Proceedings of the 2005 Crystal Ball User Conference

AN APPLICATION OF PORTFOLIO OPTIMIZATION WITH RISK ASSESSMENT TO E&P PROJECTS

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ABSTRACT

This paper presents an application of portfolio optimization with risk assessment to E&P projects. The study aims to maximize the worth of the company while accounting, investigating and analyzing the inherent uncertainties and requirements of the petroleum industry.

The results show a significant variance of the net present value of the portfolio after tax (NPV ATax) with the inherent uncertainties of the petroleum industry and reveal the importance of accounting probability to each outcome range in such a high-risk environment. The investigation reveals that some requirements of the petroleum industry may conflict with each other or lead to an inefficient portfolio management, destroying value and elevating the risk. The work proposes that the way out is to use the portfolio management as a tool to provide balanced, transparent and open discussion analyses of the impact of the proposed requirements. Sometimes they happen to be unrealistic expectations created by the desire to grow way above well-funded competitors. The study indicates the possibility to translate subjective goals from strategic plans into quantitative targets leading to a company more committed to the strategic plan.

1 INTRODUCTION

The exploration and development of hydrocarbons is a high risk venture. The geologic and economic uncertainties involved in the assessment of exploratory prospects and developed fields make for high risk decisions, with no guarantee of successfully striking hydrocarbon or finding an economic size field to develop.

Considering geologic aspects, the technical team (geologists and geophysicists) basically focus on providing 1) estimates of the likelihood of a hydrocarbon structure being present and the volume it might contain; 2) the likelihood of sufficient porosity and permeability; 3) the chances of hydrocarbons been produced; 4) the chance of having a present seal trap; 5) dimensional aspects of the hydrocarbons; 6) reservoir characteristics, among others.

The economic/commercial assessment deals with uncertainties related to the probability of finding and producing from economic reservoirs. Hydrocarbon volumes and types (oil/gas), total investments and operating costs to explore and develop prospects based on engineering designs, taxes and royalties included in fiscal regimes, market destination and product selling prices, are variables taken into account in this task.

All these parameters impact the economic indicators of an Exploration & Production (E&P) project. The prediction of these input parameters is made under uncertainty. The capacity to supply quantitative measures of the geologic and economic risks is vital to the economic analysis, because it provides a range of possible outcomes that improves the understanding of the project and the process of decision making.

Once we have defined quantitative measures of the risks involved in the E&P projects, there are some variables that the company has control over, such as working interest and start time of the project, and that can be modified to reach the objectives and goals established on the corporate strategy. These controlled variables are called decision variables. In other words, one can apply the better understanding of the project to seek an optimal working interest and starting time for each venture to maximize the total worth of the set of projects (portfolio optimization) for given risks, constrains and requirements.

Several authors point out a large gap on combining decision variables (timing included) with portfolio optimization and linking these efforts to portfolio risk management analysis process. Efficient frontier analysis considers the balance between value and risk in the selection of optimal portfolio. However, the definition of risk (originally developed for securities portfolios) is yet to be further characterized in the petroleum business and the “optimal” portfolio is strongly dependent on which definition of risk is selected. Surprisingly, there is little discussion on how to close this integration gap in both the academic literature and in practice.

This paper presents an application of portfolio optimization with risk assessment to E&P projects. The nature of the work is field data. The E&P portfolio used in this work involves three types of ventures:

1. Fields in production phase: Project 1, Project 2.
2. Projects or prospects in exploratory phase: Project 3, Project 4, Project 5, Project 6 and
3. Potential prospects in exploratory and development phases (possible acquisitions): Project 7, and Project 8.

The focus of the results presented in this paper is predominantly from the economic viewpoint of the exploration and production risk assessments.

2 METHODOLOGY

The methodology can be divided into two parts:

1. Economic analyses involving uncertainty and
2. Portfolio optimization

For the economic analysis, the methodology initially involves building an economic spreadsheet model. Every project typically has cash receipts and disbursements into ones treasury. Input parameters associated with hydrocarbon demand, price, unitary costs and fiscal regime eventually determines the inward and outward flow of cash. The model converts all future values to their equivalent of present value using the weighted average cost of capital. Finally, the correspondent net cash flow (discounted cash flow) leads to economic indicators such as net present value (NPV), internal rate of return, maximum financial exposure and payout time.

