FUNDAÇÃO GETÚLIO VARGAS
ESCOLA DE ADMINISTRAÇÃO DE EMPRESAS DE SÃO PAULO

MARCELO MOREIRA RUSSO

ARE REAL OPTIONS A REAL OPTION FOR REAL-WORLD FINANCE PROFESSIONALS?

CASE STUDY: THE APPLICATION OF REAL OPTIONS TO EVALUATE INVESTMENT PROJECTS IN THE LATIN AMERICAN OIL AND GAS FIELD SERVICES INDUSTRY.

SÃO PAULO - SP
2012

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Dissertation submitted to the Escola de Administração de Empresas de São Paulo,

Fundação Getúlio Vargas, in order to attain the Master's in Business Administration Degree.

Area of knowledge: Real Options – Corporate Finance

Evaluation Date: 13/12/2012

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Russo, Marcelo Moreira
Are Real Options a Real Option for Real-World Finance Professionals? Case Study: The Application of Real Options to Evaluate Investment Projects in the Latin American Oil and Gas Field Services Industry / Marcelo Moreira Russo. - 2012.
82 f.

Orientador: Arthur Ridolfo Neto
Dissertação (MPA) - Escola de Administração de Empresas de São Paulo.

1. Projetos de investimento. 2. Opções reais (Finanças). 3. Incerteza (Economia). I. Ridolfo Neto, Arthur. II. Dissertação (MPA) - Escola de Administração de Empresas de São Paulo. III. Título.

CDU 336.764.2

ABSTRACT

Brazil and other emerging markets will continue to present many investment opportunities in the coming years. Finance professionals who manage the company's capital budgeting processes will face challenges. Specific characteristics of these projects as commodity-linked prices (e.g., the case of oil and gas and agricultural projects) and the customary uncertainties related to emerging markets are additional challenges. In this scenario, a more sophisticated capital budgeting framework, Real Options, offers a more robust theory to deal with uncertainty, managerial flexibility, and volatile outcomes imbedded in these opportunities. Real Options theory assumes that the managers' involvement in the project generates value so they might capitalize on good outcomes or reduce losses by abandoning projects with bad results.

The primary objective of this research was to apply Real Options valuation analysis for an investment project valuation and discuss the process and the results of such methodology. The case study retroactively analyzed an investment project in Colombia and compared the results under traditional NPV methodology and Real Options. The valuation techniques were performed as if they had been applied at the time the project was approved and then compared with the project's actual performance. The case study evaluated two types of real options: first, the effect of an option to cancel a contract that is assessed from the perspective of the client; and second, the option to abandon and defer from the perspective of the company that will perform the investment.

Keywords: real options, capital budget projects, decision under uncertainty, NPV, option to cancel.

RESUMO

Brasil e outros mercados emergentes continuarão a apresentar muitas oportunidades de investimento nos próximos anos. Profissionais financeiros que gerenciam os processos de orçamento de capital nas empresas terão grandes desafios a enfrentar. Características específicas destes projetos como preços ligados a commodities (por exemplo: petróleo e gás e projetos agrícolas) e as incertezas habituais relacionadas com os mercados emergentes são desafios adicionais. Neste cenário, ferramentas mais sofisticadas de orçamento de capital como Opções Reais, oferece uma teoria mais robusta para lidar com incerteza, flexibilidade gerencial, e os resultados voláteis embutidas nestas oportunidades. A teoria de Opções Reais assume que o envolvimento dos gestores nos projetos gera valor à medida que potencializam os bons resultados ou reduzem as perdas por abandonar projetos com maus resultados.

O objetivo principal desta pesquisa foi aplicar a análise de Opções Reais para um projeto de investimento e discutir o processo e os resultados da metodologia. O estudo de caso analisa retroativamente um projeto de investimento na Colômbia e compara os resultados sob o tradicional VPL e Opções Reais. As técnicas de avaliação foram realizadas como se estivessem sendo aplicadas no momento em que o projeto foi aprovado, e depois comparadas com o desempenho real do projeto. O estudo de caso avaliado possui dois tipos de Opções Reais: primeiro, o efeito de uma opção para cancelar um contrato que é analisado a partir da perspectiva do cliente que pode exercer essa opção, e o segundo, a opção de abandonar e adiar a partir da perspectiva da empresa que irá executar a investimento.

Palavras-chave: opções reais, projetos de orçamento de capital, decisão sob incerteza, VPL, opção de cancelar.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my advisor, Professor Arthur Ridolfo Neto, for his outstanding insight and generous encouragement. I am especially thankful to all of the professors of the EAESP-FGV MPA course for their assistance and advice during the course, especially Professor Antonio Carlos Manfredini and João Carlos Douat, without whom this master's degree experience would not be as rich as it was.

I would like to thank my wife, Eniale Maion, and my daughter Ana Valentina, for their enduring love, encouragement, and understanding throughout my graduate studies.

FIGURES

TABLES

CONTENTS

"If we begin with certainties, we shall end in doubts;
but if we begin with doubts, and are patient in them,
we shall end in certainties."
Francis Bacon
"As far as the laws of mathematics refer to reality,
they are not certain; and as far as they are certain,
they do not refer to reality."
Albert Einstein

1 INTRODUCTION

1.1 Context

The decade that began in 2011 will present several investments opportunities in Brazil due huge infrastructure projects (e.g., oil exploration in the pre-salt region) and a demanding internal market boosted by the new middle class. The giant national oil company (NOC) Petrobras announced aggressive investment plans (U.S. $213.5 billion from 2011 to 2015) that will position Brazil as the 5th largest oil producer in the world. Petrobras projects, as well as several other infrastructure projects spurred by the 2014 World Cup soccer championship, the 2016 Olympics Games, and the internal market boom, all of which will present several investment opportunities for local and international companies.

