# 2
# Problem Description

To describe the problem, first we need to understand the logistic process of petroleum supply to the refineries at PETROBRAS. This process follows the general hierarchical structure of a typical supply chain (see, for instance, [Ant65]) and is divided into three levels: Strategic, Tactical and Operational as shown in Figure 2.1.

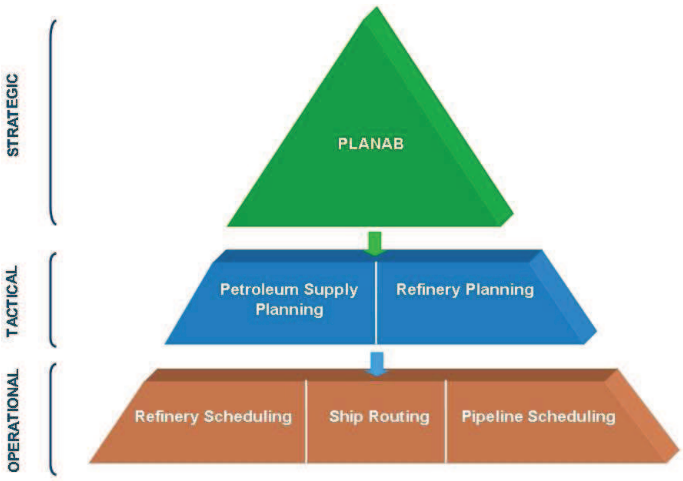


**Figure 2.1:** Simplified Hierarchical Structure of the Petroleum Supply Chain at PETROBRAS

At the strategic level, a Linear Programming tool, known as PLANAB, is used to determine on a monthly basis the amount and type of petroleum that will be processed in each refinery, as well as the amount of petroleum exported and imported for a horizon of three months. The Petroleum Supply Planning, which is a tactical activity, refines this information on a daily basis for a horizon of two and a half months considering in greater detail the constraints on the petroleum supply chain. This information will be further used for refinery planning and by the operational level activities. In the following subsections we describe each element considered in our mathematical model, as well as some simplifications that are necessary.

## 2.1 Production Sites

A production site is one or more platforms that usually produce oil from the same petroleum field. They can be offshore or terrestrial. However, in the PETROBRAS case, almost 95% of them are offshore. Moreover, depending on the infrastructure installed, the petroleum can be shipped to terminals via pipeline or tankers. Nonetheless, in Brazil, only three production sites are linked to terminals by pipelines.

The petroleum that comes out from a given production site is commonly named after the offloading platform, as depicted in Figure 2.2. This allows us to use interchangeably the same index for the production site and for the crude oil produced by it. We should mention that the platforms considered in this model are those with infrastructure to offloading, i.e., those that allow for tankers to opperate in them or have a pipeline to ship their production to a terminal. These platforms are represented by rectangles in Figure 2.2.