The undesirable event here is to evaluate economic indicators with deterministic values and results that don't reflect the inherent uncertainties involving the petroleum industry. Probabilistic analysis by means of Monte Carlo simulation is the way followed to deal with the problem.

Figure 1 presents the main premises (input parameters) of the study. Their deterministic values reflect the current operational conditions along with the contractual commitments and some conservative expectations.

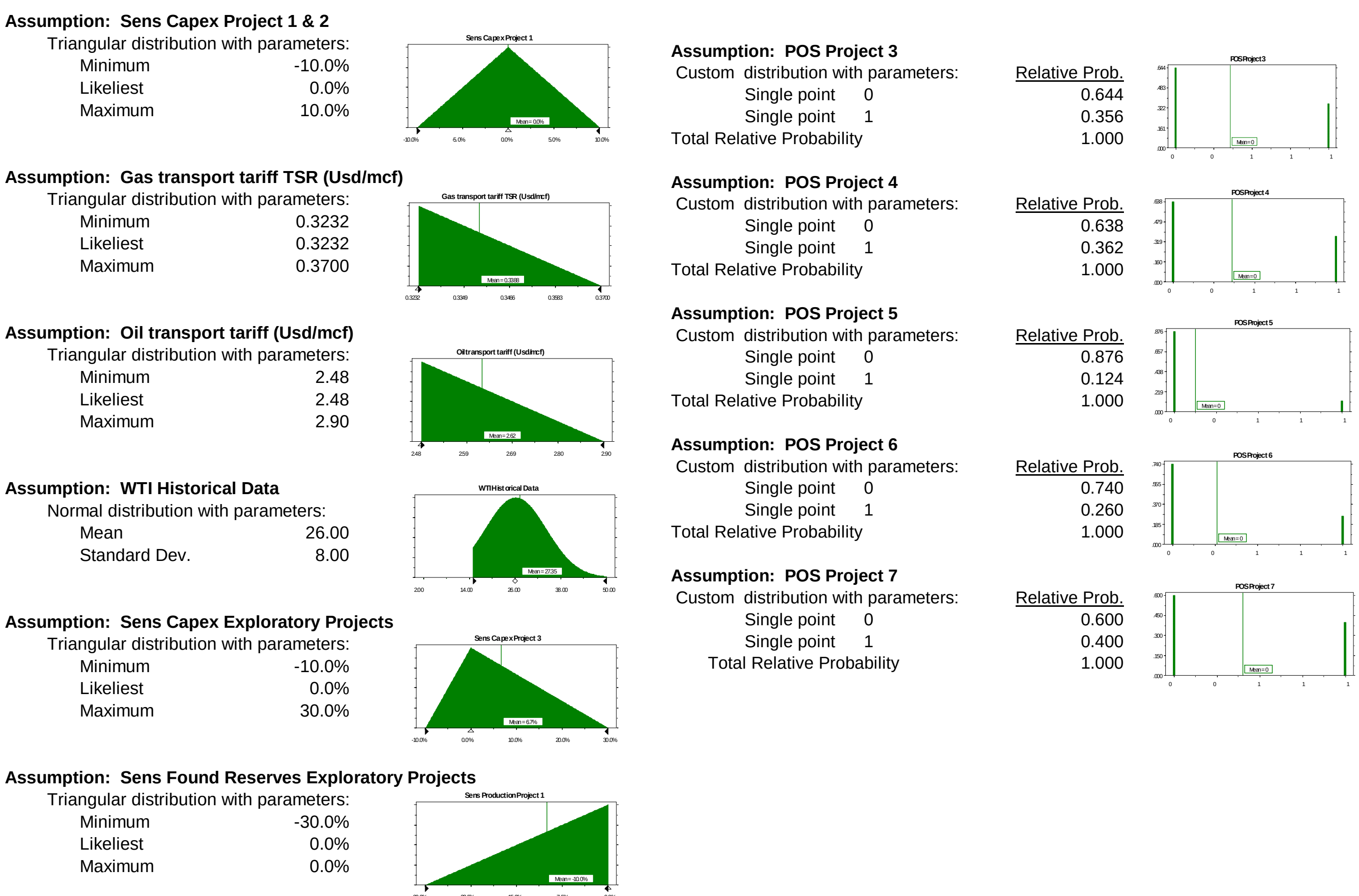


Figure 1: Principles Assumptions

A sensitivity analysis provides, as a result, the variables that have the major impact on the NPV/EMV of each project. These key variables are chosen to be represented by probabilistic distributions in the risk analysis process:

3. Gas, condensate and oil selling price (based on WTI and internal market regulations),
1. Transport tariffs (for internal and external markets),
2. Capital expenditures CAPEX (exploratory and production projects) and
3. Production (gas, condensate and oil).