These opportunities will require significant capital expenditure for several years. This will be challenging for finance professionals who manage the company's capital budgeting processes. The specific characteristics of commodity-linked prices (in the case of oil and gas and agricultural projects) and the traditional uncertainties about emerging markets add additional spice to the context. In this scenario, a more sophisticated capital budget framework, Real Options, presents a more robust framework for dealing with the uncertainty, managerial flexibility, and volatile outcomes imbedded in those investment opportunities.

The Real Options methodology represents a very comprehensive approach to evaluating those opportunities. It not only values the options imbedded in the investment decisions compressively than the traditional Net Present Value (NPV) analysis does, but also improves the planning and formulation of those projects. Unlike NPV, Real Options theory assumes that the managers' involvement in the project generates value since they might capitalize on good outcomes or reduce loss by abandoning projects with bad results.

According to Trigeorgis (1993), an options approach to capital budgeting has the potential to conceptualize and even quantify the value of options from active management. This value manifests as a collection of real (call or put) options embedded in capital investment opportunities that have as an underlying asset the gross project value of expected operating cash flows. Many of these Real Options occur naturally (e.g., to defer, contract, shut down, or abandon), while others may be planned and built in at extra cost (e.g., to expand capacity or build growth options, to default when investment is staged sequentially, or to switch between alterative inputs or outputs).

Managers have always been aware of Real Options, although perhaps not by this name. They always had the option to abandon a bad investment or stage the investment in a new plant according to demand growth, so those concepts are not new. Experienced managers have always understood the “options” concept intuitively. Still, a more systemic and structural approach to deal with those concepts in conjunction with the investment decision process adds value to the decision by quantifying it and providing a framework to analyze it. Real Options decision analysis techniques provide managers with more intuition and information for solutions to valuation problems. This is critical in an increasingly competitive business environment in which the ability to accurately assess project and asset values, including the incremental value related to a project's embedded options, will heavily influence difficult investment portfolio decisions (Hahn; Brandao; Dyer, 2010).

1.2 Research Purpose

The primary aim of this research study is to understand the practical use of Real Options valuation analysis and the tradeoff between the complexity (costs) of using it and the benefits of improving the analysis' explanatory power for decision-makers. The focus of the analysis was an investment opportunity in an oil and gas field services company in Latin America. The investment opportunity was examined using a case study methodology that retroactively analyzed the project and compared the project results under traditional methodologies (NPV) and Real Options. The valuation technique was performed as if it had been applied at the time the project was approved and subsequently compared with the project's actual performance. As a secondary objective, this study discusses the insights and options embedded in this investment opportunity.

2 MAIN CONCEPTS INVOLVED

2.1 Description of Onshore Drilling Services

A common Oil Field Services (OFS) company offers its drilling services for oil and gas operators that will manage the field after the wells are operational. The operators are typically NOCs (National Oil Companies) or private multinational companies that have the legal right to explore the field. OFS companies typically charge operators for rig services on a day rate basis at rates that are determined by the type of service and equipment required, market conditions in the region in which the rig operates, the ancillary equipment provided on the rig and the necessary personnel. The total revenues for the services are generated by multiplying the rate for the service by the time consumed in using it. The efficiency of the rig and the day rate are the most important drivers for rig profitability.

A general drilling rig contract can require a full range of land-based drilling services, including: drilling initial wells, opening new production zones in existing wells, re-completing wells in which production has declined, drilling out plugs, and converting producing wells to injection wells during enhanced recovery operations as well as mechanical repairs necessary to maintain or improve production from the well.

2.2 Risks involved on the Drilling Services Operations

There are several characteristics and risks associated with a drilling operation (from the OFS company perspective) that could substantially affect the cash flow of an operation that are not always incorporated in the capital budget decision for new investments. The main risks for a typical operation (contract) such as the one in the case study are:

- Need to make significant upfront working capital commitments (labor and transportation costs) prior to receiving payments;
- Some of the risk associated with the drilling operations, which are generally assumed by the operator of the well, including machinery breakdowns and abnormal drilling conditions. Accordingly, if severe drilling problems are encountered in drilling wells under such contracts, the client could suffer substantial losses, which may have an adverse effect on the OFS company.
- The OFS company (the contractor) may be adversely affected if customers seek to cancel or renegotiate the drilling contract during periods of depressed market conditions or if the company experiences downtime or operational difficulties. During

depressed market conditions, a customer may no longer need a rig that is currently under contract or may be able to obtain a comparable rig at a lower day rate.

- In a general contract, operators may have the right to terminate existing contracts if the company experiences downtime or operational problems above the contractual limit; certain contracts include terms allowing customers to terminate contracts without cause, with little or no prior notice and without penalty or early termination fees.
- Historically, the industry has been highly cyclical, with periods of high demand, short rig supply and high day rates often followed by periods of low demand, excess rig supply and low day rates. Periods of low demand and excess rig supply intensify the competition in the industry and often result in rigs being idle for long periods.
- Social, political, labor and economic conditions in Latin America may cause volatility in the operations, manifesting as strikes, roads obstructions, shortage of equipment replacements (due to importation constrains), environmental permit delays, and foreign exchange controls.

2.3 Drilling Market Dynamics

The onshore drilling market has similar dynamics of the more sophisticated and lager offshore market, however it is more local and more affected by regional circumstances. As described in the Harvard Business School case the Offshore Drilling Indutry (Corts, 1999) the drilling industry is very cyclical and strongly correlated to the Oil Prices, for example: The second oil crises sent oil prices from under $ 10 to over $30 in 1979 boosting the exploration. Capacity utilization for rigs climbed to 100% and rental rates paid to contractors nearly doubled. As utilization soared, new rigs were ordered and built, with new contractors and private groups entering the industry. With newly completed rigs continuing to swell rig supply, utilization rates fell below 80% on 1983, and day rates fell more than half, despite persistence of oil prices in the high $20s.