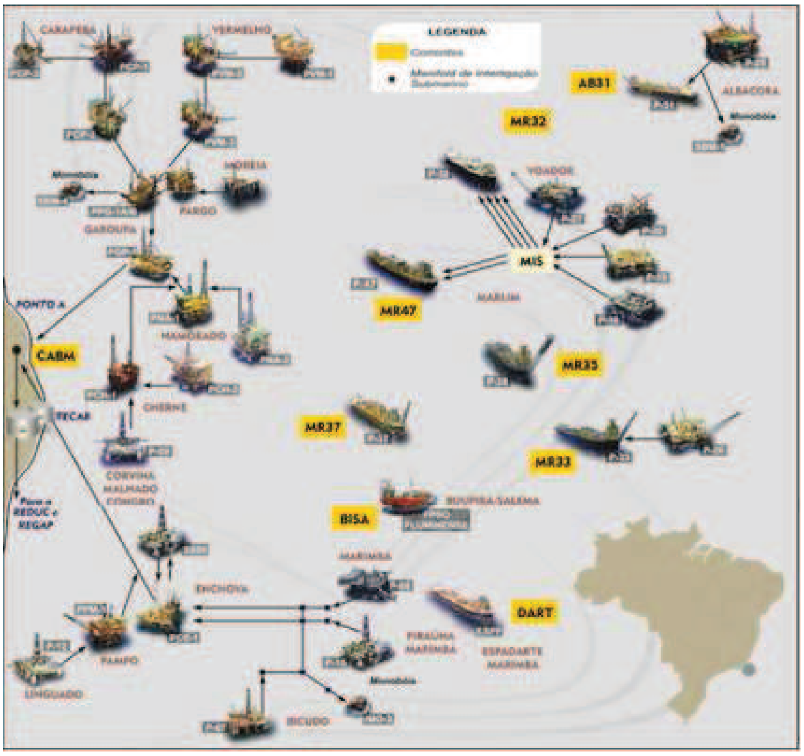


**Figure 2.2:** Schematic of the Campos Basin production area - Source: PETROBRAS

The data related to the production sites are those of the offloading platforms and can be summarized as follows:

- Production rate per day;
- Shipment transportation mode - Tankers or pipelines;

- Anchorage restrictions that are translated into classes of tankers that can be used for offloading them;
- Storage capacity - It can be either the storage capacity of the offloading platform, or the auxiliary ship that is being used as a tank.

## 2.2 Tanker Fleet

Regarding crude oil tankers, PETROBRAS operates most of its fleet. They are usually owned by PETROBRAS or rented in time charter contracts. Crude oil tankers are used to transport petroleum from the production sites to the terminals, and occasionally if needed from terminals to terminals. They are usually classified according to their size and a common measurement unit to this purpose is the Dead Weight Tonnage (DWT). In this work, we consider the number of tankers in each class owned or rented by PETROBRAS, and we associate to each class an average transportation volume capacity and an average cost per day. Following are the classes and the corresponding average capacities used in this study:

- Handy - C (19,000 $m^3$)
- Handy - R (30,000 $m^3$)
- Handy - L (40,000 $m^3$)
- Panamax (65,000 $m^3$)
- Aframax (100,000 $m^3$)
- Suezmax (140,000 $m^3$)
- New-Suezmax (160,000 $m^3$)
- VLCC (350,000 $m^3$)

## 2.3 Petroleum Category

Petroleum category means a subset of the petroleum crudes with approximately the same properties and equivalent product yields. It is introduced here for simplification as we manage inventory by category instead of by individual crude oil. This concept is used in inventory management in terminals as well as in refineries. In this work six petroleum categories are used, namely:

- Lubricant;
- Light;
- Cracked Atmospheric Residues, named here Rat-Craq;

– Low Sulfur Content - LSC;

– Marlim - a subset of petroleum produced in the Marlim field;

– Asphaltic.

## 2.4 Maritime Terminals

These are intermediate elements in the petroleum supply chain, where all petroleum from offloading platforms is sent to before reaching the refineries. They can be linked to one or more refineries by pipelines. This imposes some difficulties in the modeling since we are not managing the terminal inventory tank by tank. Nevertheless, we overcome this issue by pre-assigning tanks to refineries, and leaving some volume corresponding to tanks that can be used by more than one refinery, for the sake of flexibility, as illustrated in Figure 2.3. In terms of modeling, the following data are considered:

– Number of berths;

– Classes of tankers that can dock at the terminal - These data depend on the Dead Weight Tonnage (DWT) and the draft of tankers as well as on the depth of the sea and the structure of piers at the terminals;

– Storage capacity: by refinery connected to the terminal; by petroleum category and refinery; and total.

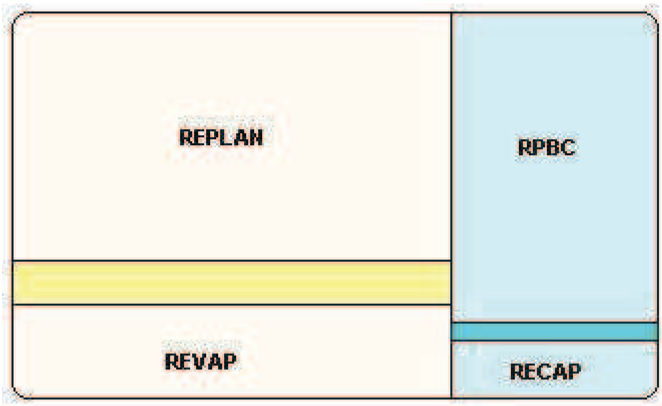


**Figure 2.3:** Schematic of the storage capacity assigned to the refineries connected to the São Sebastião terminal in São Paulo - The rectangles between refineries represent the tanks shared by them

