CAPITAL BUDGETING MODEL
FOR PEMEX EXPLORACIÓN Y PRODUCCIÓN

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Abstract

This document gives a panoramic vision of PEMEX in general and PEMEX Exploración y Producción (PEP) in particular; analyzes the behavior of its investments and its oil potential, which finally constitutes the justification for the "Capital budgeting model" that PEP successfully employs. This model is an application of Optimization Techniques and, specifically, Binary Integer Programming.

Keywords: Capital budgeting, Binary Integer Programming, Oil Industry.

1. Introduction

PEMEX Exploración y Producción (PEP) is currently the leading Mexican company in the intensive use of capital and the generation of revenue; as a consequence, "The PEP's Capital budgeting model" presented in this paper constitutes one of the most important applications of Operations Research in Mexico.

This document is divided up as follows: The section entitled background gives an overall view of PEMEX's objectives, organization, modus operandi and its position among the main oil companies of the world. The third section consists of the analysis of the behavior of PEMEX's investments, highlight the participation of its subsidiary, PEMEX Exploración y Producción, within the company's total investment budget.

Then in the fourth section appears a summary of the most relevant aspects of PEMEX Exploración y Producción: its mission statement, its strategy for improving its operating performance, oil reserves, exploration potential, production as well as its contribution to exports. The next section gives some results from the capital budgeting model together with its forecasts and its mathematical structure is shown in detail.

Finally, the conclusions, including the benefits and disadvantages of employing this model.

2. Background

Sixty-seven years since its foundation after the decree ordering the expropriation of the oil industry on March 18, 1938, Petróleos Mexicanos (PEMEX) has become one of the country’s most important sources of income.

At the present time, PEMEX aims to maximize the economic value of Mexico’s hydrocarbons and their derivatives, to be able to contribute to Mexico’s sustainable development.

PEMEX operates through a parent company and five subsidiary bodies: Exploración y Producción, Refinación, Gas y Petroquímica Básica, Petroquímica and PMI Internacional. The Parent Company is responsible for the central leadership and strategic management of the state oil industry and ensuring their integration and unity of action.

“PEMEX Exploración y Producción” is in charge of oil and gas exploration and exploitation. “PEMEX Refinación” produces, distributes and markets fuels and other oil products. “PEMEX Gas y Petroquímica Básica” processes natural gas and natural gas liquids: distributes and markets natural gas and L.P. gas; and produces and markets basic petrochemical products. “PEMEX Petroquímica”, through its seven affiliates: Petroquímica Camargo, Petroquímica Cangrejera, Petroquímica Cosoleacaque, Petroquímica Escolín, Petroquímica Morelos, Petroquímica Pajaritos and Petroquímica Tula, elaborates, distributes and markets a broad ranges of secondary petrochemical products. P.M.I. Comercio Internacional is responsible for the foreign trade activities of Petróleos Mexicanos (PEMEX).

After making a benchmarking [1], it is possible to affirm that PEMEX is considered the ninth oil company in the world for the following reasons (see table 1):

- Third crude oil producer in the world
- Proven reserves the equivalent to 11 years of production
- Low production costs vs. market average
- Key supplier of crude oil to the United States market

- The largest company in Mexico with a revenue of sixty-nine billion dollars in 2004
- Sole producer of crude oil, natural gas and refined products in Mexico
- Sole supplier of refined products in Mexico

Table 1. Rankings Based On Six Operational Criteria

Place	Company	Country	Reserves		Production		Refining	
			Oil	Gas	Oil	Gas	Sales	Capacity
1	Saudi Aramco	Arabia Saudita	1	4	1	7	7	8
2	Exxon Mobil	EUA	12	14	4	2	1	1
3	NIOC	Irán	2	2	2	6	10	14
4	PDVSA	Venezuela	5	6	5	12	8	4
5	BP	Reino Unido	17	15	9	4	3	3
6	RD Shell	Holanda y Reino Unido	21	17	6	3	2	2
7	Chevron Texaco	EUA	19	22	11	9	4	9
8	Total	Francia	20	21	14	8	6	6
9	**Pemex**	**México**	**9**	**28**	**3**	**15**	**12**	**13**
10	Petrochina	China	14	18	10	20	11	12