The triangular distribution is commonly used in this work where the variable distributions are not well known, especially for Capex and transport costs estimations, and not suitable for a (log) normal distribution because it is bounded. The petroleum industry uses commonly the log-normal distribution to simulate the behavior of the geologic, reservoir and production aspects. Even the oil price behavior, based on historical data, has the shape of log-normal distribution. Because the main purpose of this work is to present a methodology of portfolio optimization and not to exactly describe the behavior of some variables, the triangular distribution is widely used for simplicity and because it is flexible, simple and intuitive to understand. The study also uses normal and log-normal distributions for some uncertain variables.

The price and transport tariff are considered as global variables, meaning that, for each iteration of the Monte Carlo Simulation, each project uses consistent prices. This has the effect of establish correlation between the projects contained in the portfolio.

The production of the actual portfolio (Project 1 and 2), mostly associated with gas and having contractual terms established, follows a uniform probability distribution with the maximum and minimum values related to the daily contracted quantity (QDC) and the take or pay commitment (80% of the daily contracted quantity). The expected production of exploratory projects, mostly based on preliminary estimates, follows a triangular distribution. The most likely values are based on correlations with historical production data of other areas. The maximum values collapse with the most likely ones, reflecting a conservative approach to estimate the potential production curve. The minimum values bear a reduction of 30% of the most likely ones. Figure 1 shows the charts and main parameters of the distribution.

The economic analysis of exploratory projects carries the assumptions of two possible outcomes: success and failure. The first one heads to a profit based on the net cash flow result of the development of a commercial hydrocarbon accumulation. The second one leads to a loss based on the costs of acquisition, G&G and dry holes. The probabilistic distribution of the outcomes for exploration ventures is binomial. The probability of success (POS) depends on the geological, completion and economic/commercial chances. The recommended methodology establishes to apply the probability of commercial/completion success (something around 60-80%) on top of the geological chance. Figure 1 presents the charts and parameters related to the probability of the exploratory projects based on the calculations of geological chances only. To add realism to the process, the POS was correlated for some exploratory projects that are similar in several geologic aspects.

The forecasts variables (physical and economic indicators) are:

1. Net Present Value After Tax (NPV ATax) of each production project,
2. Expected Monetary Value After Tax (EMV ATax) of each exploratory project,
3. Expected NPV ATax of the consolidated cash flow, E(NPV),
4. Maximum financial exposure for new ventures.
5. Minimum daily oil equivalent production of the consolidated projects.

The sampling method of simulation for the risk analysis is Monte Carlo. The maximum number of trials is limited to 5000. The risk model is based on Crystal Ball® software.

For the Portfolio Optimization, the methodology requires the definition of:

1. Objective of the optimization: Maximize the E(NPV) ATax of the consolidated portfolio in line with the main strategy of the company (Create Value),
2. Decision variables: Working Interest (WI) and the Start Time of each project included in the portfolio based on contractual terms defined in the Concession Contracts.
3. Decision variables constraints: The start time variable is applied only for the exploratory projects because they don't have a final decision on when to start. Although the government gives a deadline to drill an exploratory well, the company has the right to decide, before that deadline, when to start the project based on the economic and the commercial opportunities of the field. The working interest (WI) is the percentage of participation of the company in the project. Both decision variables may vary within specific ranges limited by contractual or estimated constraints. Table 1 presents the decision variables and correspondent constraints (lower and upper bounds) of each project.
4. Requirements for the forecasts variables: The maximum financial exposure, NPV ATax and EMV ATax for each project and the minimum daily oil equivalent production of the consolidated portfolio. The requirements follow the strategic plan (goals) of the company. Table 2 shows the requirements of the optimization.