## 2.5 Pipelines

In this problem, pipelines are used to transport crude oil from platforms to terminals, and from terminals to refineries. We should mention that pipeline scheduling issues are out of the scope of this model, and basically we are only concerned with the estimated transfer time and daily maximum pumping rate. Regarding the pipelines that link platforms to terminals, transfer times are not considered since they always handle the same crude oil.

## 2.6 Refineries

The refineries are the demand points of the problem considered, and need to be fed by the correct amount and type of petroleum in order to supply their market with the right products. We do not go into the detail of refinery modeling. Furthermore, we assume that the daily consumption rates by category of their crude distillation units are given. This information is usually obtained by analysis of the strategic planning directives. In summary, the following data are taken into account in our study for each refinery:

- Number of CDU;
- Storage capacity by petroleum category and total;
- Terminals pumping to it. Figure 2.4 shows the terminals that can pump petroleum to each refinery in the actual problem configuration;
- CDU's campaigns. These data are given by the starting time, the ending time and the daily consumption rate by category.



## 2.7 Problem Statement

Given:

(a) A set of production Sites P

(b) A set of terminals T

(c) A set of refineries R

(d) A set of classes of tankers Cl

(e) The daily crude oil production of each production site

(f) The consumption campaign of each crude distillation unit in refineries

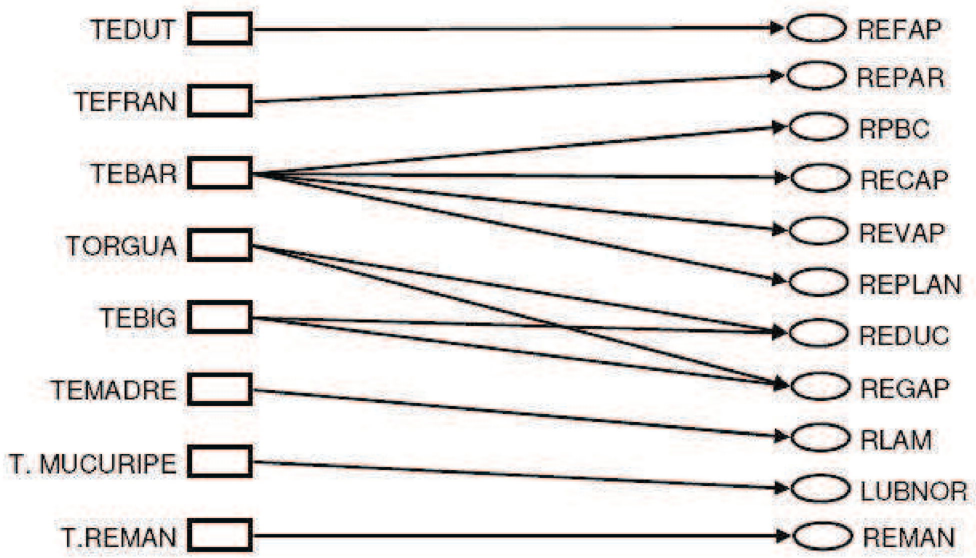


**Figure 2.4:** Connection between terminals and refineries

(g) The logistic infrastructure restrictions, namely, storage capacity at production sites, terminals, and refineries; maximum pipeline flow rate between terminals and refineries; number and transportation capacity of tankers available in each class of tanker; number of tankers that can operate simultaneously in each terminal.

Determine a minimum cost offloading scheduling for each production site in order to supply each refinery with the correct type and amount of oil indicated by the strategic planning. The costs considered in the objective function are as follows:

- Tanker operational cost;
- Deviation penalty from strategic planning;
- Penalty for petroleum shortage in refineries;
- Freight cost of additional tanker.