are organized in functional lines which regroup all geographical operations. In Figure 9 we represent the current organization of the refining, distribution, and marketing activities.

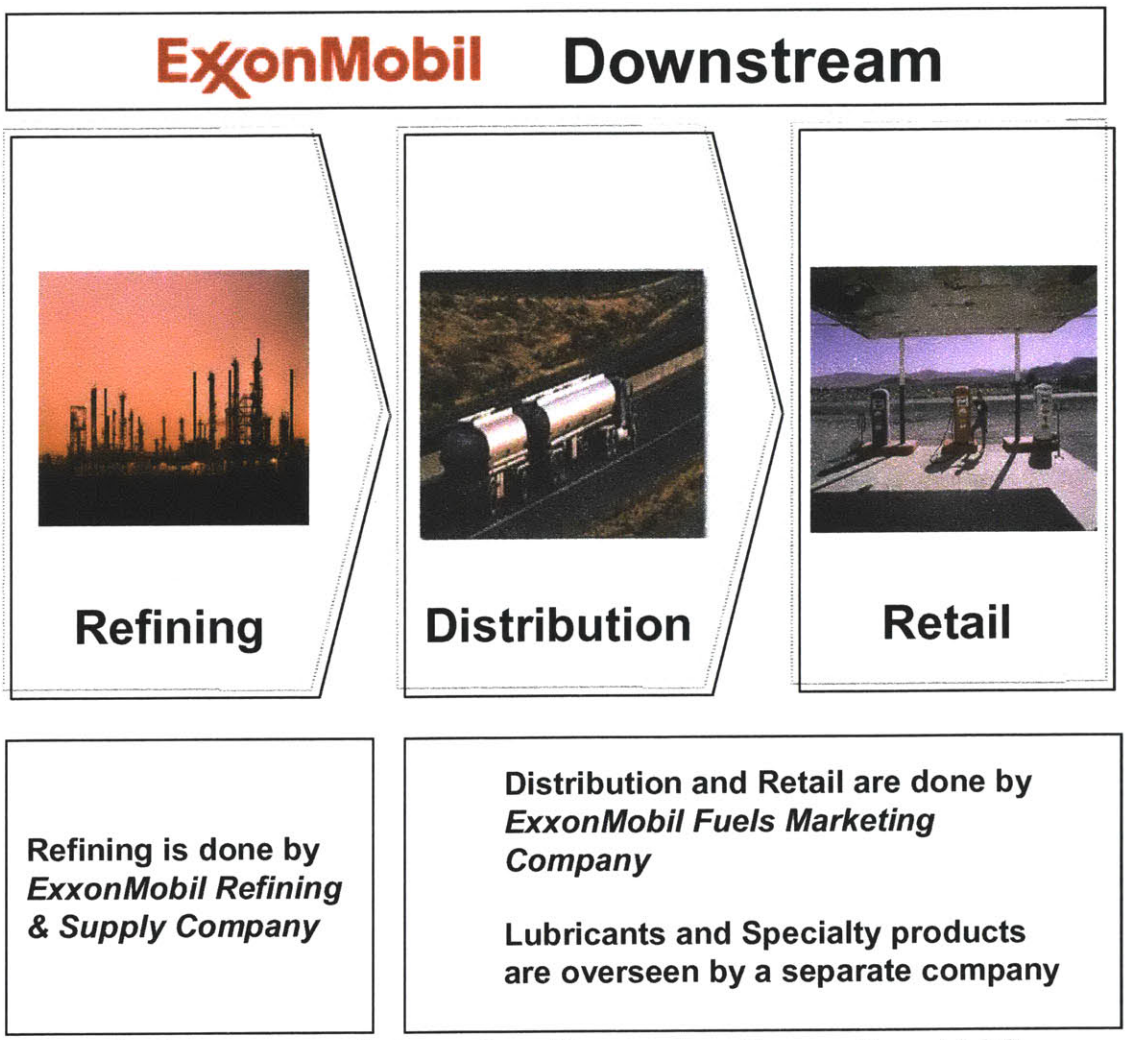

Figure 9 *– Downstream refining and retailing structure (Source: ExxonMobil)*

Some of the tangible measures ExxonMobil has started in the marketing part of the business to increase per site efficiency are:

- raising per-site sales volumes
- increasing non-fuels income and sales of higher-margin fuels
- standardizing procedures across the globe (create a global retail "template" for gas stations and convenience stores)
- outsourcing retail project development and construction
- centralizing customer service centers and other support functions (relocation to Eastern Europe and Malaysia)
- developing customer loyalty programs (e.g., Speedpass)
- developing automation and self-service sites
- creating new alliances with retailers (e.g., Tesco in the US, 7-Eleven in Japan)

5 ExxonMobil's Main Issues in Downstream Supply Chain

The main goal of Exxon Mobil's strategy for the downstream is to preserve its existing downstream competitive advantage.