The similar dynamics affected the Colombian onshore drilling industry; however, as a local market other aspects also influenced the growth and declines of the market. In the 2000s Colombian government launched several efforts to build and developed its oil industry bringing significant amounts of foreign investments to its industry as it leased new promising exploration areas. These efforts also boosted the Oil field Service industry. The number of onshore drilling and workover (maintenance services rigs) rigs in the country grew from 80 rigs in 1999 to 274 in 2012. The Colombian Market is considered a very competitive and open market. In this environment of strong competition and abrupt responses to utilization as the market changes, the right to cancel rental contracts that the Oil Field Industry (contractors) award to the Operators could be very valuable to operators in the downturns and most of times neglected by the OFS industry. This case will further discuss and value such real option.

3 LITERATURE REVIEW

3.1 Capital Budgeting

Companies make capital investments to create and exploit profit opportunities that generate value for the organization when those projects are mature and well implemented. The analysis, approval, and control of capital investment projects are the main purposes of a well-defined capital budgeting process. Investment proposals may emerge from different parts of the organization, so companies need procedures to ensure that every project is assessed consistently. When managers are presented with a black and white Excel spreadsheet containing a discounted cash flow analysis, they should not take it at face value. Instead, they should ask for more "color" (contextualization) in the numbers and understand the context of the proposal, the strategic consideration of the project, what makes it "tick", the options involved in it, and the possible pitfalls of its assumptions. Once one understands those implications, one might want to reconfigure the project to improve its chances of success (Myers, Stewart et al., 2011). In proper capital budgeting analysis, managers should look for ways to capitalize on success and reduce the cost of failure. The company also should consider the value of the right to modify the project as the future unfolds. This is the main pillar of Real Options theory as applied to capital budgeting.

3.2 Financial Options

A financial option is a derivative instrument that specifies a contract between two parties for a future transaction of an asset at a reference price (the strike price). The buyer of the option gains the right, but not the obligation, to engage in that transaction, while the seller incurs the corresponding obligation to fulfill the transaction. The price of an option is derived from the difference between the reference price and the value of the underlying asset (commonly a stock, a bond, currency or a futures contract) plus a premium based on the time remaining until the expiration of the option. An option that conveys the right to buy something at a specific price is referred as a call; an option that conveys the right to sell something at a specific price is called a put. If the option is not exercised by the expiration date, it becomes worthless. In return for assuming the obligation, or writing the option, the originator of the option collects a payment, the premium, from the buyer. The writer of an option must make good on delivering (or receiving) the underlying asset or its cash equivalent if the option is exercised. Its original buyer can usually sell the financial option to another party. Many options are created in standardized form and traded through an anonymous options exchange, while other over-the-counter options are customized to the desires of the buyer, usually by an

investment bank. The most common type of standardized financial options are: the European option—an option that may only be exercised on expiration; and the American option, an option that may be exercised on any trading day on or before expiration.
A financial option is itself an asset that derives its value from (1) the underlying asset's value, which can fluctuate dramatically prior to the date on which the opportunity to purchase or sell the underlying asset expires, and (2) the decisions made by the investor to exercise or hold the option. Option's pricing methods have been developed to estimate option values from parameters characterizing the underlying asset's value and investor behavior (Cobb; Charnes, 2009).
The payoff from a long position in a European call option is expressed as the following:
$V_T = \max[S_T - X, 0]$, where T is the expiration date, X is the strike price, and S_T is the final price of the underlying asset. The decision rule is that the option will be exercised if $S_T \geq X$ and not be exercised if $S_T < X$.
The payoff to the holder of a long position in a European put option is expressed as the following:
$V_T = \max[X - S_T, 0]$. The decision rule is that the option will be exercised if $S_T \leq X$ and not to be exercised if $S_T > X$ (Jiao, Y.-Y. *et al.*, 2007).

3.3 Origins and Building Blocks of Real Options

The Real Options revolution arose in part as a response to the dissatisfaction experienced by corporate practitioners, strategists, and some academics with traditional capital budgeting techniques. Well before the development of Real Options, corporate managers and strategists were grappling intuitively with the elusive elements of managerial operating flexibility and strategic interactions (Trigeorgis, 1993).

Myers (1977) first coined the term "Real Options," recognizing that particular growth opportunities could be addressed as call options and their value would depend on optional future investments. Later, Ross (1978) discussed a valuation approach for Real Options. Trigeorgis (1993) organized and discussed the several Real Options categories according to their flexibilities. Many of the Real Options theories were developed based on these seminal works. Afterwards, several articles, such as Dixit & Pindyck (1995), began advocating the use of Real Options as a substitute for static NPV analysis and its pitfalls.

According to Trigeorgis' (1993) literature review and categorization, it is possible to analyze the application approach in two subgroups that are not mutually exclusive and differ from each other by the lenses used to read the situation and approach the problem, not necessarily by the framework applied. According to Trigeorgis (1993), the most common Real Options generic applications are:

- Option to defer: Management holds an agreement on (or an option to buy) valuable land or resources. It can wait to see if output prices justify constructing a building or plant or developing a field. This option is usually applicable in real estate development and commodities exploration (oil, farming, and mining);

- Time to build option (staged investment): Staging investment as a series of outlays creates the option to abandon the enterprise midstream if new information is unfavorable. Each stage can be viewed as an option of the value of subsequent stages and can be valued as a compound option. This approach can be used in R&D intensive industries, especially pharmaceuticals;

- Option to alter operating scale (e.g., to expand, contract, shut down, and restart): If market conditions are more favorable than expected, the line can expand the scale of production or accelerate resource utilization. Conversely, if conditions are less favorable than expected, it can reduce the scale of operations. In extreme cases, production may temporarily halt and start up again;

- Option to abandon or Shut Down*:* If market conditions decline severely, management can abandon current operations and realize the resale value of capital equipment and other assets in secondhand markets; and

- Growth options: An early investment (e.g., R&D, lease on undeveloped land or oil reserves, strategic acquisition, information network, and infrastructure) is a prerequisite or link in a chain of interrelated projects, opening up future growth opportunities (e.g., a new generation product or process, oil reserves, access to new markets, or strengthening of core capabilities).

