2
Refining Industry Overview

This chapter presents general information on refining industry. The goal is not to conduct an extensive review, but just build a knowledge base to allow a better understanding of the proposed planning models. The interested reader can refer to refining textbooks, Gary and Handwerk (1994) for instance, for further details.

The oil chain covers stages from oil exploitation to product distribution including a complex logistic network and several transformation processes that take place in refineries. The petroleum supply chain is illustrated in Figure 2. The activities that comprise the oil chain are divided into three major segments: upstream, midstream, and downstream. The upstream segment includes the exploitation and oil production. The midstream is an intermediate segment and consists of the refining activity which includes the transportation of oil from the production site to refineries. The logistical tasks necessary to move the refined products from the refinery to the consumer points are in the downstream segment.

Petroleum may be produced in exploitation fields of the company itself or be supplied from international sources. The domestic oil is sent by pipeline or oil tankers to terminals from where the oil meets the demand of the refineries or is exported. Crude oil obtained from international sources is transported by pipeline or oil tankers to the terminals. The domestic terminals are in charge of receiving and forwarding oils and refined products, whereas international terminals represent points of offer and demand for foreign oils and products. The oil terminals are then connected to refineries through a pipeline network. Crude oil is converted to refined products at refineries which can be connected to each other in order to take advantage of each refinery design within the network (Neiro and Pinto, 2004). Besides oil, the refineries may also receive natural gas from domestic or international suppliers. Natural gas producers can also directly supply the distribution bases that, in turn, supply the consumer market. The refined products can be moved along the logistic network by road, water, rail, and pipeline modes. Crude oil and refined products are often transported to distribution centers through pipelines. From this level on, products can be transported either through pipelines or trucks, depending on consumer demand points. In some cases, products are also transported through vessels or by train.

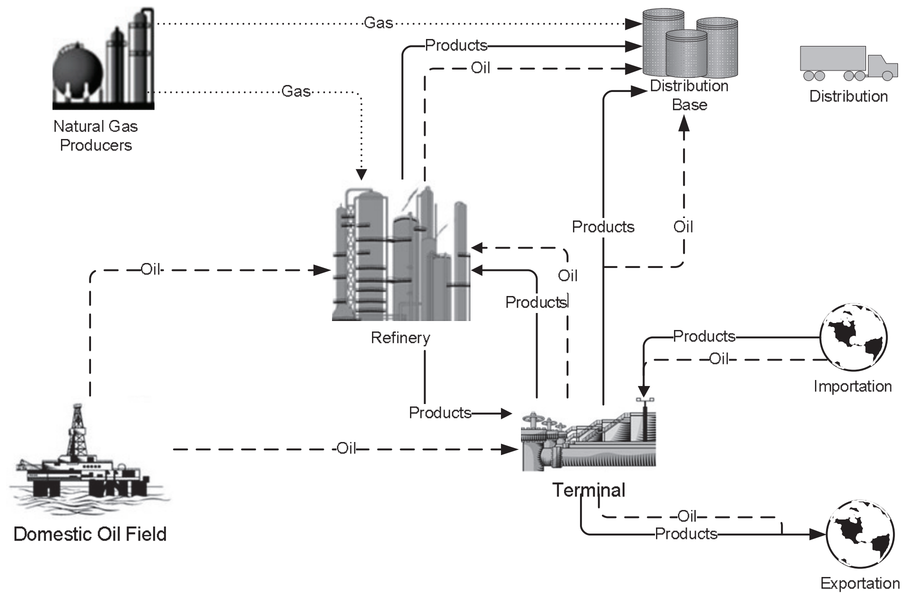

Figure 2. Oil supply chain (adapted from Ribas *et al.*, 2010)

Petroleum refinery is a central key and a crucial link in the oil supply chain (Khor and Elkamel, 2008). The main objective of a refinery is to transform crude oil into products of higher aggregate value, in addition to maximize the profit. The refinery produces light (propene, liquefied petroleum gas, gasoline, and naphta), medium (aviation kerosene, and diesel) or heavy (paraffin, lubricants, light cycle oil, gas oil, coke, and fuel oil) fractions, according to the length and complexity of their carbon chains. The refined products have many applications such as automotive fuel, aviation fuel, solvents, lubricants, asphalt, coke, and raw material for petrochemical industry. The production profile depends on the oil blending processed by the refinery. The American Petroleum Institute ranks the crude oil according to a density gradient that goes from light (less dense) to heavy (more dense), known as API index. The lower the oil density, the higher the API index and higher the commercial value of oil and the products produced from this type of oil. A planning model for oil refineries must allow for the proper selection of oil blending and consider an appropriate manipulation of intermediary streams to obtain the final products in the desired quantities and qualities.