5.1 Analysis of downstream supply chain strategy

ExxonMobil identifies its existing downstream competitive advantage in four areas (ExxonMobil, 2004):

- Scale: being the largest downstream operator in the world and having the largest refineries
- Integration: creating a global functional organization and leveraging the scale via integration: among the different units in the refining sites; between refining and petrochemical plants (80% of plants are now integrated); among neighboring refineries (clusters); and with other business segments
- Technology: focusing on the development and application of proprietary technology and the reduction of capital and operating costs
- Brand: creating and maintaining superior brand identities

5.2 Porter five forces analysis in the case of fuel retailing

Michael Porter's five forces model provides a useful perspective for assessing and analyzing the competitive strength and position of a corporation or business organization in a

particular industry. Porter's framework is focused on analyzing five issues that shape the competitive panorama in the studied industry: existing competitive rivalry, threat of new market entrants, power of buyers and suppliers, and threat of substitute products. Figure 10 shows the graphic representation of Porter's framework:

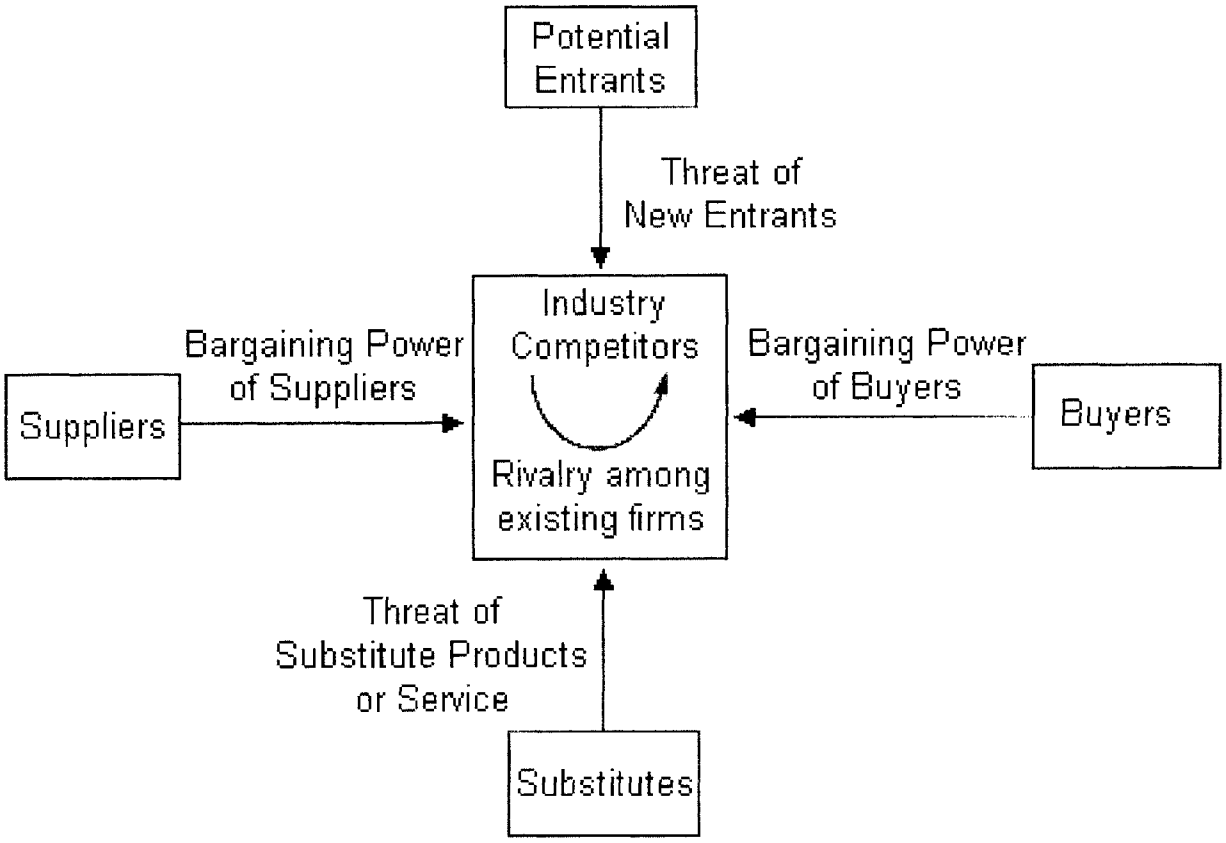

Figure 10 *– Porter five forces model diagram (Source: Porter 1980)*

We will use this framework as a tool to study a part of the downstream supply chain: fuel retailing. This framework is particularly appropriate for obtaining a global overview of the current and future dynamics of fuel retailing. The objective is to get a vision of the overall competitive landscape and a better understanding of the particular positioning of ExxonMobil in

this crucial part of the supply chain. The scope of the analysis will be the main markets of the industrial countries (with special focus on North America and Western Europe). The analysis would be different for smaller or very specific markets.

In Figure 11, we summarize the results of this analysis for the fuel retailing industry sector and in the next sections we offer a detailed explanation of the character of each of the forces shaping the competitive landscape of the industry.