Source: Petroleum Inteligence Weekly, December 2004

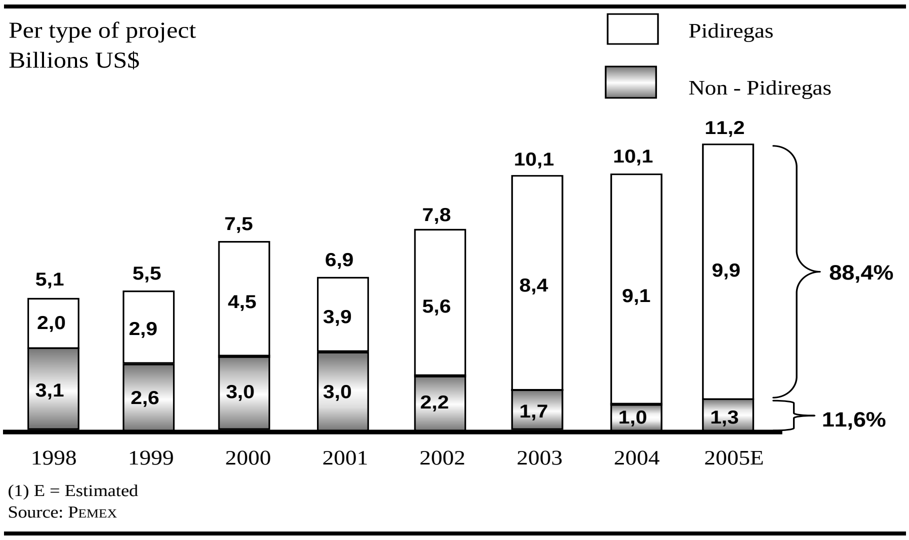
2. Investments

The Productive Infrastructure with Deferred Expenditure Impact Projects, better known as Pidiregas, have in recent years been instrumental in PEMEX being able to expand its investment capacity. Pidiregas are public works projects financed and carried out by third parties that are paid off over a certain period of time. To get an idea of the importance of this instrument, it is sufficient to point out that almost three-quarters of PEMEX’s total investments fall into this scheme.

PEMEX invests in pidiregas and non-pidiregas projects. Pidiregas projects are financed and the non-pidiregas are paid for from the budget that the federal government assigns to PEMEX. In the 1980s, the Federal Government allowed PEMEX the total budget to make the investments required for its operations. In exchange, the profits from the company, as it belongs to the state, went to the federal treasury.

However, since the 1990s, the Government found a formula for attracting investment into the country, asking for financial backing for oil investment projects and, as can be seen in graph (1), gradually abandoning its obligation to provide PEMEX with sufficient resources for its productive activities.

At the present time, [2] PEMEX faces a difficult financial situation, characterized by growing liabilities that include the pidiregas debt to finance investments and an important labor liability. Unquestionably, the growth of the pidiregas debt is necessary and advisable, 98 percent of PEMEX's primary production comes from the pidiregas projects, which are the most profitable in the country.

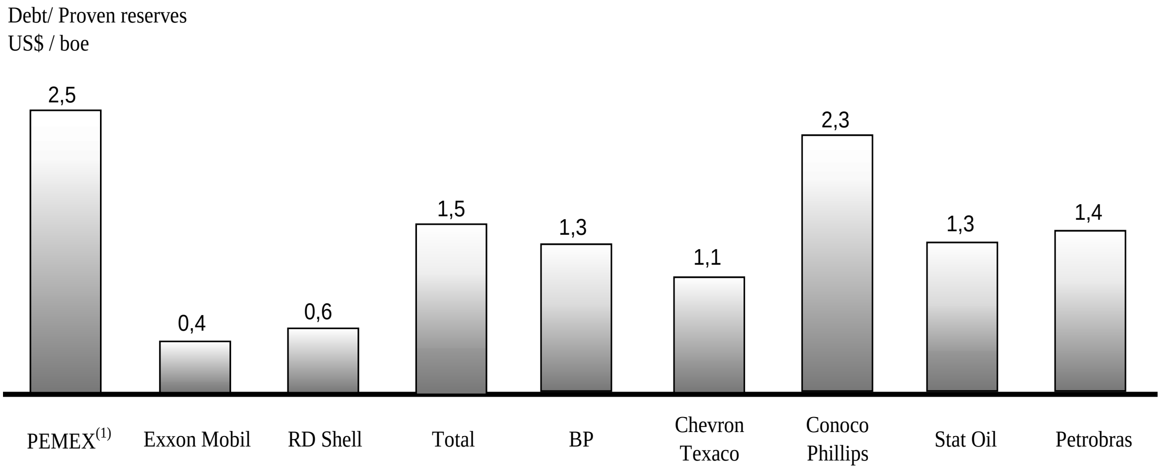


Graph 1. Investment behavior

This policy is reflected in the 2005 investment budget authorized for PEMEX, which is made up by 11.6% resources assigned by the Federal Government and 88.4% resources obtained through loans.