The refinery processes the crude oil into marketable products through three main types of process: separation, conversion and treatment. Separation processes (crude distillation and vacuum distillation) are designed to separate the oil into its basic fractions (whose the yields depends on the oil processed) or to process a previously generated fraction to produce a specific group of components. Depending on the production targets, different conversions and treatment processes are applied to the crude fractions. Conversion processes (cocker, fluid catalytic cracker, catalytic reforming, and hydrocracking) transform a fraction into another one or change the molecular structure of a fraction (for example, heavy products can be transformed in light or medium products which have higher commercial value). Treatment processes (hydrodesulphurization and hydrotreatment) provide better cutting of semi-finished products by reducing contaminants (sulfur, nitrogen, and metals) or removing them from their structure. Table 1 describes the feedstock and the products derived from the above mentioned processes. These processes are highly complicated and involve different process mechanisms that occur at process units. A unit is defined as a continuous processing element that transforms inlet streams into several products (output streams). The physical/chemical properties (such as sulfur content and the viscosity) and yields of these products are related both to the feed flowrate and its properties as well as to the unit operating variables (Moro *et al.*, 1998). The processing units are subject to special conditions (operating variables) such as high temperatures, high pressures, and the addition of inputs that take part in the physical and chemical reactions necessary to obtain the output streams.

Table 1. Summary of general processes of oil refining (Khor and Elkamel, 2008)

Process	Feedstock	Products
Atmospheric crude distillation	Crude oil	Fuel gas, liquefied petroleum gas (LPG), light naphtha, heavy naphtha, jet fuel or kerosene, light gas oil, heavy gas oil, residuum
Vacuum distillation	Atmospheric residuum	Gas oil, lube feedstock, residuum
Cocker	Gas oil, coke distillate	Gasoline, petrochemical feedstock
Fluid catalytic cracker (FCC)	Gas oil, cycle oil, coke distillate, residual fuel oil, reduced crude	Fuel gas, propane, butane, naphtha, light gas oil, heavy gas oil, decanted oil
Catalytic Reforming	Naphtha, cocker, hydrocracker naphtha	Gasoline blending, H2 fuel gas, C3 and C4, Aromatics
Hydrocracking	Gas oil, cycle oil/ cracked oil, cocker distillate, residuum	Lighter, higher quality products (e.g., naphtha, fuel gas, light distillates from C3 and C4)
Hydrodesulphurization	High-sulphur residual/ gas oil	Desulphurized olefins
Hydrotreating	A range from naphtha to reduced crude of cracked hydrocarbons (HCs) to residuals	Stabilized feedstock (e.g., for cracker feed), distillate, lube

Refineries carry not only process units but also tanks to store and blend products and produce intermediate streams that can be blended to create distinct commercial offerings within the standards of quality specifications. The refinery topology is defined by a set of process units, storage and blending tanks, and pipes interconnecting all the components. The arrangement of all tanks and process units in a refinery is called refinery flowchart. Figure 3 illustrates a flowchart where the lines represent the streams and the boxes represent the process units. Actual refinery flowcharts, however, are much more complex than suggested by Figure 3. Figure 4 shows a more detailed flowchart where the tanks are also represented. Choosing the best configuration for a refining park and the ideal plan for operations are difficult tasks due to the high number of variables and constraints present in these processes.