Table 1: Decision Variables

WI Project 1		**WI Project 2**		**WI Project 6**		**Start time Project 6**	
Variable bounds:		Variable bounds:		Variable bounds:		Variable bounds:	
Lower	35%	Lower	35%	Lower	0%	Lower	2005
Upper	50%	Upper	50%	Upper	75%	Upper	2008
Step	1%	Step	1%	Step	1%	Step	1
WI Project 3		**Start time Project 3**		**WI Project 7**		**Start time Project 7**	
Variable bounds:		Variable bounds:		Variable bounds:		Variable bounds:	
Lower	0%	Lower	2005	Lower	0%	Lower	2005
Upper	100%	Upper	2007	Upper	70%	Upper	2006
Step	1%	Step	1	Step	1%	Step	1
WI Project 4		**Start time Project 4**		**WI Project 8**		**Start time Project 8**	
Variable bounds:		Variable bounds:		Variable bounds:		Variable bounds:	
Lower	35%	Lower	2005	Lower	0%	Lower	2005
Upper	50%	Upper	2008	Upper	50%	Upper	2008
Step	1%	Step	1	Step	1%	Step	1
WI Project 5		**Start time Project 5**					
Variable bounds:		Variable bounds:					
Lower	0%	Lower	2005				
Upper	100%	Upper	2009				
Step	1%	Step	1				

Table 2: Forecast Requirements

	Base Case	**Units**
Max Financial Exposure =>	-200	MMusd
Minimum Daily BOE Prod =>	70,000	BOE/d
EMV Project 3 (Mean) =>	0.0	MMusd
EMV Project 4 (Mean) =>	0.0	MMusd
EMV Project 5 (Mean) =>	0.0	MMusd
EMV Project 6 (Mean) =>	0.0	MMusd
EMV Project 7 (Mean) =>	0.0	MMusd
NPV Project 8 (Mean) =>	0.0	MMusd

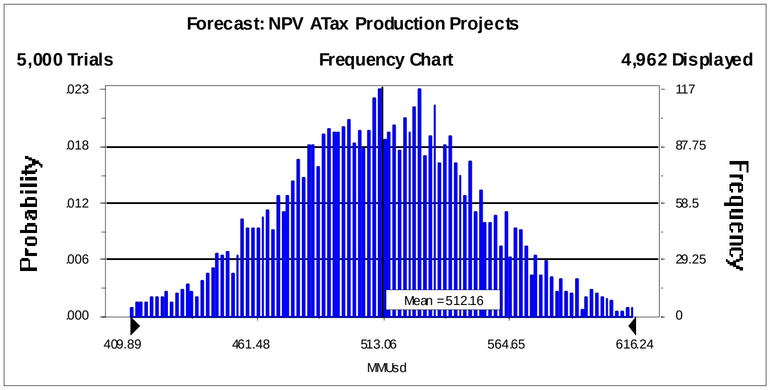
The main task of the model is to find the optimal value for the objective by selecting and improving different values for the decision variables and keeping the restrictions within their limits. The model will have a feasible solution when constraints and requirements are satisfied. That will mean a rate of return equal or greater than the weighted average capital cost of the company (NPV ATax consolidated > 0), a risk tolerance equivalent or lower than the established maximum financial exposure and production above a pre-defined target. This study evaluates three maximum financial exposures for new ventures that relate to an optimistic, base and pessimistic debt to equity corporate situation with the purpose to show the different allocation on the available cash in between projects based on restrictions.

The economic spreadsheet model consolidates the exploratory and production projects of the portfolio. It can also mimic the whole corporative performance taking into account administrative and other costs not usually accounted in a project-by-project basis. The consolidation includes not only ring fenced taxes but also corporative taxes, allowing results before and after tax.

3 RESULTS

For the economic analyses with risk assessment:

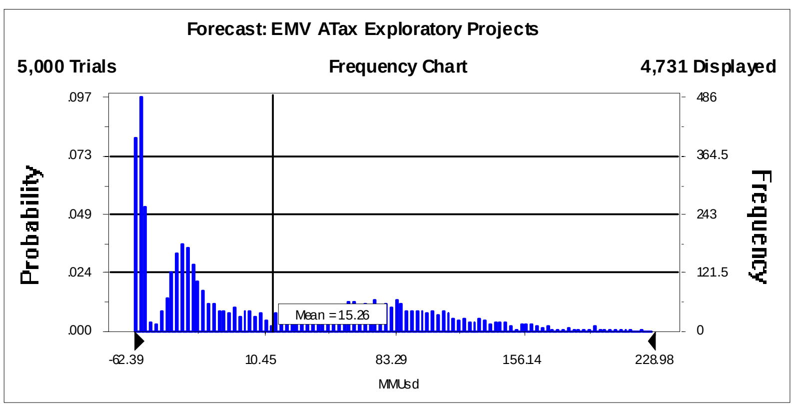
Figure 2 presents the probabilistic distribution of the NPV ATax of the group of production projects with the most likely decision variables (current working interests and best estimates of start time). The chart and statistics reveal a mean value of 512 MMUsd and a standard deviation of 39.8 MMUsd. The minimum and maximum values are 370 and 657 MMUsd respectively.