As a consequence of the policy for financing investment projects, PEMEX still hands over its profit to the Federal Government, however, the loans received over the last few years have increased its debt in such a way that it owes 2.5 dollars for every barrel of proven reserves. See graph (2).

Table (2) shows the participation of PEMEX's subsidiary bodies in the investment budget.



Sources: Financial statements of companies on December 31, 2003 and proven reserves on December 31, 2002.
(1) Unaudited financial statements and proven reserves on December 31, 2004.
The debt is the sum of the documented debt, notes to contractors and the sale of accounts receivable.

Graph 2. Ratio of debt-reserves Vs. Competitors

As can be seen PEMEX Exploración y Producción has a participation of 85% in 2005. The fact alone explains the importance of having a model that optimizes the assignment of this subsidiary's investments.

TABLE 2. 2004 and 2005 Investment

	Investment Billions in US$ 2004		2005	
Exploración y Producción	***9,3***	***92%***	***9,5***	***85%***
Refinación	0,4	4%	1,1	10%
Gas y Petroquímica Básica	0,2	2%	0,3	3%
Petroquímica	0,1	1%	0,2	2%
Otros	0,1	1%	0,1	1%
Total	10,1	100%	11,2	100%

Source: PEMEX

4. PEMEX Exploración y Producción

The high level of profitability of PEMEX Exploración y Producción has allowed it to be an important contributor to the Treasury, whose resources are used for the benefit of the nation.

Its cutting-edge technology has increased its reserves and reconfigured its export platform, exporting better quality crude oil at a better price, as well as being self-sufficient in natural gas.

The mission of PEMEX Exploración y Producción (PEP) is to maximize [20] the long-term economic value of Mexico's reserves of crude oil and natural gas, guaranteeing the security of its installations and personnel, in harmony with the community and the environment. Its main activities are exploration and exploitation of oil and natural gas, transporting and storing them in terminals and selling them first hand; these activities are ongoing in the four geographic regions that the entire country is divided into: North, South, North-Eastern Marine and South-Eastern Marine.

PEP is third in the world in terms of crude oil production, first in offshore production of hydrocarbons, ninth in crude oil reserves and tenth in revenue.

The strategy [10] for improving its performance in the short and medium term has been to adopt the best practices in the oil industry in terms of business plans, productivity, the environment and industrial safety in its operations. Its capacity for execution has also been strengthened as well as its exploratory activities in order to be able to make PEMEX Exploración y Producción the most successful oil company of the twenty-first century

4.1 Oil reserves

The reserves of crude oil and natural gas [15] are classified as follows:

- Proven reserves
- Probable reserves
- Possible reserves
- 3P reserves

The SEC (Securities and Exchange Commission) only considers the proven reserves, which are those associated with the projects of oil field exploitation and development. Probable reserves are those that are estimated through the exploratory projects for the incorporation of oil reserves and those corresponding to the delimitation and characterization of oil fields. Possible reserves are the result of the exploratory activities that make up the oil potential assessment projects. Finally 3P reserves are the total reserves, i.e., the sum of the three types of reserves mentioned. It is worth pointing out that the reserves of hydrocarbons in our country are certified by external companies such as Netherland, Sewell and DeGoyer & MacNaughton.

If we consider the reserves on December 31, 2004 and the average production of 1.6 Million BOE that same year, we find that the life of the proven reserves is 11 years and 29 years for the 3P reserves.

4.2 Exploratory potential

As a country's exploratory potential is in direct proportion to the geographical surface area and the geological characteristics of the terrain, the following are some interesting data.

The territory has been divided into: *land* with 1 923 040 Km^2, *continental platform* with 263, 259 Km2 and *deep offshore* with 567 477 Km^2, giving a total of 2 753 776 Km^2, of which 1 054 586 Km^2 have oil potential and 1 699 190 Km^2 do not have any potential. The sedimentary basins in question cover an area of 174 400 Km^2 and as such the percentage studied is 17. See figure (1).

