Volatility in exploratory projects of unconventional oil & gas

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Sumary: This “paper” mainly seeks to show the use of volatility calculation in exploratory projects of unconventional, can, when compared to traditional methods, lead to improved decision-making. For such purpose, a new methodology involving the Monte Carlo simulation and the volatility calculation is presented, based on volatility calculation method that allows to define which ones the options in each project are. To develop such application, a hypothetical area of “Play” of “shale” of a basin Middle Magdalena Valley (VMM)” of Colombia is considered, framed by a decision tree, according to the following stages: 1) Prospective area evaluation; 2) Productivity verification; 3) Commercial viability and 4) Development, including technical and economic uncertainties at every stage, allowing volatility calculation, and the expected value with the objective of forming the portfolio that allows this to make the optimal decisions of the exploratory investment. In addition, it was analyzed, using the “waiting option”, which allowed to define which project to start with.

Introduction

Companies’ main concern is that decision making allows to validate that in exploratory projects of unconventional, whereby there are reservoir indepence characteristics or heterogeneity, without clarity about resource allocation priorization in the project portfolio; the implementation of a valuation method of such investment projects must be allowed the visualization of appropriate value creation possibilities capture, which might, in the future, generate the project. The most widely used method by most companies to achieve this objective is the discounted cash-flow valuation and a decision tree, expected value calculation.

The main objective of this work is to evaluate in an area of "Shale" type exploratory projects of unconventional reservoir, determining the volatility that each project might have, crossed with the expected value, which will allow to have the facts for decision making and on which or which ones should have investment or/and divestment options and the path to take to validate the prospectivity of this type of reservoir.

With the use of this method (Volatility calculation) and the combination of other methods, such as decision trees, it is possible to configure accurate information that allows improving the orientation to the decision-makers in order to make investment decisions, allowing the identification of how far to invest directly, diversify or not.

Theoretical framework

The term “Unconventional Reservoir”, specifically in the type of "Shale", corresponds to source rocks where the main characteristic is that they have very low permeability, from which the hydrocarbon migrated to the existing conventional reservoirs; by means of more complex and expensive technologies the hydrocarbon can be extracted; for the development of unconventional reservoir, it is necessary to drill a considerable number of production wells and develop operating processes to optimize costs and execution times.

The unconventional reservoir were accumulated before the conventional reservoir, but because the extraction techniques and the high operating costs were complex, the companies did not exploit them. In order to be self-sufficient, not having dependence on other countries in power generation and generating value to the country, in the United States the way of exploiting this type of reservoir was found and developed.

From the rapid advances in the US, it has been shown that:

- The potential is greater than that of conventional reservoirs.
- This type of reservoir are found in several countries and will allow energy self-sufficiency.

• In Colombia, the type "Shale" unconventional reservoir according to the report "Technically Recoverable Shale Oil and Shale Gas Resources Northern South America" of the EIA, September 2015, for the river basin of the Middle Valley of Magdalena, the recoverable resources are around 4.76 trillion barrels of crude and 18.3 trillion cubic feet of gas.

The concepts of exploration and production for unconventional reservoir are different from the conventional reservoir and the following stages of the exploratory and exploitation process are:

1) Prospective area evaluation;
2) Productivity Verification;
3) Commercial Viability
4) Development

The exploratory risk for unconventional reservoir is low (The World Energy Book, 2007, among others); but the exploration processes and exploitation require a high drilling technology and completion combined with soft technologies (process analysis "LEAN", application of just-in-time "JIT", among others), which allow the implementation of light processes, on the spot decision making, cost reduction and optimization of execution times, therefore having tools where the agility and efficiency is the constant for the exploitation is required.

<u>Important concepts</u>

In this section, the following concepts taken from resolution 90 341 of March 27, 2014, of the Ministry of Mines and Energy of Colombia, are considered keys for the development of this work:

• Wells reparation: Set of wells. Minimum three (3) up to ten (10) wells, where the main characteristic is given by the geographical proximity and properties of similar reservoirs to maximize production efficiency. The settlement base unit involving payment of royalties will be limited by the envelope formed by the sum of the drainage area of the most distant producing wells the well reparation.

• Economic limit: Production rate of one or more wells reparations beyond which the net flows of the operations are negative.