Statistics:	Value
Trials	5000
Mean	**512.16**
Standard Deviation	39.75
Range Minimum	370.24
Range Maximum	657.20

Figure 2: NPV ATax Probability Distribution of the Production Projects

Figure 3 depicts the probabilistic distribution of the EMV ATax of the group of exploratory projects with current working interests and best estimates of start time. The chart and statistics indicate a bimodal distribution: one mode reflecting the capital risk of dry holes with -60 MMUsd and the other reflecting the NPV ATax in case of economic success with 83 MMUsd (as a possible mean of success). The mean value is 15.3 MMUsd (EMV ATax) and the standard deviation is 78.3 MMUsd. The minimum and maximum values are –69 and 368 MMUsd respectively.



Statistics:	Value
Trials	5000
Mean	**15.26**
Standard Deviation	78.36
Range Minimum	-69.03
Range Maximum	368.88

Figure 3: EMV ATax Probability Distribution of the Exploratory Projects

Figure 4 shows an overlay chart that compares the probabilistic distribution of the production and the exploratory projects.

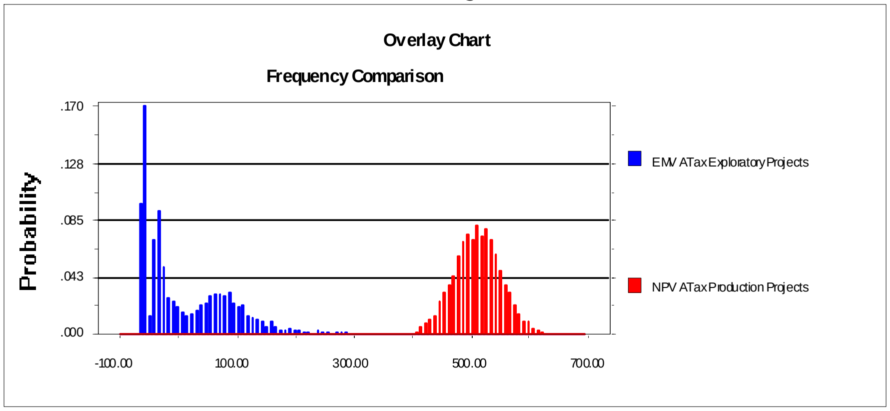
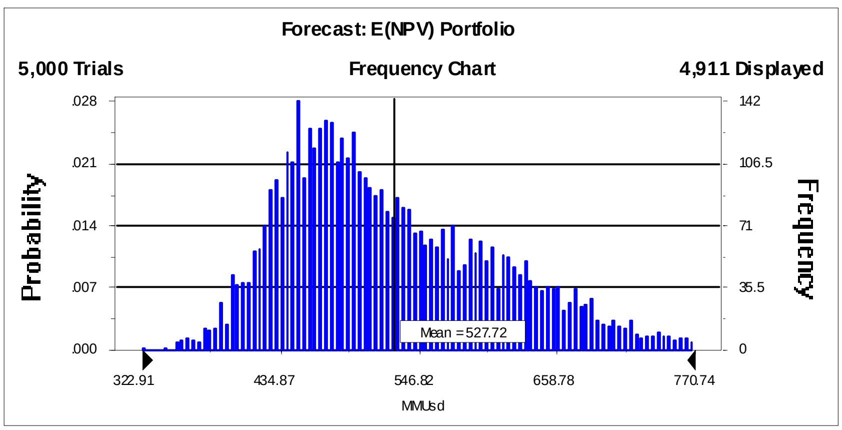


Figure 4: Comparison of NPV/EMV ATax Probability Distribution of the Exploratory and Production Projects

Figure 5 presents the probabilistic distribution of the E(NPV) ATax of the hypothetic actual portfolio of the company (production and exploratory projects) with current working interests and best estimates of start time. The chart and statistics reveal a mean value of 527.7 MMUsd and a standard deviation of 92.8 MMUsd. The minimum and maximum values are 322.9 and 957.3 MMUsd respectively.



