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Optimal Decisions in Oil Industry*

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Abstract

As part of larger research that deals with modeling different aspects concerning oil and gas industry, this paper explores the possibilities of building up operational models for optimal decisions in the oil industry through linear programming aiming at the analysis of investment efficiency in oil and gas industry. Hence, in the beginning, a special focus is placed on revealing some applications that may help us estimate the optimal distribution of investment funds in the oil structures where wells will be drilled in the coming years, for generally, the investment funds allocated to a branch or enterprise are limited. Then, the paper presents a numerical example of a model for the optimal distribution of investments between oil structures. This is just one of many examples of the application of linear programming that has been used to distribute investments in the oil extraction industry. The paper demonstrates that problems may arise regarding the optimal distribution of equipment and material depots in the territory where the wells are drilled, problems regarding the maximum efficiency of certain natural factors.

Keywords: oil and gas reserves, oil and gas wells, optimal decisions, operational models, investment efficiency.

Introduction

Literature Review

Sustained development of production and the increase of its economic efficiency involves as a necessity the rational use and exploitation of material resources and energy [Hartwick and Olewiler, 1986; Home, 1979]. Therefore, increasing material and energy resource recovery is a major coordinate for economic growth and improvement in economic efficiency.

On the other hand, viewing the problem from another angle, economic sustainability is not just how to become wealthy as a nation or as individuals [Kula, 1994; Pearce and Turner, 1990]. Besides GDP, exchange rates, inflation, and profits are a part of this image, while economic sustainability is deeper involving production, distribution, and consumption of goods and services as well.

This concept is addressed to the unavailability of exhaustible resources [Hotelling, 1931], to the global constraints on growth and strategies for implementing proper environmental costs of pollution or other negative impacts generated by the company as a whole. The exchange of goods and services has a significant negative impact on the environment, and this situation will not change as long as the environment serves both as the exclusive source

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of resources, and is the final destination of waste products.

Despite the fact that oil extraction is achieved in a closed system [Hussein, 2023; Kasukabe, 2023], which should enable it to avoid or, at least, substantially reduce all forms of pollution, the exploration and exploitation of oil deposits continue to be among the most polluting industrial activities [Bulearca and Popescu, 2014; 2019].

Oil, heavy oil, salt water and various chemicals contamination of land around drilling and extraction oil-wells is, with all its incidentally character, extremely harmful to soil, surface water and groundwater. In this respect, the severity of pollution will depend, of course, on the nature of the pollutant, its quantity and why this pollution occurs.

Efficiency in global petroleum production has become an overriding issue of concern around the world due to extreme competition and the effects of global uncertainties such as the COVID-19 pandemic, sanctions on Iranian oil industry, the Russia–Ukraine war, and the US–China trade war. Needless to say, the oil industry is among the essential industries in the world today. It is the primary source of global energy supply and plays a significant role in long-run economic growth. According to the International Labor Organization (ILO), roughly 6 million people are employed directly, and over 50 million are indirectly employed in the oil industry [Hatami-Marbini *et al.*, 2022].

The industry invariably faces multiple challenges and uncertainties associated with crude oil production and refining petroleum product at the lowest possible cost to retain market competitiveness [Temizel *et al.*, 2019]. These uncertainties range from global demand, price volatility, increasing rise in a global pandemic, international cooperation, technological advantage, and increasing stagnant environmental controls. With this in mind, it is imperative to continuously measure the efficiency and productivity growth of petroleum production activities [Al-Mana, 2020]. Performance measurement brings the strength and vulnerabilities of a production system to the fore to ensure a wider and smarter system, encourage customer satisfaction, enhance internal and external relations, and direct the system objectively [Atris, 2020].

As a result, this paper will explore the possibilities of building up operational models for optimal decisions in the oil industry through linear programming aiming at the analysis of investment efficiency in oil and gas industry. Hence, the remaining part of this paper will largely address these topics.

Operational models for optimal decisions in the oil industry through linear programming

Applications will be presented for the optimal distribution of investment funds in the structures where wells will be drilled in the coming years.

Generally, the investment funds allocated to a branch or enterprise are limited.

The problem in oil extraction is to use these funds in such a way that:

- To obtain the highest production within the limits of a certain investment fund;
- To achieve the lowest cost price of a planned production, which is equivalent to obtaining the highest profit.

Given that production and investment funds are established by plan, only the extraction cost price remains to be optimized.

The production set by the plan will be obtained from wells in operation on January 1st and from wells drilled during the year.

If we denote last year's production by *P* and the production decrease coefficient by *K*, then the year's production will be:

$$P + \Delta P = P(1-K) + NnDn$$

where: ΔP = production increase;

Nn = number of new wells;

Dn = average flow rate of these wells.