• Hydraulic stimulation: Treatment of the formation of interest or producer of a well through the use of a stimulation fluid with the aim of improving its productivity. This stimulation is carried out through the pumping of a fluid composed of water, chemicals and propane at a high pressure through the hole of the well, in order to induce fractures in the rock to increase its permeability.

• Horizontal well: Well that contains a section whose deviation from the vertical is greater than 80 degrees and is projected more than 100 feet within the formation of interest.

• Exploratory Confirmation Program: Exploratory activities tending to confirm that there is a discovery of hydrocarbons in an unconventional field.

• Global Drilling Program: Wells reparation, which involves drilling and completion.

• Propant: Constituent of the hydraulic stimulation fluid, usually sand or granulated material, which is used to keep the fracture open, once the pressure of hydraulic stimulation is reduced.

• Wells Pilot Test: Period to determine the productive capacity of the accumulation, estimate the petrophysical characteristics, evaluate the area of influence, the spacing and the possible completions and technologies of stimulation in unconventional reservoir.

For the purpose of Decree 3004 of December 26, 2013, Unconventional Reservoir will be understood as the rock formation with low primary permeability to which stimulation must be carried out to improve the conditions of mobility and recovery of hydrocarbons. The Unconventional Reservoir include gas and oil, in pressed sands and carbonates, methane gas associated with coal seams, gas and shale oil and tar sands.

<u>"Shale"</u>

Technically, the term "shale" refers to the size of the grains. "Shale" is a fine-grained sedimentary rock rich in organic, interlayer with siliceous and carbonaceous material. They are expected to be friable (vertically and length); few "plays" are pure clays; the most productive have compositions rich in carbonates and / or silica with less than 25% clays. They are typically the bedrock of conventional reservoir. Another important characteristic is that if the deposit is in a gas window, it can be produced more easily than liquids (smaller molecular size and oil viscosity).

To extract the hydrocarbons from these rocks, we need to use hydraulic fracturing. According to Lahee (1961) the objective is to create conductive channels through which the hydrocarbon can flow easily into the well. To form a hydraulic fracture it is necessary to pump a fracture liquid (for example water, gels, nitrogen, among others) in the perforation. The rate at which this liquid is pumped must be sufficient to increase the pressure of the well and exceed what is known as fracture gradient of formation. This pressure exerted by the liquid causes cracks in the formation. Then the fracture fluid enters these cracks and increases the size (and length) of the crack. In order to keep the fractures that were formed open, a solid (usually sand screen) is added to the liquid fracture.

Aspects for structuring the financial model

Monte Carlo Simulation

This method involves the simulation of thousands of possible interactions of a project and the calculation of the net present value of the project (NPV) or the present value (PV) for each interaction, using the discounted cash-flow method (DCF) and the analysis of the probability distribution of the NPV results (Kodukula & Papudesu, 2006). In general, each interaction is constructed by taking random values from the probability distributions of the input variables and by calculating the NPV. In contrast to the DCF method, the Monte Carlo method takes into account the uncertainty of the input variables, admitting that their future behavior is unknown. The projects to analyze have the condition of total uncertainty.

Decision tree

The decision tree, in the project evaluation involving contingent decision-making, is an effective tool. This is represented on a map showing the different strategies that can be taken, their costs and possible outcomes and the probability of a given payment. The NPV of the project is calculated by using the expected value method (Kodukula & Papudesu, 2006).

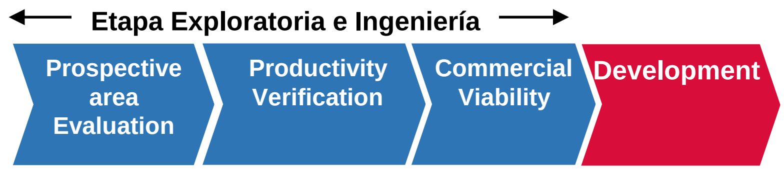
Consider three elements (Bautista, 2010):

• Decision node, It is represented as a square-shaped figure.
• State node (probabilistic node), It is represented as a circular-shaped figure.
• Connecting arcs between the tree nodes.