Statistics:	**Value**
Trials	5000
Mean	**527.72**
Standard Deviation	92.77
Range Minimum	322.91
Range Maximum	957.35

Figure 5 –E(NPV) ATax Probability Distribution of the Portfolio (Exploratory + Production Projects)

For the portfolio optimization:

Figure 6 presents the results (including best solution, feasible requirements, performance graph and decision variables results) of the E(NPV) ATax of an optimum portfolio for a maximum financial exposure for new ventures of 200 MMUsd. The chart shows the increase of E(NPV) ATax (objective) with a number of decision variables arrangement. After 200 simulations (with 5000 trials per simulation) the objective achieves a mean value of 566.45 MMUsd.

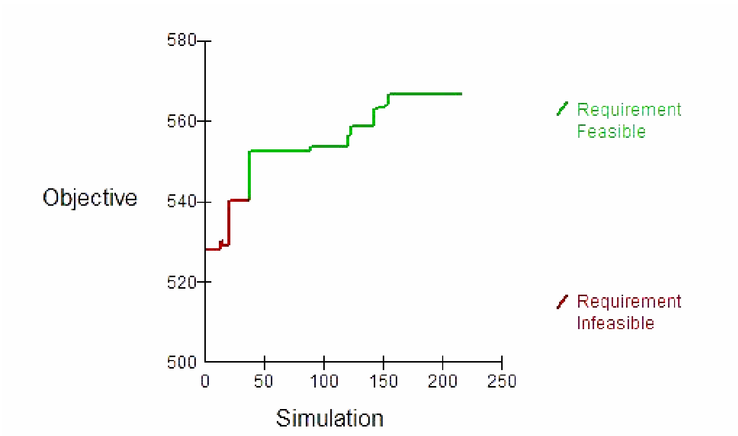
BEST SOLUTION

Values of Variables:

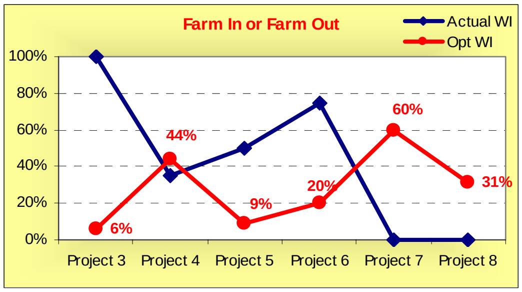
Objective			
E(NPV) Portfolio:	Mean	566.45	MMusd

Requirement Feasible			
Max Financial Exposure		-197.15	MMusd
Minimum Daily BOE Prod		76,119.0	BOE/d
EMV Project 3	Mean	0.61	MMusd
EMV Project 4	Mean	7.73	MMusd
EMV Project 5	Mean	7.10	MMusd
EMV Project 6	Mean	2.79	MMusd
EMV Project 7	Mean	19.13	MMusd
NPV Project 8	Mean	24.07	MMusd

Performance Graph



Decision Variables Results



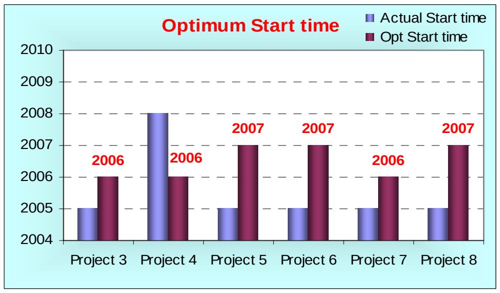


Figure 6 – Results: E(NPV) ATax Optimization for the 200MMUsd Maximum Financial Exposure for New Ventures Case

The results of the decision variables suggest optimum working interests of 6% for Project 3, 44% for Project 4, 9% for Project 5, 20% for Project 6, 60% for Project 7 and 31% for Project 8. They also suggest the optimum start time of Project 3, 4 and 7 for 2006 and start time of Project 5, 6 and 8 for 2007.

The application of different financial exposure scenarios aims to determine how the company can change its decision variables in case the available capital is lower or greater than defined on a base case. The results suggests an important modification on the E&P strategy of the company (different outcomes for the decision variables) to maximize its value. Figures 7 and 8 describe this situation.