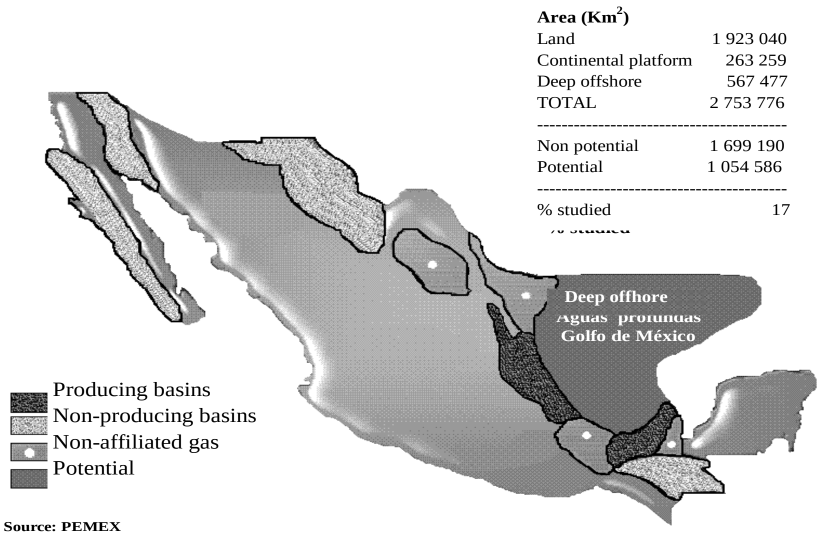
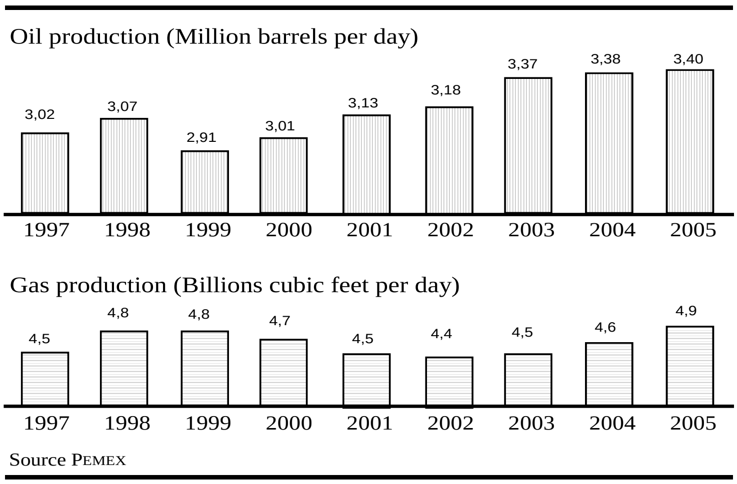


Figure 1. Exploratory potential

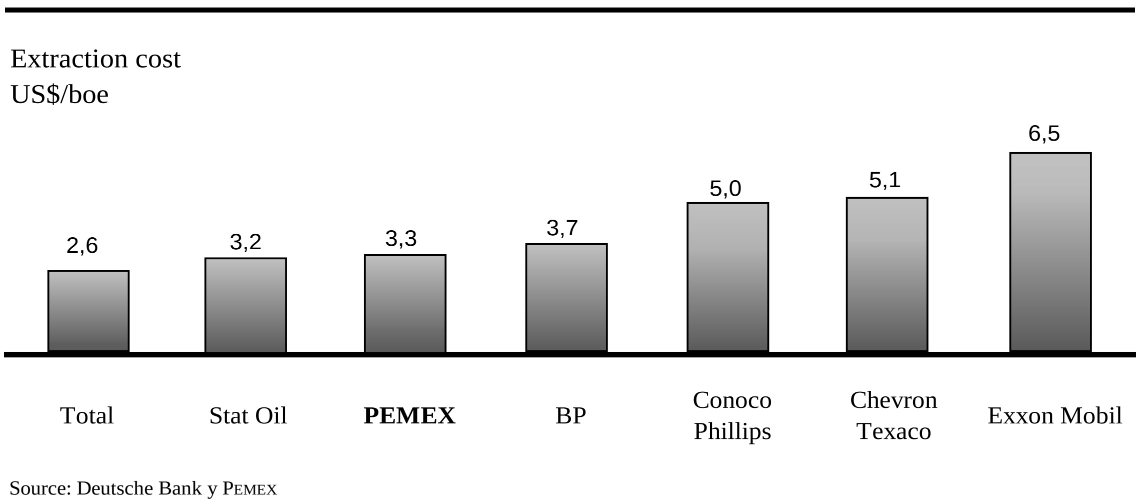
4.3 Production

In respect of the company's production profile [3], it must be pointed out that the production of crude oil has grown constantly since 1999 and the downward trend in the production of natural gas was reversed in 2003. See graph (3).