Development of the model

In order to make decisions about this type of projects, the process that allows to diagram the accurate analysis must be taken into account (see Figure 1); the process is described at each stage hereunder:

Figure 1 Process of Exploration, Engineering and Development of "Shale" Projects



Source: Author

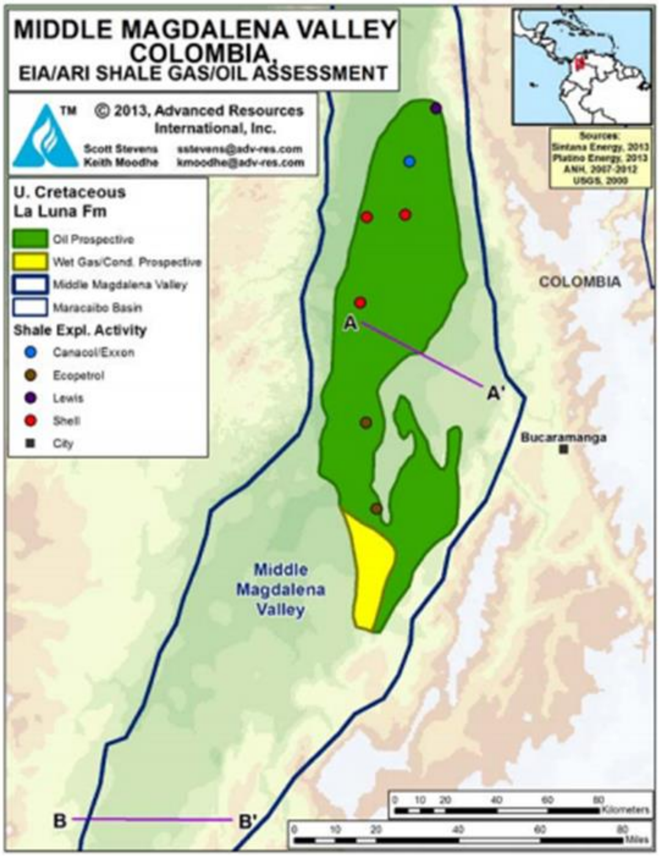
Stage 1) Evaluation of the prospective area: as an application of the set theory, is defined as the area where the variables that define the possible location of the hydrocarbon are intercepted. The thermal maturity (Ro%), the total organic content (TOC%), the thickness of the rock and the depth are crucial to define the most probable area (see figure 2).

• Ro%: refers to thermal maturity and vitrinite is measured at reflectance. Yes:
Ro%> 1.0% Dry Gas
Ro% 0.5% - 1.0% Condensed
Ro% <0.5% Liquids

• TOC% ("Total Organic Content"): refers to organic materials, fossil micro-organisms and plants deposited in the rock that provided the required carbon, oxygen and hydrogen to hold a total of organic matter. It is an important measure of the potential of gas generation or liquid in the formation of the "Shale". For the area to be prospective TOC% must be greater than 2% (the range is from 2% to 14%). If the TOC% drops the Ro% is high.

• Rock Thickness: it is expected that at least it is greater than 100 " that allows to identify the intervals of organic matter.• Depth: It allows the kind of technology required to reach the rock.

Figure 2 Prospective area of the VMM of Colombia



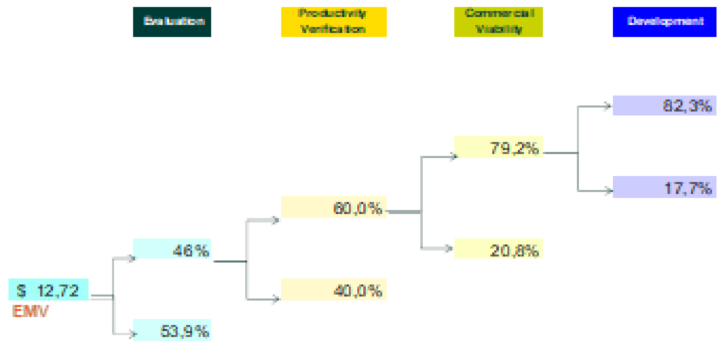
Source: ARI 2013

Stage 2) Productivity Verification: at this stage, a vertical well is drilled to obtain information of each possible interval, such as "Core" rocks collection that are analyzed in laboratories to identify the mineralogy, fracturability, pore pressure and permeability; then, defining the best interval, a horizontal reentry is perforated in which the stimulation, completion and production tests are performed; in addition, at this stage the reservoir pressure, the type of hydrocarbon, temperature and how it can reach the surface are determined.