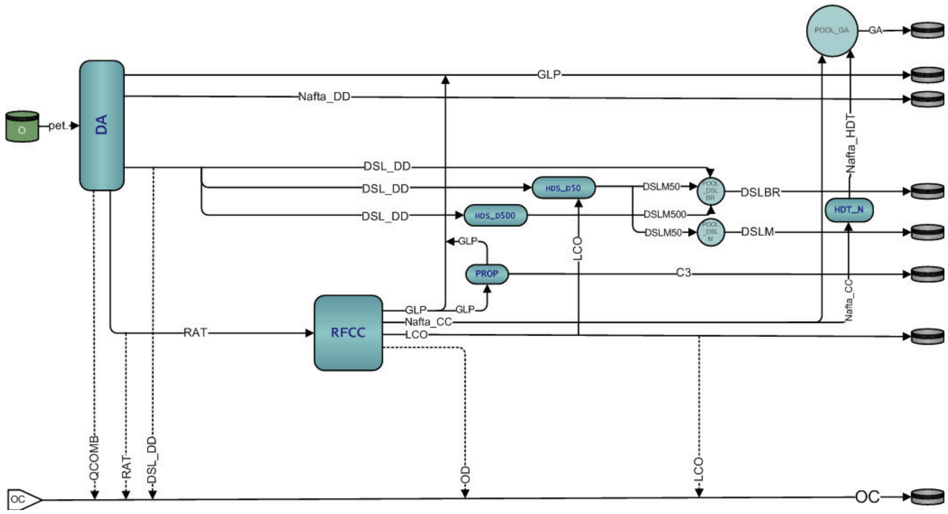

Figure 3. A simplified refinery flowchart

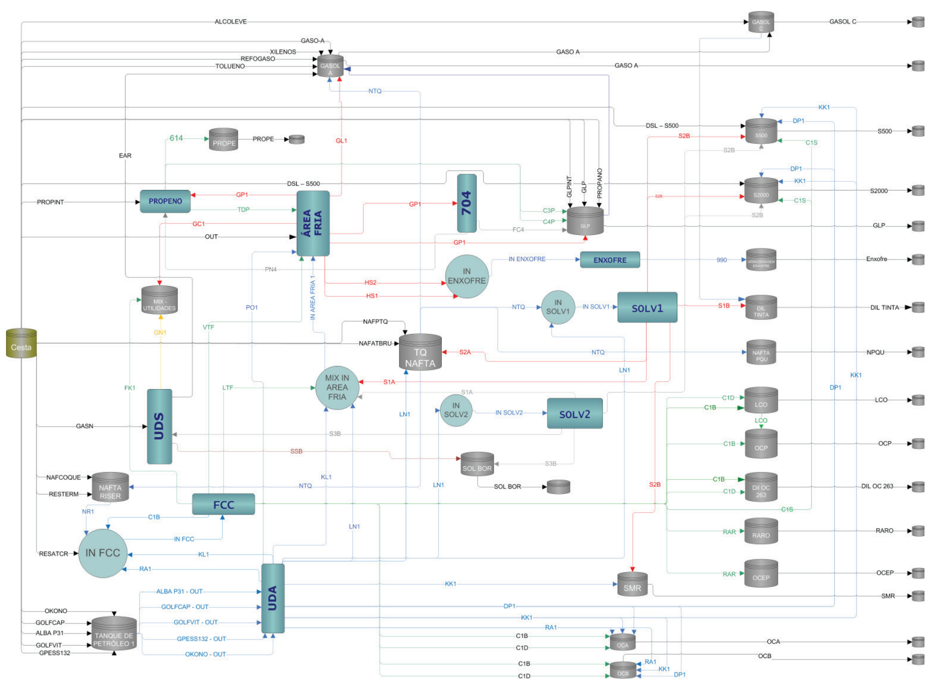

Figure 4. A detailed refinery flowchart

2.1. Chapter conclusions

As a result of the complex characteristic of the oil chain, planning of the oil chain must be aided by decision-making systems, especially those that employ mathematical programming or optimization – for example, RPMS - Refinery and Petrochemical Modeling System (Bonner and Moore, 1979), OMEGA - Optimization Method for the Estimation of Gasoline Attributes (Dewitt *et al.*, 1989), and PIMS - Process Industry Modeling System (Bechtel, 1993). In this regard, mathematical programming plays a crucial role to assist the decision-making process in the oil supply chain planning.

A review of works on mathematical programming applied to the oil chain planning is presented in the next chapter.