Copeland and Weston (1982) also discussed an important application especially for this study: the option to cancel a contract. This option is quite different from the traditional Real Option approach as it is an American put option that one presents to another party during a contract negotiation. In the case of a financial lease with such an option, it is equivalent to a pure financial lease minus an American put option with a (non-stochastic) declining exercise price. The expected rate of return on a cancellable lease is shown to be higher than the rate on a pure financial lease in order to pay for such option.

From a general environment, competition, and strategic viewpoint, Real Options has the potential to make a significant difference when applied to competition and strategy analyses. Sustainable competitive advantages resulting from patents, proprietary technologies, ownership of valuable natural resources, managerial capital, reputation or brand name, scale, and market power enable companies with valuable options to grow through future profitable investments and more effectively respond to unexpected adversity or opportunities in a changing technological, competitive, or general business environment. The classical applications in this concept are:

- Oil and gas and mining industries*:* Mining and oil companies have to decide when to develop the reservoirs they own and how much to bid for the right to develop additional properties or fields. Such decisions often involve a combination of options such as the option to learn about the quantity of minerals present underground and the option to defer development until mineral or oil prices are favorable (Trigeorgis, 1993);

- Cancelable Operating Lease: A manufacturer of jet engines, for example, would regularly purchase the plane for its client airline and lease it for commercial use, provided the airline agreed to install the manufacturer's engines in the plane. Additionally, it was customary to give the airlines the right to cancel the lease and return the plane during a period prior to delivery and for up to a year after delivery. The costs involved in this option were immense and would fluctuate according to the client's operation performance volatility. The right to cancel the lease was treated as an American put option that could be exercised by the airline when, during a downturn in passenger revenue miles, the value of the plane in operation became less than the value of the lease payments due (Copeland; Antikarov, 2005);

- Flexible manufacturing: Flexible manufacturing systems, flexible production technologies, and other machinery having multiple uses can be analyzed from an options perspective. It might value the flexibility, for example, of a dual-fuel industrial steam boiler that can switch between alternative energies (natural gas and oil) as their relative prices fluctuate (Trigeorgis, 1993);

- Land development industry: It can show that the value of vacant land should reflect not only its value based on its best immediate use (e.g., from constructing a building now), but also its option value if development is delayed and the land is converted for its best alternative use in the future. It may thus be beneficial to hold land vacant for its option value even in currently thriving real estate markets (Trigeorgis, 1993);

- Competition analysis: Smit and Ankum (1993) considered that an investment strategy encompasses a sequence of tactical investment projects, of which several may yield a low return when considered in isolation. The net present value method has serious shortcomings for analyzing projects when future decisions are contingent on intermediate developments in an uncertain environment. Option theory provides a better analytical tool to evaluate such projects. Postponement under perfect competition implies a loss in the expected value of the project due to anticipated competitive entry. (Boyer & Gravel, 2004).

3.4 Main Differences between Real Options and Financial Options

3.4.1 Terms and Parameters

When financial options have a detailed contract, real options must be identified and specified. Although insights from the Real Options way of thinking are relevant across a number of industries, each application must be fit for the specifics of the particular industry as well as the market. Table 3.1 has a comparison between the two types of options.

Table 3.1 Terms and Parameters of Financial Options and Real Options

Black-Scholes Parameter (Financial Options)	Analogous Real Options Parameters	Example of Sources of Uncertainty
Stock price, S	Present value of expected cash flows from investment	Market demand for products and services, labor supply and cost, materials supply and cost
Exercise price, X	Present value of required investment (CAPEX)	Availability, timing and price of assets to be purchased
Stock price volatility, σ	Volatility of underlying cash flows	Volatility in market demand, labor cost, materials cost, correlation of model assumptions
Time to expiration, T	Period for which investment opportunity is available	Product life cycle, competitive advantage
Dividend rate, *δ*	Cash flows lost to competitors	Product life cycle, competitive advantage, convenience yield
Risk-free interest rate, r	Risk-free interest rate	Inflation, money market behavior

Source: Cobb and Charnes, 2009.

3.4.2 Value Observation

The underlying assets of Real Options are different from financial options in that they are rarely traded in quoted markets, which might create difficulties in establishing their fair prices. Moreover, the nonexistence of a historical price series of the underlying assets makes it difficult to calculate their historical volatility. In the context of financial options, one can clearly state a priori when a given option will be profitable and worth exercising. However, in the case of Real Options regarding strategic opportunities in which new possibilities are identified as a consequence of a firm's actions, such a priori specification may not be possible. Experiments, even unsuccessful ones, not only provide information about intended investment paths but also provide information about other possibilities that may not even have been envisioned at the time of the initial investments (Adner; Levinthal, 2004).

3.4.3 Knowledge and Information

Real Options gives the investing firm access to proprietary knowledge that a non-investing firm cannot obtain (or will take longer to obtain). In contrast, financial options do not provide access to “inside” knowledge about the investment opportunity; all investors have access to the same knowledge about the investment opportunity at the current and in the future. A real option can also provide privileged access to resources, hence restricting potential competitors. Financial options do not preclude others from making the same or similar investments. Real Options provides learning curve advantages that can be leveraged into a competitive advantage if the investment opportunity subsequently proves beneficial; something financial options do not provide (Brouthers; Brouthers; Werner, 2008).

3.5 Real Option Quantitative Models and Valuation

According to Trigeorgis (1993), the quantitative origins of Real Options derive from the seminal work of Black and Scholes and Merton in pricing financial options. Cox, Ross, and Rubinstein's binomial approach enabled a simpler valuation of options in discrete time. The actual valuation of options in practice has been greatly facilitated by Cox's and Ross's recognition that an option can be replicated (or a "synthetic option" created) from an equivalent portfolio of traded securities.

Being independent of risk attitudes or capital market equilibrium considerations, such risk-neutral valuation, enables present-value discounting at the risk-free interest rate of expected future payoffs (with actual probabilities replaced with risk-neutral ones), a fundamental characteristic of "arbitrage-free" price systems involving traded securities.