Stage 3) Commercial viability: at this stage, the operational model is designed and implemented, at a certain scale, in an appraisal campaign concept of a well plant, taking into account ease of production and modular or fixed hydrocarbons transportation.

Stage 4) Development: at this stage a drilling manufacturing model is projected, tested in the previous process. Based on the well distance model and expected production, compared to the cost of each well, a drilling plan is developed in the wells reparation, as defined by the technical standard. This is integrated into the decision tree and the expected value (EMV) is calculated (see figure 3). This process must be developed with the techniques of Just-in-Time Series Production, Theory of Constraints and Planning of Requirements, among others, which allow the development of "LEAN" processes.

Figure 3 Decision tree Calculated EMV



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$$\mathbf{EMV} = \mathbf{POS}_{\text{Evaluation}} * (\mathbf{POS}_{\text{Productivity Verification}} * (\mathbf{POS}_{\text{Commercial Viability}} * (\mathbf{NPV}_{\text{Development}} * \mathbf{POS}_{\text{Development}}))) + (+/- \mathbf{NPV}_{\text{Fault Development}} * (1 - \mathbf{POS}_{\text{Development}}) +/- \mathbf{NPV}_{\text{Fault Commercial Viability}} * (1 - \mathbf{POS}_{\text{Commercial Viability}}) - \mathbf{PV}_{\text{Fault Productivity Verification}} * (1 - \mathbf{POS}_{\text{Productivity Verification}}) - \mathbf{PV}_{\text{Evaluation}} * (1 - \mathbf{POS}_{\text{Evaluation}})$$

Where:
EMV=Expected Monetary Value
POS=Probability of success in each stage
NPV = Present Value Net
PV = Present Value
+/- = indicate Value of PV o NPV in this stage

Portfolio of Unconventional Reservoir

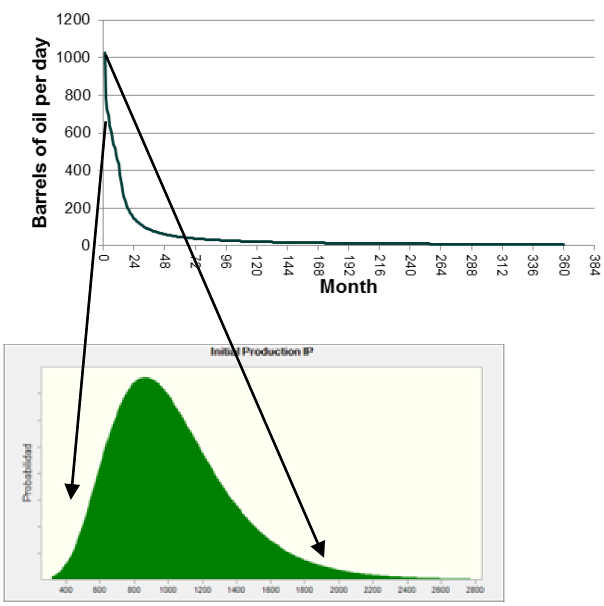
Four projects were taken in which stage 2 will be developed. These projects will be denominated as follows:
Project 1: South Central Zone Li
Project 2: Central North Zone Sal
Project 3: North Western Zone LS
Project 4: Northern Zone Li

Proposed methodology

Using the Excel model, structured to calculate the base value of each project from the FCF, it was determined that the random variables that have the greatest impact are the production profiles, the price and the investments, from which the following variables were correlated: Prices from one validity to another and to each variable was associated with the respective distribution of probability, according to the available record. Figure 4 shows an example of the variables distributions in Project 1, which were extracted when running the model in the Crystal Ball software.

Production Profile per well: the characteristic of these reservoir is that in the first year it declines by 70%

Figure 4a Production per well



Source: Author

The Decline Curve Application analysis in the case is still based on equations and curves described by Arps. Arps applied the Hyperbola equation for defining three general equations to model production declines.

In order to locate a hyperbola three variables are followed.

- The starting point on Y axis, (qi), initial rate.
- Initial decline rate (Di)
- The degree of curvature of the line (b).