BEST SOLUTION

Values of Variables:

Objetive			
E(NPV) Portfolio:	**Mean**	**606.30**	**MMusd**

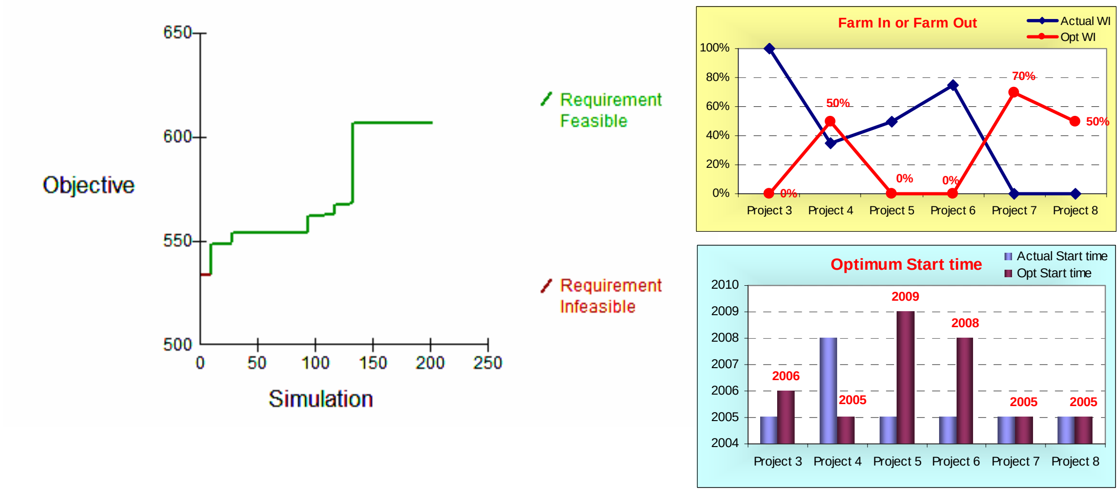


Figure 8 – Results: E(NPV) ATax Optimization for the 150MMUsd Maximum Financial Exposure for New Ventures Case

BEST SOLUTION

Values of Variables:

Objetive			
E(NPV) Portfolio:	**Mean**	**554.94**	**MMusd**

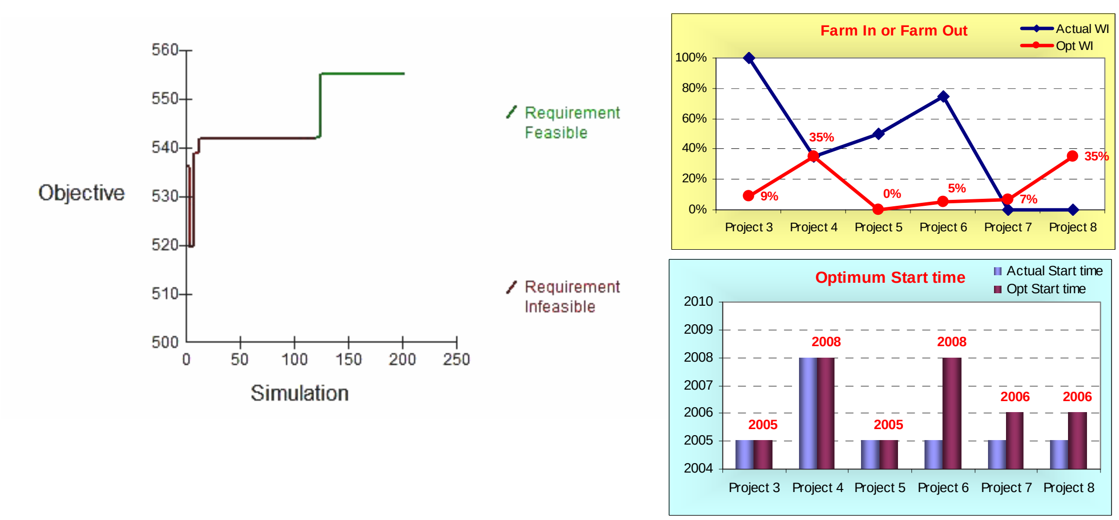


Figure 7 – Results: E(NPV) ATax Optimization for the 250MMUsd Maximum Financial Exposure for New Ventures Case

4 DISCUSSION

The results show that the NPV ATax of a project or group of projects may vary significantly with the inherent uncertainties of the petroleum industry (Figures 2 to 5). This reveals the importance of relating a probability to each single value or range of values in such a high-risk environment.

The combination of decision variables such as working interest and start time of the projects of a portfolio can be further optimized (Figure 6) to achieve a maximum worth of the company.