The main quantitative model and theories that will be used in the research are:

3.5.1 Black-Scholes Model

The practical application of options to projects has been discussed by Luehrman (1998). He discussed the analogy between financial options and corporate investments, provided a framework for mapping the project onto the option framework, and reinforced that DCF techniques and Real Options are complements rather than substitutes to each other. The capital investment decision is compared to a European call option that is valued using the Black-Scholes Model. To map a corporate investment onto a call option opportunity, he proposes: $C = S_0N(d_1) – Xe^{-rT} N(d_2)$, where (Varma, 2011):

- C is the value of call option;

- S_0 is the present value of a project's operating assets to be acquired;
- X is CAPEX required to acquire the project assets;
- r is the risk-free rate of return;
- T is the length of time the decision may be deferred;
- σ^2 is the riskiness of the project assets;
- $d_1 = \{\ln(S_0 /X) + (r + \sigma^2 /2)*t\}/ (\sigma 2)*T$
- and $d_2 = \sigma \sqrt{T} - d_1$.

The total value of the project will be the Adjusted Present Value, composed for: Traditional NPV + Value of Real Options.

3.5.2 Binomial Lattice Model

The binomial option pricing model has been presented by Cox, Ross, and Rubinstein (1979) as a simpler and more efficient numerical procedure for valuing options in which a premature exercise may be optimal. The basic idea was replicating the option payoff by constructing a portfolio out of a risk-free rate bond and the underlying stock (replicating portfolio). The unique feature of the binomial tree is that the outcome from moving up and then down is the same as the outcome of first moving down and then up. This sequence is repeated over time. The advantage of using a binomial lattice model over the Black-Scholes model is that it can be used to value American options. Consider, as in Trigeorgis (1993), valuing a generic investment opportunity as an example of the backward induction calculation used the Real Option valuation:

- The opportunity to invest I_0= $104 (in millions) in an oil project whose value in each period will either move up by 80% or down by 40%, depending on oil price fluctuations. The current oil price is $20, which represents a project gross value of $100 million. One year later, the project will have an expected value (from subsequent cash flows) of $180 if the oil price moves up ($C^+ = 180$) or $60 if it moves down ($C^- = 60$). There is an equal probability ($q = 0.5$) that the price of oil will move up or down in any year.
- The extension of the binomial movements, up by 80% or down by 40% in this case, and risk-neutral probabilities could be estimated by several methods. They incorporate information about the uncertainty, or "volatility," of outcomes associated with the project. The most common method is to follow the convention used by Cox, Ross, and Rubinstein (1979). The up and down movements at each step are $u = e^{\sigma \sqrt{\Delta t}}$ and

d=1/u, where σ is the volatility of asset returns per time increment in the tree and $\sqrt{\Delta t}$ is the length of the time increment (Hahn; Brandao; Dyer, 2010).

- Let S be the price of oil or generally of a "twin security" that is traded in the financial markets and has the same risk characteristics with the real project under consideration, for example a stock price of a similarly operating unlevered oil company. Both the project and its twin security (or oil prices) have an expected rate of return (or discount rate) of k = 20%, while the risk-free interest rate is 8%.
- Consider the following binomial tree:

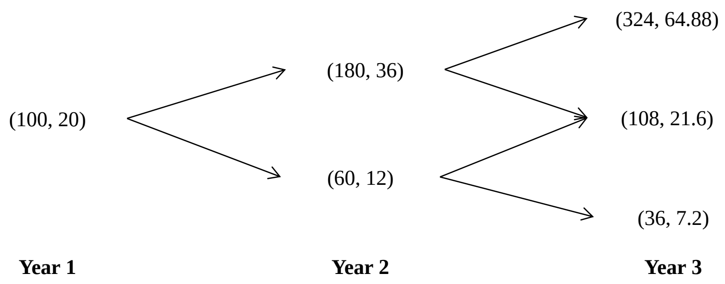


Figure 3.1 Binomial tree for investment opportunity example
Source: Trigeorgis (1993)

- For example, the pair (V0, S0) above represents a current gross project value of $100 million, and a spot oil price of $20 a barrel (or a $20 per share of the twin oil company).
- Under traditional (passive) NPV analysis the current gross project value would be obtained first by discounting the project's end-of-period values (derived from subsequent cash flows), using the expected rate of return of the project's twin security (or, here, of oil prices) as the appropriate discount rate, i.e., V_0 = (0.5 x 180 + 0.5 x 60)/1.20 = 100. After subtracting the current investment costs I_0= $104, the project's NPV is finally given as: NPV = V_0- I_0= -4 (<0).
- Because of the absence of managerial flexibility or real options, traditional DCF analysis would have rejected this project based on its negative NPV. The fundamental problem lies in the valuation of investment opportunities whose claims are not symmetric or proportional and whose discount rates vary in a complex way over time. Using contingent claims analysis (CCA) within a backward risk-neutral valuation process, the same solution can be obtained in our actual risk-averse world as in a "risk-neutral" world in which the current value of any contingent claim could be obtained from its expected future values with expectations taken over the risk-neutral

probabilities *p*, inputted from the twin security's (or oil) prices discounted at a risk-free rate, r. In such a risk-neutral world, the current (beginning of the period) value of the project (or of the equity holders' claims), *E*, is given by: $E = \frac{\mathrm{p}E^{+} + (1-\mathrm{p})E^{-}}{1+\mathrm{r}}$ where $p = \frac{(1+\mathrm{r})S - S^{-}}{S^{+} - S^{-}}$, the probability, *p*, can be estimated from the price dynamics of the twin security (or of oil prices in the example): $= \frac{(1.08 \text{ x } 20) - 12}{36 - 12} = 0.4$.