Arps did not provide physical reasons for the three types of decline. It only indicated that exponential decline (b=0) is the most common and that the coefficient b generally ranges from 0 to 0.5.

Arp's Equation

$$q(t) = \frac{q_i}{(1 + bD_i t)^{1/b}}$$

q(t) = Production rate at time t

qi = Initial Production rate

Di = The initial decline rate, in percent per year

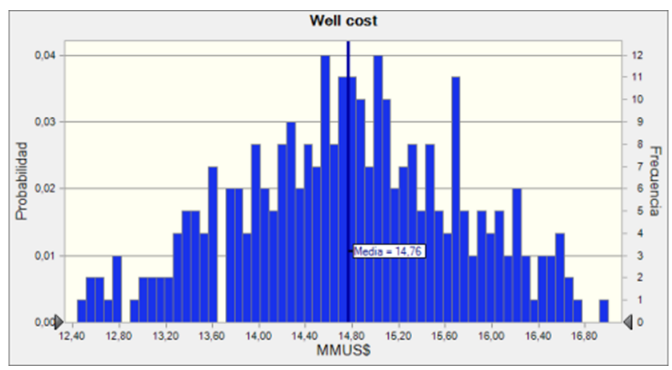
t = Cumulative time in days, since the start of production

b = The decline exponent

The b factor is a correction to the empirically derived decline curve equations which assume non-turbulent, radial flow in the reservoir rocks.

The cost of the well, was determined, according to the historical data and, thus the estimate was made.

Figure 4b Cost per well (CAPEX)

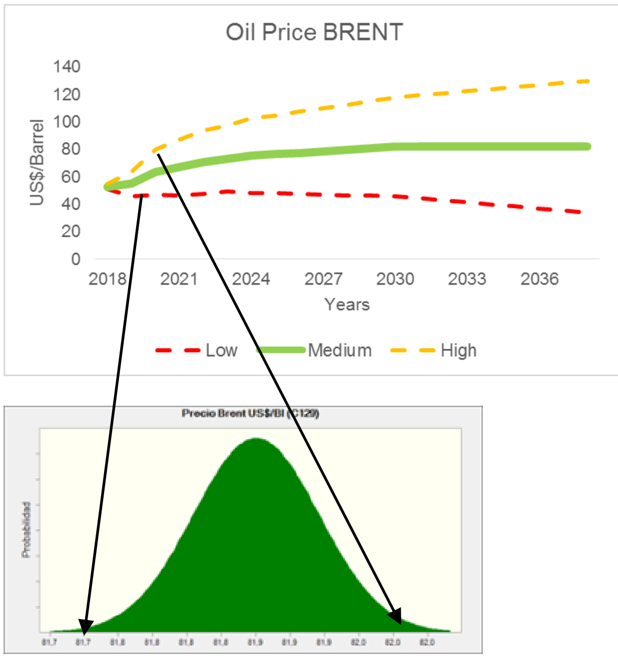


Source: Author

It is important to note that the cost of the well in the development stage is expected to be 60% lower than the well in the evaluation (exploration) stage; Even so, there is the uncertainty that the value of the well depends on its design and length. The cost of the well under evaluation is worth 37 million dollars.

For the price, the BRENT brand estimate was used in the Low, Medium and High scenarios and each year was correlated using a stochastic process (geometric Brownian motion).

Figure 4c Oil Price Brent



Source: Author

Oil prices have been recovered to levels allowing the development of this type of projects, but the uncertainty of what a future price may be, is very high (until February 2019 it is at US $ 63.91 / Bl).

For volatility estimation, the approach taken by Copeland & Antokarov (2001) "Logarithmic present value simulation approach" was taken. The method defines, as a variable to simulate, the standard deviation of the returns from one period to another, which will be denoted as variable Z and which, as a formula, is:

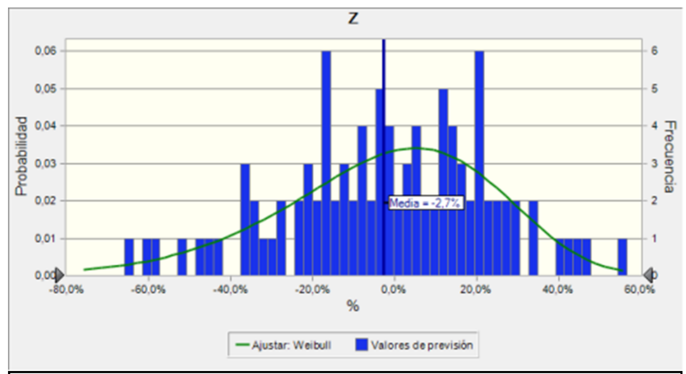
$$z = \ln\left(\frac{PV_1 + FCF_1}{PV_0}\right) \tag{1}$$

Where PV1 means present value at time t = 1, FCF1 means free cash flow over time 1, and PV0 means the present value at the beginning of the project over time t = 0.

The standard deviation obtained in the simulation for variable Z is the volatility of the project.

After having all the variables that handle uncertainty with their respective distributions and dependencies, by means of the Monte Carlo simulation, all the possible values that stochastically can take the returns of the underlying asset are represented. From the table of statistical indicators, the standard deviation of the variable Z is taken as the value of the volatility. Figure 5 shows an example of the output distributions of the variable Z (standard deviation of the yields) of the project (1), which were extracted when running the model in the CrystalBall software.

Figure 5 Variable Distribution Z

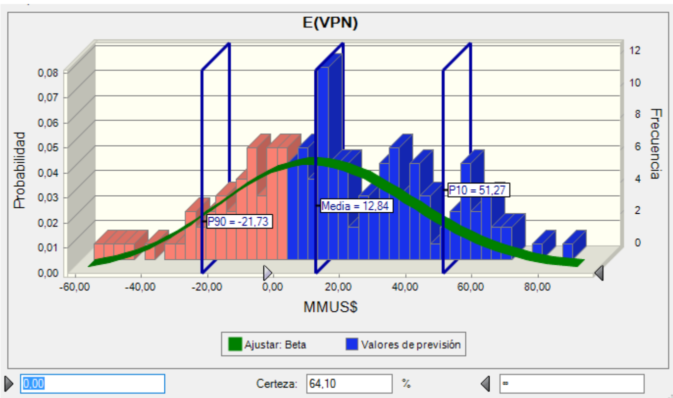


Statistics:	Forecast Values
	100
Base Case	1,8%
Mean	-2,7%
Median	-0,9%
Mode	---
Standard Deviation	26,6%
Variance	7,1%

Source: Author

The result of the expected value (EMV) of each project with its distribution was also obtained (see figure 6).

Figure 6 Expected Value of Project



Source: Author

From the resulting value of the simulation (the volatility obtained), the matrix is constructed between the expected value and Volatility (see figure 7)

Figure 7 Expected Value vs Volatility of Portfolio the Unconventional Projects

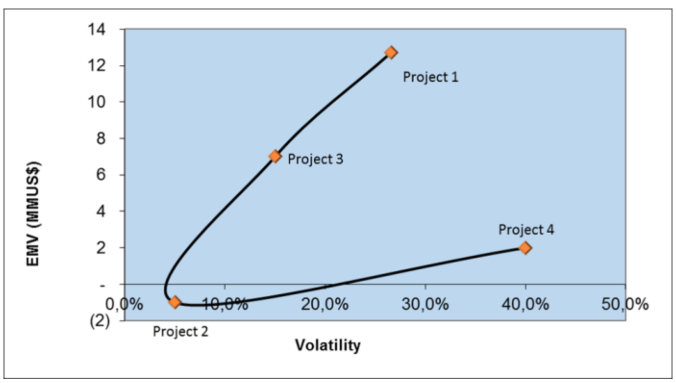


Figure 7 shows four projects. The most important decision making is decided what project can invest or not execute additional, which feasible portfolio will be to take, according to the results the project 2 should not be executed because its EMV<0 and low volatility, the project 4 has high volatility and the recommendation will be to search a partner to share the risk. And finally the projects 1 and 3 are the efficient and envelope for the unconventional reservoir.