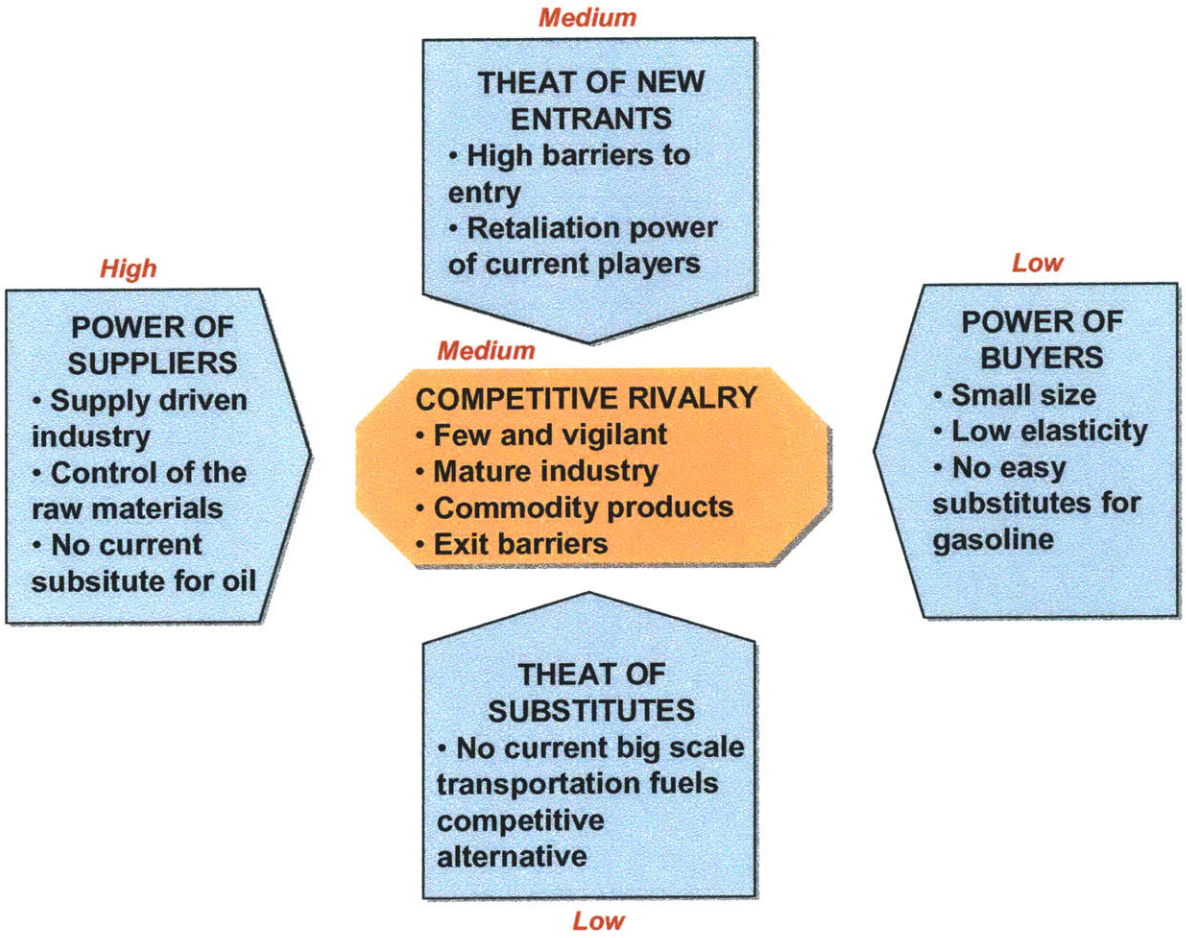

Figure 11 – *Porter five forces diagram for fuel retailing*

5.2.1 Threats of entry

First, the threats of entry are identified. In this case, this risk is medium since even if entry into the industry is not straightforward, there are some counteracting factors that make the entry easier than before (e.g., increased deregulation)

The main deterrents to any new potential entrant in the industry are:

- Important barriers to entry:
    - Heavy regulations in environmental compliance requirements, quality standards, limits on the number of gas stations or price setting.
    - High capital requirements as initial expenditures or working capital for fuel stocks
    - Need of a specialized and wide logistical infrastructure
    - The operations in this industry are subject to important economies of scale as a network of gas stations becomes bigger
    - The supply of the product itself is limited as alternative bulk suppliers are not always available. The local production or the import of products requires the control of regulated or very specialized assets (e.g., refineries, coastal tanks, pipelines)
- High reaction/retaliation power from existing competitors. The oil major companies have extensive financial resources allowing them to start large scale defensive mechanisms.

And the counteracting elements that progressively diminish the importance of the previous factors are:

- The increasing deregulation and privatization movements in many countries, making entrance for potential competitors easier than before.
- The powerful potential and current new entrants, as it is the case for big retailers like Wal-Mart or Carrefour. This market shift is particularly evident in Europe.

5.2.2 Power of buyers

In this case and as a result of the structure of the industry, this power is low because of two main factors (Pindyck, 2004):

- Low short-term elasticity of demand as gasoline is a non-durable good
- No demand aggregation as a result of a market formed by many small consumers

However, some compensating issues could make the buyer power higher in some cases:

- Products are undifferentiated and mostly commodities (even if the mentioned diversity of quality standards would weaken this)
- Buyers face few switching costs as they can easily find other gas stations
- Buyers might consider possible backward integration. An example would be the creation of farmer fuel cooperatives.