- Observe that the value for p = 0.4 is distinct from the actual probability, q = 0.5. This can be used to determine expected cash flows, which can be properly discounted at the risk-free rate. For example, $V_0 = \frac{\mathrm{p}C^{+} + (1-\mathrm{p})C^{-}}{1+\mathrm{r}} = V_0 = \frac{0.4\ x\ 180 + 0.6\ x\ 60}{1.08} = 100$
- This confirms the gross project value V_0 = 100, calculated early using traditional DCF with the actual probability q = 0.5 and the risk-adjusted discount rate (K = 0.20). Although it achieved the same results, this approach is extremely practical to address more complex real option situations. The investment outlay (having a present value of $104 million) will not be spent immediately but in future installments. The amount that is not immediately spent should earn the riskless interest rate. This framework allows for the evaluation of upside-potential options, such as deferring or expanding; and downside-protection options, such as abandoning for salvage value or defaulting during construction.

3.5.3 Main Characteristics of Black-Scholes and Binomial Models

Table 3.2 Methodology Comparison[1]

	Standard Black-Scholes	**Standard Binomial[2]**
Explicit Assumptions		
S - value of underlying Project	lognormally distributed	binomially distributed (in practice, binomial parameters are typically chosen assuming that *S* is lognormally distributed)
σ - volatility of S	constant	
X - option's exercise price	deterministic	
r - interest rate	constant	
T - option's life span	short-lived (have to define)	no-limit
Existence of market for S	A is traded and no arbitrage opportunities exist	
Properties		
Solution approach	closed-form (analytic) formula	numeric simulation
Sensitivity analysis using	analytic partial derivatives	numeric approximation of "partial derivatives"
Calculates option price on-or-before expiration	No (only on expiration) the traditional, but derivate models allows (Black's approximation)	Yes (can find optimal exercise time)
Implementation	Computational simplicity	conceptual simplicity and flexibility

Source: Benaroch and Kauffman (1999)

[1] Legend: S: Present value of expected results from the operational project (i.e., the value of option's underlying risky asset); X: Cost of converting the investment opportunity into an operational project (i.e., the option's exercise price); T: Maximum time to defer conversion of the investment opportunity into an operational project (i.e., the option's time to expiration).

[2] Cox, Ross & Rubinstein model.

3.6 Main Concepts Involved on Real Option Methodology

3.6.1 Contingent Claims Analysis (CCA)

This approach assumes the existence of a sufficiently rich set of markets in risky assets so that the stochastic component of the risky project under consideration can be exactly replicated. Through appropriate long and short positions, a riskless portfolio can be constructed consisting of the risky project and investment assets that track the project's uncertainty. In equilibrium with no arbitrage opportunities, this portfolio must earn the risk-free rate of interest, which allows the value of the risky project to be determined. The no-arbitrage assumption avoids the necessity of determining the appropriate risk-adjusted discount rate. However, if a portion of the return from holding the risky asset is due to an unobservable convenience yield, it is still necessary to estimate either that convenience yield or a market price of risk, which is often complicated (Insley; Wirjanto, 2010).

3.6.2 Geometric Brownian Motion (GBM)

Geometric Brownian motion (also known as exponential Brownian motion) a continuous-time stochastic process in which the logarithm of the randomly varying quantity follows a Brownian motion, is an important example of stochastic processes satisfying a stochastic differential equation. In particular, it is used in mathematical finance to model stock prices in the Black–Scholes model.

3.6.3 (MAD) Market Asset Disclaimer

The Market Asset Disclaimer (MAD) approach developed by Copeland and Antikarov treats the project and real option as if they were actually traded. The best replicating asset for the option is assumed to be the project without flexibility, which is valued using the NPV method. The need to find an actual traded replicating portfolio is removed because Copeland and Antikarov reason that no "asset has a better correlation with the project, than the project itself." The NPV approach does not value risks properly, so correctly pricing the project without flexibility (e.g., using the correct discount rate) is just as complex and important as valuing the flexibility (Edge, 2011).

3.6.4 Binomial Lattice in Terms of cash Flow

One very important approach used in this Real Option application, described by Brandão, Dyer and Hahn (2005), is to project the binomial lattice using the basic variable: the project cash flows instead of only the total project value of each node.

To do this, the cash flow payout rate is used $\delta = C_i / V_i$ to calculate the cash flows that are paid out at the end of each time period as a function of the project value. It is assumed that the cash flows will vary over time, reflecting the uncertainty of the project value, but that they will remain a constant fraction of the residual value of the project in each period. These cash flows($C_{i,j}$) will therefore be a function of the project value and the stochastic process that drives the binomial model. The primary advantage of this approach is that it provides greater flexibility in the modeling of the real options of the project. To obtain the cash flows, the first step is to build the pre-cash flow payout values tree. These values are calculated according to the following equations, in which the superscripts u and d correspond to the up and down state values and the state subscript is suppressed: $V_i^u = (V_{i-1} – V_{i-1}\delta_{i-1})u$ and $V_i^d = (V_{i-1} – V_{i-1}\delta_{i-1})d$.

4 RESEARCH METHOD

4.1 Case Study Methodology

There is a considerable amount of literature regarding Real Options and its applications to capital budgeting with solid methodologies developed on this theme. Because there is a huge resource bank of case studies available in the current literature and I have access to internal operational and financial information, I favored a case study method. This research used the current literature and application of Real Options methodology in a real case study to discuss the application and insights in a real-world situation.

The corresponding research question is therefore: Which of the most common frameworks of Real Options better fits the evaluation of capital investments for the proposed case study? The best framework should improve the analysis' explanatory power for decision makers and be a feasible application for finance professionals.

The form of the research questions, the focus on understanding the dynamics presented within a single set of parameters, and the combination of data collection methods such as archives and observations will all contribute to the choice of case study as the research method, following the recommendations of Eisenhardt, (2011).

Furthermore, as a director of an oil and gas field services company responsible for the capital budgeting process and someone who has worked with capital budgeting for more than 10 years, I have had the opportunity to obtain in-depth information that is probably not available to outside investigators. This unique perspective rendered the case revelatory.

Initially, the current body of literature was reviewed (papers and surveys) to analyze the most common investment project valuation methods (NPV) analysis (Payback, Real Options, etc.) and their restrictions from the perspective of finance professionals. The aim was to understand the main difficulties faced in the application of the methodologies.