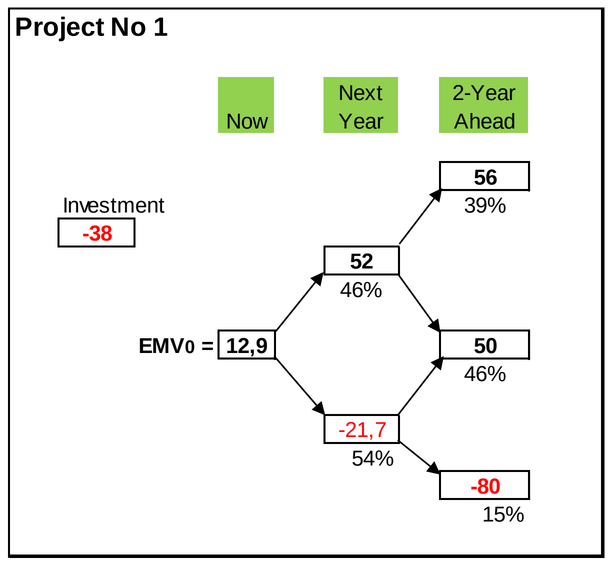
Two-year Waiting Option Analysis

The question is: Which project to initiate with (Project 1 or Project 3), taking into account the following:

a. The country will lose its crude self-sufficiency in 6 years, since the reserves are of 2.0 trillion barrels and gas self-sufficiency is of 5 years, as the reserves are 4.5 trillion cubic feet. According to the above, it is necessary to start the exploration of this type of deposits, which in initial calculations may be in a range of 2 to 7 billion recoverable barrels and 20 trillion cubic feet of gas.

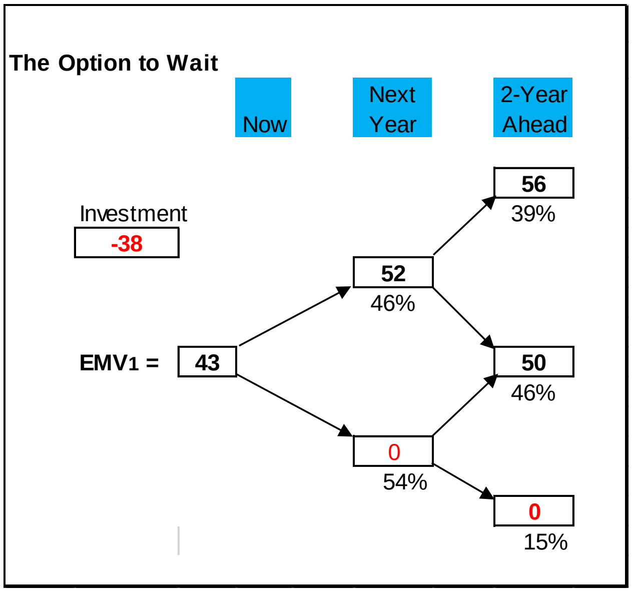
b. For the analysis of the "waiting" option, the decision tree was used with probabilities and it was found that project 1 must wait for better technical information to be obtained which will allow to reduce subsoil uncertainties and thus improve its value, as shown in Figure No. 8a and 8b.

Figure 8a Expected Value of execute project now



Source: Author

Figure 8b Expected Value the option to wait



Source: Author

Conclusions

Companies make the project prioritization decisions under a deterministic conception, limited to the moment of acceptance or rejection, but the reality is different, since it may be losing value by not identifying the real value with evaluation methodologies, more in line with the successive decisions and changes that make up an inversion project; such is the case in the hydrocarbons evaluation of unconventional reservoir, specifically "Shale".

In the document became evident that the analyst must pay special attention when applying methods that were originally developed for evaluation. There are shortcomings when making a direct extension of valuation methods from financial options to real options. If the mathematical assumptions on which the theory is based do not correspond to the practice. In these cases, variations of the method should be applied to correct the problems of non-compliance of the assumptions.

The presented methodology is one of the possible alternatives for the project valuation in unconventional reservoir, based on volatility, so it can be enriched, according to the needs of the specific cases to be evaluated. It is also possible to modify it to improve the estimation of the input variables. For example, the assigned probabilities can be perceived as subjective. To obtain a better and more reliable estimate, you can make use of tools such as Bayesian networks. You should seek ways to complement the methodology without complicating it to a large extent.

The analysis of the “waiting” option allows us to conclude that when there is high volatility it is advisable to wait for projects with less volatility to be developed initially, as long as the expected value is positive. Therefore, the analysis shows that it must start with Project 3.

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