- The buyer has easy access to information and therefore can make optimal decisions about where to buy products

5.2.3 Power of suppliers

The industry presents powerful suppliers because of the following factors:

- The industry of petroleum is a supply driven industry and the suppliers control a scarce resource (crude oil). The raw materials supply is dominated to a important extent by a reduced number of big suppliers, some of them organized in a cartel (Masseron, 1990)
- Crude oil, the suppliers' product, has no current viable large scale substitutes. The use of other raw materials for the manufacturing of fuels for transportation is still not economically competitive.
- The supplier presents a significant threat of forward integration as it has important financial resources generated by crude oil sales. Some producing national oil companies like Petróleos de Venezuela (PDVSA) or Kuwait Petroleum Corporation have created refining and marketing branches in the oil consuming countries (Citgo and K8, respectively).

5.2.4 Threat of substitutes

The threat of substitutes for oil-based fuels is currently low, but new factors could potentially make the substitutes a serious threat in the mid and long term.

The main reason for the low current threat is based on the current non-existence of large scale alternatives to oil based fuels for transportation (main market for fuel retailing) offering a realistic price/performance trade-off

On the other hand new developments could change this scenario:

- Emerging technologies and innovations could create competitive substitutes to conventional oil fuels or reduce the consumption of the current products sold in service stations. Examples of these technologies would be hybrid cars, fuel cells

and biodiesel fuels. On the other hand, this could also create an opportunity for oil companies to leverage their existing logistical networks for the distribution of the potential non-oil based fuels.

- In the case of public transportation, the use of substitutes is more developed (e.g., compressed natural gas, hydrogen).
- With high prices of oil products, substitution effects and conservation efforts will increase. In this case, the substitute would not be another product but a reduction in oil products consumption either through lower use of current equipment or by using more efficient appliances.