The number of new wells will be:

$$Nn = \frac{P + \Delta P - P(1-K)}{Dn} = \frac{\Delta P + Kp}{Dn}$$

Considering that the average investment per new well is *Is*, the volume of investments will be given by:

$$I = NnIs = ct.$$

Both *Is* and *Nn* are variable, depending on the structure where the new wells are located. In structures with deep deposits *Is* will be higher and therefore the number of wells will be lower. In this case it is assumed that deeper wells give higher production.

If there are *n* structures, when the exploitation activity is developed, the structures will have to be chosen in such a way that:

$$I_{s1} N_1 + I_{s2} N_2 + I_{s3} N_3 + \ldots.. + I_{sn} N_n = I$$

This represents a condition for choosing the structures where the activity will be developed through exploitation drilling.

It is obvious that this can develop in all structures or only in certain structures, leaving some as a reserve.

However, the condition must be that the cost price is minimal.

The cost price is in turn a result of the cost price of old structures where drilling is still taking place and of new structures, with the possibility of developing production.

The cost price on old structures will be:

$$p_v = a_v + \frac{C}{D_v} + \frac{A}{P(1-k)} \quad (1)$$

where: a = fixed costs per ton extracted;

C = average cost per well-month excluding depreciation, of old structures;
D = average monthly flow of old structures;
A = annual depreciation of investments in old structures.

In calculations, p_v must be taken constant for all variants of distribution of new wells on structures.

The cost price for new structures will be:

$$p_n = a_n + \frac{C}{Dn} + \frac{I_s N_n}{n_a N_n D_n}$$

where: n_a = depreciation type of new investments.

It follows that introducing the values of N_n and I_s, we obtain:

$$p_n = a_n + \frac{C}{D_n} + \frac{I}{n_o(\Delta P + KP)} \quad (2)$$

Since p_v is the same in all cases, the minimum cost price will be given by relation (2).

In this relationship, we can take a_n constant, and the 3rd term is also constant because *I*, n_a and *(ΔP+KP)* are constant.

In this equation, the only variable term is $\frac{C}{D_n}$.

The average flow rate of new wells, D_n will be given by the relationship:

$$D_n = \frac{N_1 D_1 + N_2 D_2 + N_3 D_3 + \ldots..}{N_1 + N_2 + N_3 + \ldots..} = \frac{\Delta P + KP}{IN_n}$$

Considering indices *1, 2, 3, ...* in the structures put into operation, equation (2) becomes:

$$p_n = a_n + \frac{N_n}{\Delta P + KP}\left(C_s + \frac{I_s}{n_a}\right)$$

where: I_s = average investment per well;
C_s = average cost per well.

Both C_s and I_s are variable according to the number of wells that will be drilled on the new structures that will be exploited.

If a_n is assumed to be constant, the minimum will be given by the 2nd term of the equation.

$$p_{\min} = \frac{N_n}{\Delta p + KP}\left(C_s + \frac{I_s}{n_a}\right)$$

Total investments are considered constant, so: . $I_s \Delta \int_n = I$.

Then the equation becomes:

$$p_{\min} = \frac{I}{\Delta P + KP}\left(C_s N_N + \frac{I}{n_a}\right)$$

The minimum of this equation will be given by the relationship:

$$p_m = \frac{C_s N_n}{\Delta P + KP} = K_1 C_s N_n,$$

Where the variables are C_s and N_n determined by the number of wells that will be drilled on each structure.

The structures must be chosen in such a way that $Y = \Sigma N_n C_s$ is minimal. The minimum will be:

$$Y = N_1 C_1 + N_2 C_2 + N_3 C_3 + \ldots.. \quad (3)$$

In this equation C_1, C_2, C_3 can be considered constant.

The number of oil wells will be determined by the relationship:

$$N_1 I_{s1} + N_2 I_{s2} + N_3 I_{s3} + \ldots.. = I, \quad (4)$$

In this relationship, I_{s1}, I_{s2}, I_{s3} are constants.

On the other hand, the well flow rates on the structure are also constant. It results:

$$N_1 D_1 + N_2 D_2 + N_3 D_3 = \Delta P + KP \quad (5)$$

Relations (3), (4), and (5) will give the number of wells that will extract production at the lowest price.

The number of new structures to be exploited being greater than *I*, other relationships will have to be found in order to determine the number of wells in the *n* structures. However, it is known that the number of wells per structure is limited by the number of locations found in the exploitation area. Therefore, it will result:

$$N_1 \leq N_{G1}$$

$$N_2 \leq N_{G2}$$

and so on

where N_G = number of oil wells in the area.

In these calculations, it was assumed that I_s and C_s are constant. In reality, however, the average investment per well varies according to the number of wells drilled on the structure, due to the overall investment of the structure, so:

$$I_{s1} = I_c + \frac{I_G}{N}$$

where: I_c = is constant and represents the cost of drilling and the cost of production facilities from wells and separators;

I_G = general investments (approx. 20% of I_{s1}).