In order to take advantage of accounting risk in the project valuation and further portfolio optimization, the evaluator and the decision maker shall work in the proper way as follows.

1. In one side, the evaluator shall be able to model the problem and assemble most representative or best estimate of the main uncertain variables (Figure 1).
2. In the other side, the decision maker shall be able to account the risk that the company is prepared to take/consider along with the requirements and inherent limitations of the decision variables (Tables 1 and 2).

The probabilistic representation of the forecast variables based on the probabilistic distribution of the main uncertain variables allows a better insight of the project and promotes the culture of risk analysis inherently attached to the petroleum industry (Figures 2 to 5).

The work stresses the direct relation of requirements with risk and total worth of the portfolio. Sometimes the requirements may conflict with each other or lead to an inefficient portfolio management, destroying value and elevating the risk. For instance, an oil equivalent production above 80,000 boe/d would be unfeasible for the maximum financial exposure and rate of return requirements. Moreover, lower financial exposure leads to a lower E(NPV) ATax. A misleading need to show a rising production profile may encourage strategic acquisitions at a high premium price and risk that not only destroy value but also elevate the financial exposure of the acquiring company. In the long run, the creation on Total Shareholder Value will depend in being able to maximize the value of the company through an efficient use of capital. For this reason, the solution is to use the portfolio management tool to investigate and to analyze the impact of the proposed requirements on the creation of worth for the company. Sometimes the goals and requirements may conflict with each or happen to be out of reach outlooks created by the aspiration to expand way above strong competitors.

Deepening the trend of quantitative analyses, the application allows the possibility to translate subjective goals from strategic plans into quantitative targets (Table 1 and 2). Subjective goals, such as an *important* participation on the gas market, capital *discipline* or consolidate a *strategic* position on the energy market, can be investigated and translated into single numbers. The portfolio management will eventually guide to a realistic plan of investment and/or des-investment in line with the company’s strategic plan.

The inclusion of quantitative risk analyses in the portfolio management also permits the possibility to set standards in the evaluation of oil and gas ventures. The use of common assumptions is useful to evaluate projects in the same foundation and prevent personal or biased valuations.

Besides the commonly used measures of risk, as standard deviation and semi-standard deviation, the study makes use of the maximum financial exposure as a risk measure, based on the criterion that the company will establish the maximum capital that is willing to spend in new ventures (capital at risk or tolerance to risk) to accomplish the strategic goals without harming its financial health. In a real life situation, managers will define the risk a company can afford to take in terms of budget and financial constraints. The definition of risk on the portfolio optimization analysis can significantly affect the portfolio selection. Furthermore, by examining different definitions of risk, important insights can be gained on which projects continue with consistent results after these variations, creating a richer portfolio management.

The scenario analysis of the maximum financial exposure gives a sense of what could happen to the value of the company by changing the risk tolerance for new ventures, which E&P strategy has to be taken to accomplish the requirements and to analyze if they still feasible goals to reach.

5 CONCLUSIONS

The results show a significant variance of the NPV ATax with the inherent uncertainties of the petroleum industry and reveal the importance of accounting probability to each single outcome in such a high-risk environment and to consider the requirements and limitations of the decision variables to reach an appropriate value creation process to the company.

The study reveals that some requirements of the petroleum industry may conflict with each other or lead to an inefficient portfolio management, destroying value and elevating the risk. The application allows the possibility to translate subjective goals from strategic plans into quantitative targets leading to a company more committed to the strategic plan and to provide options of the better allocation of scarce resources.

Finally, we believe that the true value of portfolio management applied to the petroleum industry is not to provide a certain and unique answer but to gain insights into what makes a desirable portfolio for the company than an undesirable one.

ACKNOWLEDGEMENTS

We would like to express our thanks to Petrobras Bolivia for the support and permission to publish this paper and to our colleague and friend Flavio Altoé for the contributions and support.

NOMENCLATURE

EMV	Expected Monetary Value
E(NPV)	Expected Net Present Value
NPV ATax	Net Present Value After Tax
bbl/d	Barrels per Day
Oil equivalent	Oil and Gas Production based on barrel units
BOE/d	Barrels of Oil Equivalent per Day
MMbtu	Million of British Thermal Units
MMUsd	Million USA dollars
Musd	Thousand USA dollars
Usd/bbl	Dollar per barrel

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BIOGRAPHIES

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