5.2.5 Competitive rivalry

Finally, we study the internal rivalry in the fuels retailing sector and we find the current situation as being of intermediate rivalry. However, the trend is towards an increase in the competitive struggle. The current competitive landscape is a result of different factors:

- A relatively low number of big competitors looking after each other. Additionally, in some markets, other smaller players are increasingly becoming significant.
- Fuel retailing is a mature industry with a slow but constant rate of sales growth
- Fuels are basically commodity products that lack essential differentiation. However, companies try to differentiate their offers by offering premium services in their gas stations, developing customers loyalty programs and improving the quality of the products with additives.
- Fuel retailing has been suffering from excess capacity and low sales per site in some markets. This is particularly acute in Europe, where the process of

progressive reduction and consolidation of the number of sites is especially significant (e.g., in Italy).

- New non traditional rivals have entered fuel retailing, such as consumer products retailers like Wal-Mart or Carrefour.
- The industry is confronted with relatively high exit barriers as sites could face environmental liabilities or soil remediation charges.

Some companies use a multi-brand strategy, as is the case for ExxonMobil. Its fuel retailing supply chain is structured around two brands: Exxon/Esso (Exxon for the US market and Esso for the European market) and Mobil.

The two brands strategy in ExxonMobil's supply chain has a primary objective of segmentating the customers in two main classes. The respective brands objectives are:

- Esso/Exxon: "value" brand targeting price-conscious consumers
- Mobil: "performance" brand aimed at convenience-oriented consumers

Moreover, the different brands offer geographical complementarity as they have been used in different markets for many years:

- Mobil: well established in Asia and US
- Esso: well known in Europe and Latin America
- Exxon: widely established in the US

The products are manufactured in the same refineries and distributed using the same channels and the differentiation usually comes in the "last mile" of the distribution systems through the incorporation of additives to the basic fuels. Therefore, from a point of view of

supply chain management, this strategy allows ExxonMobil to take advantage of the structure of the market, proposing a diversified fuel retailing offer without duplicating the logistics network.

5.2.6 Conclusions of Porter's five forces analysis

The rivalry in fuel retailing is progressively increasing in some markets and the traditional barriers to entry are progressively being softened even if it is not probable that they will be completely removed. Fuel supply is strategic and highly political. Additionally, fuel taxes are an important part of the budget in many countries. All these factors provide an incentive for strong government regulations.

However, 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.

Finally, we would highlight that ExxonMobil's global downstream strategy is consistent with the previous analysis. Fuel retailing operations are part of the downstream operations of the company, and therefore are not seen as one of the major strategic priorities. However, they are valuable as a way of achieving vertical integration and generating cash for other activities. Moreover, the brand-segmented network of gas stations reinforces the company's image to the consumers.

Fuel retailing operations are therefore aligned with the global ExxonMobil downstream supply chain strategy, focused on costs reduction and efficiency gains, and a careful selection of new investments.

6 Conclusions

We would like to conclude this study with a summary of the analysis of the petroleum downstream supply chain.

First, we would highlight that this industry is confronted with an extremely challenging and highly volatile environment. The traditional silos approach prevalent in the industry has generated local suboptimal structures in the downstream supply chain. Even if much advancement has been made in the development of a true supply chain management culture, there is still much room for improvement. The industry cannot only rely on technology investments even if they are a basic condition of success. A more develop "pull" paradigm leading to more demand-driven operations will be needed to achieve significant profitability gains from supply chain enhancements.

Following this route, the industry will need to carefully align the supply chain structures and processes with the overall company strategy. As par of these efforts, a successful supply chain strategy development will need to carefully establish plans for process re-engineering, change management, and information technologies design and implementation (Lewin, 2003).

The actual progress will be dependent on a combination of the mentioned business process improvements and the channeling of existing expertise of industry professionals into a common effort for value creation.

Finally, we would like to suggest further areas that could be studied in more depth in this field:

- What are the change management tools that could be used to achieve the cultural change and the new supply chain paradigm shift in the petroleum downstream industry
- A detailed analysis of how the different software providers have dealt with the supply chain challenges described in the previous sections
- What best practices of other industries could be profitably adopted by the petroleum downstream and how they could be implemented

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