Graph 3. Profile of production

The extraction cost for PEP [17] averages out at 3.3 dollars per barrel of oil-equivalent, which means that PEMEX Exploración y Producción is an *efficient producer*, as can be seen in graph (4).

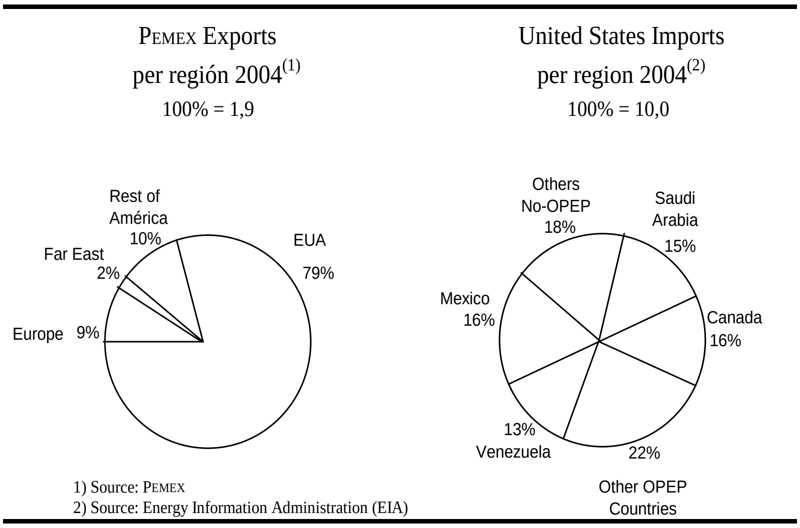


Graph 4. Efficient producer

4.4 Exports

PEMEX exports 1.9 million barrels a day [16], of which 79% goes to the United States of America, corresponding to 16% of that country’s imports.

In graph (5) we can see that PEMEX’s exports strategy is based on the vicinity of the United States of America, which is also a trading associate of Mexico, unlike that country’s imports strategy, which is based on diversification.



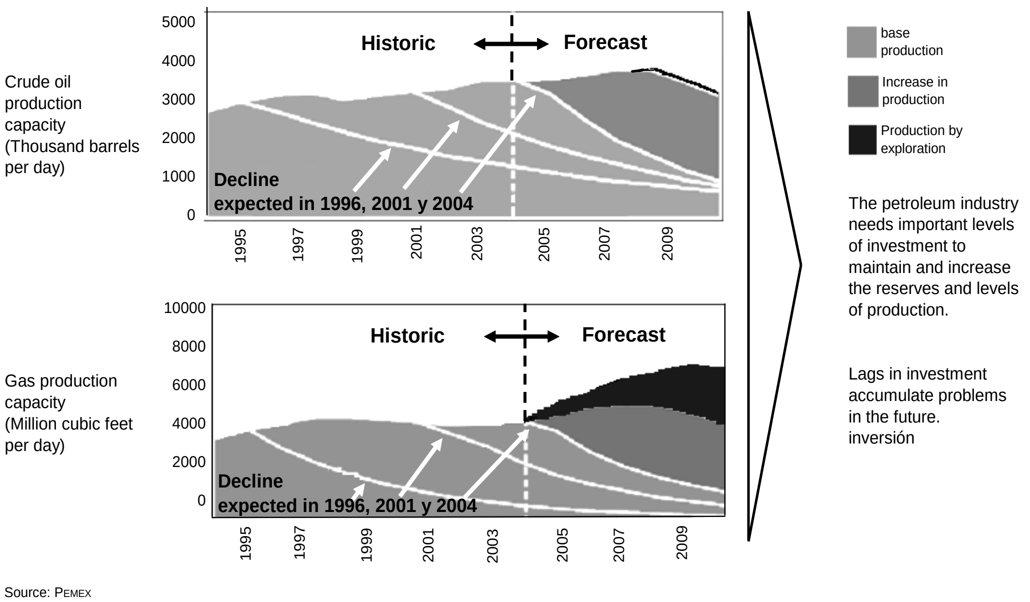
Graph 5. Important supplier of crude oil to the United States

5. The Model

The complexity involved in the management and planning of the costly operations [14] inherent in the exploration and exploitation of hydrocarbons, entailing thousands of variables, means that we need to have advanced tools [5, 6, 9, 11, 13, 18] to decide how to allocate capital, without losing sight of the interaction that exists between the operations and the goal of maximizing the economic value of the hydrocarbons.