In the second stage, data was collected, focusing on the raw data regarding the investment opportunities approval and historic performance of the projects. The information was gathered following the data collection plan outlined in Appendix A.

Finally, one Real Options methodology was applied to the case study following a proper methodology. Results were analyzed, and the following points were discussed:

- Types of embedded Real Options that the project had;

- Methodologies used to assign risks to the projects;
- Expected results (project valuation) versus actual results comparative analysis;

4.2 Choosing the Right Framework for the Case Study

After reviewing several Real Options methodologies and reproducing several of these case studies, the Real Options field appears very disperse among several streams, with no mainstream approach. Up to this point, the research was jeopardized due to the lack of practical and applicable framework to evaluate the proposed case study. The research needed focus, and a series of three articles helped to clarify the current situation of the field and the position I should take for this study. The three articles are a sequence of discussions on the future and applicability of the methodology:

- Real Options Analysis: Where are the Emperor's Clothes? (Borison, 2005)
- Real Options: Meeting the Georgetown Challenge (Copeland; Antikarov, 2005)
- A Response to “Real Options: Meeting the Georgetown Challenge" (Borison, 2005)

After analyzing the different positions set forth by the above articles, this research employed that of Copeland and Antikarov (2005). Their article was a response to the Real Options symposium held on the campus of Georgetown University in 2003, during which a panel of knowledgeable academics and practitioners voiced concern about the need for both a consensus about methodology and easy-to-use software for Real Options. In the article, the authors attempted to provide the foundation for establishing a consensus on methodology. They also responded to criticism by Adam Borison (2005) of both the theory and current practice of Real Options. They proposed the methodology described in Figure 4.1. based on the Binomial Lattice model. They discarded the use of the Black-Scholes model for the following reasons:

- The Real Options approach assumes that the value of the project with flexibility should be equal to the NPV of the “base case” cash flows (the value of the project without flexibility) plus the (option) value of the management’s ability to respond to change. This is an especially important point because the cash outflows from a project are analogous to dividends paid on a stock; just as the price of a stock drops when it goes ex-dividend, cash outflows reduce the value of the project as they are paid (Copeland; Antikarov, 2005). The traditional Black-Scholes formula assumes that the underlying risky asset (the capital project) pays no dividends (has no cash flows) during its life, which is not the case for most investment projects such as the one examined in this case study.

- Most Real Options can be exercised at any time during the life of a project, such as the option to cancel the contract, which will be later discussed. Real Options requires an American option valuation technique. Black-Scholes, however, is designed to value European options for which exercise takes place only at the expiration date.
- Another limitation of Black-Scholes is that most Real Option projects involve compound options, as demonstrated in this case study. Black-Scholes is not well suited to valuing such options.
- Projects can have negative NPVs, a possibility that cannot be accommodated by the Black-Scholes model, which is designed to work with financial options. Such options always have non-negative values.
- Use math that everyone can understand. The Black-Scholes model is usually called a “black box,” which refers to a formula that, once the inputs are placed, the results are calculated and the process cannot be easily audited or variables cross-checked. As discussed by Copeland and Antikarov (2005), who knows whether the conclusions are right or wrong? How does one explain them to the top management of a company? How would you like to explain the difference between a Gauss-Wiener process, geometric Brownian motion, arithmetic Brownian motion or a jump process to a competent CFO?

One of the important screenings in the selection of the methodology to be applied in the case study was my ability to be comfortable with the algebra involved. As an average practitioner of capital budget analysis, any method involving complex calculus, advanced statistics or stochastic calculus was disregarded as viable methodology.

1-Calculate NPV

a) Estimate expected free cash flows
b) Estimate The Cost of Capital
c) Separate different flows*
d) Calculate NPV

2-Analyze Uncertainty

a) Map the uncertainties *
b) Keep separate those uncertainties that evolve discretely
c) Combine those risks that evolve continuously through time using Monte Carlo techniques
d) Use either historical data or subjective forward looking management estimates
e) Estimate the volatility of the return based on value

3-Build Event Tree

a) Construction of the underlying asset event tree*
b) Models dividends payment*
c) Ensure no arbitrage with underlying and risk-free bond, event tree should reduce to PV

4-Create Decision Tree

a) Understand the type of option being modeled
b) Can have multiple decisions at one node

5-Estimate Value of Real Option

a) Solution provides decisions as well as a value

* Revised by the Author

Figure 4.1 Five-Step Process for Real Option Valuation

Source: Author adaptation of COPELAND, T. E.; ANTIKAROV, (2005)

5 CASE STUDY

5.1 Company Description

The company chosen for this study has invested more than $300 million in capital projects in the past five years among dozens of projects of several sizes and having various characteristics. It has operations in several countries in Latin and North America. Currently, the company has structured a formal capital budgeting process based on senior management discussions and DCF analysis supported by traditional metrics such as NPV, IRR, and Payback. The company in which the case study took place is referred as OFS and the investment project “Rig O.” To comply with the confidentiality of some information true parameter values were replaced by imagined ones. All the figures were multiplied by a randon number. However, the analysis and Real Option computation and conclusion remain valid.

5.2 Investment Decision for Drilling Rig in Colombia

OFS management analyzed and approved the drilling rig project in mid-2008. At the time of the investment approval, the Colombian operation of OFS was presenting very good results as shown in Figure 5.1 and the market was very bullish in Colombia. The CDS (credit default swap), a measure of investment risk in Colombia, was low, as shown in Figure 5.2, and oil prices were at an all-time high, Figure 5.3, guaranteeing comfortable returns for new drilling activity.