The same can be said about C_s that represents the cost of exploitation per well-year. Here, the variation of the cost per well-year does not depend much on the number of wells, but on the depth.

Therefore, to establish the minimum price per well, it is necessary to know C, I_s, and D_m for each structure that will be put into operation.

Numerical example. Model for the optimal distribution of investments between oil structures

A number of five structures are proposed, which have the characteristics given in Table 1.

Table 1 Optimal distribution of investments between oil structures

Structure	Production, thousand t per well-year	The investment, million lei per well	Annual operating expenses, million lei/well	Maximum number of locations
1	5	2.0	0.4	70
2	6	2.5	0.43	50
3	6.5	3.0	0.46	40
4	7	3.5	0.48	30
5	8	4.2	0.52	25

Denoting by $x_1, x_2, ...,$ the number of oil wells on the structures, the condition equations will be:

$$\text{Production: } 5x_1 + 6x_2 + 6.5x_3 + 7x_4 + 8x_5 = 700 \text{ thousand tons}$$

$$\text{Investments: } 2x_1 + 2.5x_2 + 3.0x_3 + 3.5x_4 + 4.2x_5 = 300 \text{ million lei}$$

Minimum expenditure requirement in the first year should be:

$$Y = 0.4x_1 + 0.43x_2 + 0.46x_3 + 0.48x_4 + 0.52x_5$$

One of the minimum conditions that gives results in integers is obtained when:

$$x1 = x2 = x3 = 40 \text{ oil wells}$$

$$x4 = x5 = 0$$

In this case it results:

As production: 5 x 40 +6 x 40 + 6.5 x 90 = 700 thousand t

As investments 2 x 40 + 2.5 x 40 + 2 x 40 = 300 million lei

Minimum expenses in the first year:

0.4 x 40 + 0.43 x 40 + 0.46 x 40 = 57.6 million lei/year

Therefore, based on the optimization of annual expenses, it was calculated that the optimal solution is to drill 40 wells in the first year on the first 3 structures.

Taking into account equations (1) and (2), the total cost price in the next year can be calculated.

Obviously, the problem can also develop over time, considering the entry into production in the coming years of the other possible wells on these structures, as well as the entry into production of the other 2 structures and certainly others.

The optimization, however, was only done for the first year of production. In the third year, a similar calculation can be made based on the new structures that are ready for operation and the results obtained in the previous year.

This is just one of many examples of the application of linear programming that has been used to distribute investments in the oil extraction industry.

Problems may arise regarding the optimal distribution of equipment and material depots in the territory where the wells are drilled, problems regarding the maximum efficiency of geological works, the optimal distribution of these works in the various geological areas, etc.

Conclusions

This paper had explored the possibilities of building up operational models for optimal decisions in the oil industry through linear programming aiming at the analysis of investment efficiency in oil and gas industry. In doing this, the present paper has aimed to build up a range of more econometric models applicable in oil industry that may be useful for managers working in oil industry.

In the beginning, a special focus was placed on revealing some applications that may help us estimate the optimal distribution of investment funds in the oil structures where wells will be drilled in the coming years, for generally, the investment funds allocated to a branch or enterprise are limited.

We started the analysis from the problem in oil extraction is to use these funds in such a way that: to obtain the highest production within the limits of a certain investment fund; to achieve the lowest cost price of a planned production, which is equivalent to obtaining the highest profit.

It then resulted that, given that production and investment funds are established by plan, only the extraction cost price remains to be optimized as the production set by the plan will be obtained from wells in operation on January 1st and from wells drilled during the year.

Then, it was analyzed that depending on the structure where the new wells are located, in structures with deep deposits will be higher and therefore the number of wells will be lower. In this case it is assumed that deeper wells give higher production. The paper identified that if there exists a given number of structures, when the exploitation activity is developed, the structures will have to be chosen in such a way that this can develop in all structures or only in certain structures, leaving some as a reserve.

Then, the paper presented a numerical example of a model for the optimal distribution of investments between oil structures by using a number of five structures, which have certain given characteristics revealed in the analysis. Starting from production, investments, annual operating expenses, and maximum number of locations per each structure, as an optimal solution it was calculated the number of wells to be drilled in the the first year on the five structures. Obviously, the problem could also be developed over time, considering the entry into production in the coming years of the other possible wells on these structures, as well as the entry into production of other structures and certainly others.

This is just one of many examples of the application of linear programming that can been used to distribute investments in the oil extraction industry. Problems might arise regarding the optimal distribution of equipment and material depots in the territory where the wells are drilled, problems regarding the maximum efficiency of geological works, the optimal distribution of these works in the various geological areas, etc.

Finally, we may say that the obtained results and conclusions can be useful for further analysis. As such, for deepening the analysis related to these issues, in the following papers, other models that solve the problem of optimal decisions in the oil industry through linear programming aiming at the analysis of investment efficiency in oil and gas industry.

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