This situation was solved through the design [8], development and implementation of a mathematical model that made it possible to construct different scenarios in support of the planning budgeting of the company’s capital.

This model makes it possible to guarantee maximum economic value in the allocation of the investments [21] and obtain, among other things, the multiannual production forecasts, attending to the multi-periodic demand for hydrocarbons to meet the requirements for national consumption and the export platform, under limited budget conditions [7]. Graph (6) clearly shows some of the forecasts obtained by applying the optimization model. It is worth mentioning that every one of the estimated declines in production are derived from the optimizations done for those years.



Graph 6. Forecasts for crude oil and natural gas production

The basic structure of the capital budgeting model for PEMEX Exploración y Producción, which is a binary integer-programming model [12, 19, 22], solved by using CPLEX on a Digital Alpha server that has four mathematical processors, is presented below.

This model makes it possible to build as many scenarios of maximum economic value and minimum cost.

Scenario: *Maximizing economic value and meet the requirements of oil and gas under limited budget conditions.*

Objective Function:

$$Maximize\ \ NPV = \sum_{i=1}^{k} \sum_{j=1}^{m} npv_{i,j}\, x_{i,j}$$

Subject to:

Investment Budget Constraints:

Lower Bound:

$$I_{L1}: \sum_{i=1}^{k} i_{i,1}\, x_{i,1} \geq lbi_1 \qquad \textit{for year } 1$$

$$I_{L2}: \sum_{i=1}^{k} i_{i,1}\, x_{i,2} + \sum_{i=1}^{K} i_{i,2}\, x_{i,1} \geq lbi_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$I_{Lm}: \sum_{i=1}^{k} i_{i,1}\, x_{i,m} + \ldots + \sum_{i=1}^{K} i_{i,m}\, x_{i,1} \geq lbi_m \qquad \textit{for year } m$$

Upper Bound:

$$I_{U1}: \sum_{i=1}^{k} i_{i,1}\, x_{i,1} \leq Ubi_1 \qquad \textit{for year } 1$$

$$I_{U2}: \sum_{i=1}^{k} i_{i,1}\, x_{i,2} + \sum_{i=1}^{K} i_{i,2}\, x_{i,1} \leq Ubi_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$I_{Um}: \sum_{i=1}^{k} i_{i,1}\, x_{i,m} + \ldots + \sum_{i=1}^{K} i_{i,m}\, x_{i,1} \leq Ubi_m \qquad \textit{for year } m$$

Oil Production Constraints:

Lower Bound:

$$O_{L1}: \sum_{i=1}^{k} o_{i,1}\, x_{i,1} \geq lbo_1 - baseo_1 \qquad \textit{for year } 1$$

$$O_{L2}: \sum_{i=1}^{k} o_{i,1}\, x_{i,2} + \sum_{i=1}^{K} o_{i,2}\, x_{i,1} \geq lbo_2 - baseo_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$O_{Lm}: \sum_{i=1}^{k} o_{i,1}\, x_{i,m} + \ldots + \sum_{i=1}^{K} o_{i,m}\, x_{i,1} \geq lbo_m - baseo_m \qquad \textit{for year } m$$

Upper Bound:

$$O_{U1}: \sum_{i=1}^{k} o_{i,1} x_{i,1} \le Ubo_1 - baseo_1 \qquad \textit{for year } 1$$

$$O_{U2}: \sum_{i=1}^{k} o_{i,1} x_{i,2} + \sum_{i=1}^{K} o_{i,2} x_{i,1} \le Ubo_2 - baseo_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$O_{Um}: \sum_{i=1}^{k} o_{i,1} x_{i,m} + \ldots + \sum_{i=1}^{K} o_{i,m} x_{i,1} \le Ubo_m - baseo_m \qquad \textit{for year } m$$

Gas Production Constraints:

Lower Bound:

$$G_{L1}: \sum_{i=1}^{k} g_{i,1} x_{i,1} \ge lbg_1 - baseg_1 \qquad \textit{for year } 1$$

$$G_{L2}: \sum_{i=1}^{k} g_{i,1} x_{i,2} + \sum_{i=1}^{K} g_{i,2} x_{i,1} \ge lbg_2 - baseg_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$G_{Lm}: \sum_{i=1}^{k} g_{i,1} x_{i,m} + \ldots + \sum_{i=1}^{K} g_{i,m} x_{i,1} \ge lbg_m - baseg_m \qquad \textit{for year } m$$

Upper Bound:

$$G_{U1}: \sum_{i=1}^{k} g_{i,1} x_{i,1} \le Ubg_1 - baseg_1 \qquad \textit{for year } 1$$

$$G_{U2}: \sum_{i=1}^{k} g_{i,1} x_{i,2} + \sum_{i=1}^{K} g_{i,2} x_{i,1} \le Ubg_2 - baseg_2 \qquad \textit{for year } 2$$

$$\vdots$$

$$G_{Um}: \sum_{i=1}^{k} g_{i,1} x_{i,m} + \ldots + \sum_{i=1}^{K} g_{i,m} x_{i,1} \le Ubg_m - baseg_m \qquad \textit{for year } m$$

Multiple Choice Constraints:

$$MCh_1 : \sum_{j=1}^{m} x_{1,j} \leq 1$$

$$MCh_2 : \sum_{j=1}^{m} x_{2,j} \leq 1$$

$$\vdots$$

$$MCh_m : \sum_{j=1}^{m} x_{m,j} \leq 1$$

where:

$npv_{i,j}$ *= current value of project i in year j*

$x_{i,j}$ *= binary variable for decision*

k *= number of projects*

m *= optimization period*

$i_{i,j}$ *= investment required for project i in year j*

lbi_j *= lower bound or minimum investment budget for year j*

Ubi_j *= upper bound or maximum investment budget for year j*

$O_{i,j}$ *= oil production from project i in year j*

lbo_j *= lower bound or minimum demand for oil in the year j*

Ubo_j *= upper bound or maximum demand for oil in the year j*

$g_{i,j}$ *= gas production of project i in year j*

lbg_j *= lower bound or minimum demand for gas in the year j*

Ubg_j *= upper bound or maximum demand for gas in the year j*

$baseo_j$ *= Oil production for year j from the exploitation and maintenance of the fields that are already being exploited.*

$baseg_j$ *= Gas production for year j from the exploitation and maintenance of the fields that are already being exploited.*

Moreover, the binary structure of the model [12, 19, 22] makes it possible to add constraints for handling committed, rejected, complementary and sequential projects:

Constraints for Committed Projects:

$$Commited: \sum_{l=1}^{L} \left(x_{i,j} \right)_l = L$$

with: i = *committed project*

j = *year when committed*

L = *number of committed projects*

Constraints for Rejected Projects:

$$\text{Re}\ jected: \sum_{l=1}^{L} \left(x_{i,j} \right)_l = 0$$

with: i = *rejected project*

j = *year when it is rejected*

L = *number of projects rejected*

Constraints for every pair of complementary projects:

Complementary$_1$: $x_{a,1} - x_{b,1} = 0$

Complementary$_2$: $x_{a,2} - x_{b,2} = 0$

$\vdots$

Complementary: $x_{a,m} - x_{b,m} = 0$

Constraints for every pair of sequential projects:

Sequential$_1$: $x_{a,1} - x_{b,1} \geq 0$

Sequential$_2$: $x_{a,2} - x_{b,2} \geq 0$

$\vdots$

Sequential$_m$: $x_{a,m} - x_{b,m} \geq 0$

6. Conclusions

The model's importance is unquestionable; however, this paper concludes by mentioning its advantages and disadvantages:

Advantages:

- It guarantees the maximization of the company's economic value.

- It provides the multiannual project portfolio that complies with the budget constraints and the demand for production.
- It estimates production forecasts for the short, medium and long term.
- It presents the multiannual investment requirements per project type.
- It makes it possible to calculate the cost of the constraints.
- It facilitates the programming of the dependence between projects: economic, technology, etc.
- It gives the elements needed to be able to successfully enter into negotiations about the budget with the Federal Government.

Disadvantages:

- Despite being a robust model its results do not allow us to analyze the possible contingencies that could arise.
- The construction of scenarios to assess the policy changes requires highly specialized personnel and is not immediate.
- To date, Binary Integer Programming does not have an effective method for the analysis of sensitivity.
- Expensive infrastructure (Software and hardware) is required for the convergence of this model.

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