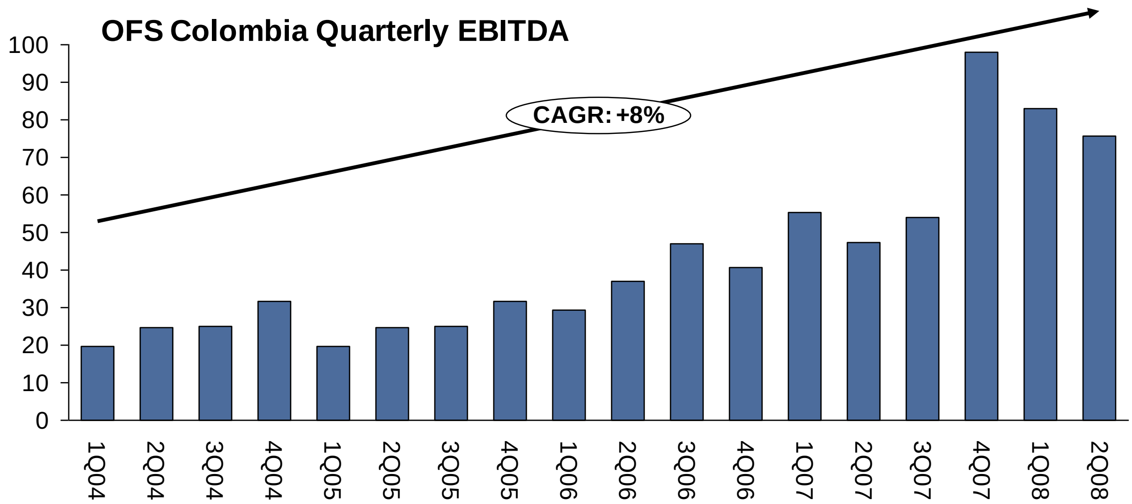


Figure 5.1 OFS Colombian Operation Financial Performance[3]

Source: OFS Information

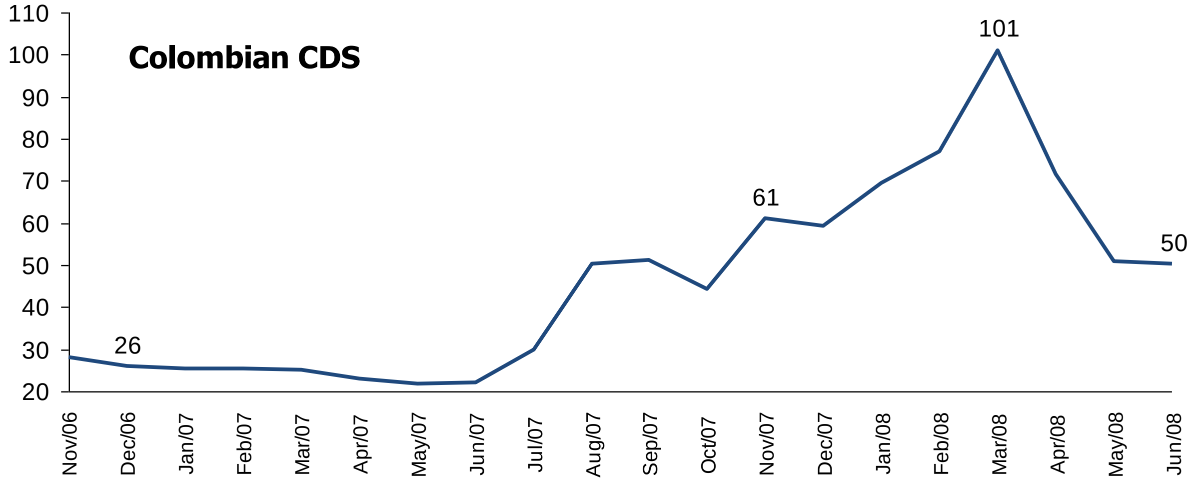


Figure 5.2 Colombian Credit Default Swap
Source: Bloomberg

[3] CAGR: Compound Average Growth Rate

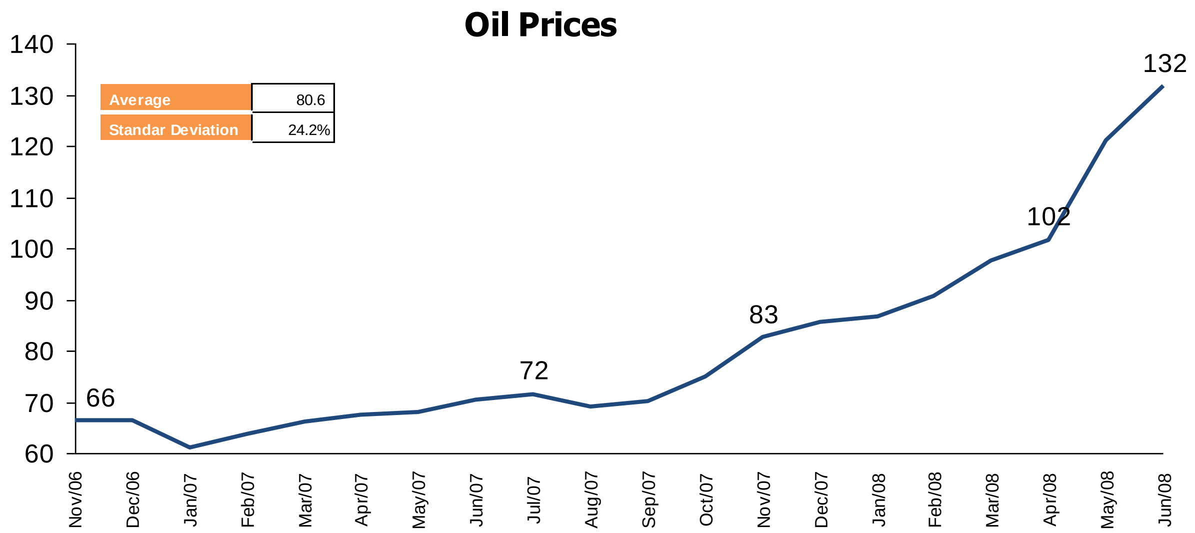


Figure 5.3 Oil Prices and monthly average and standard deviation for the period
Source: Bloomberg

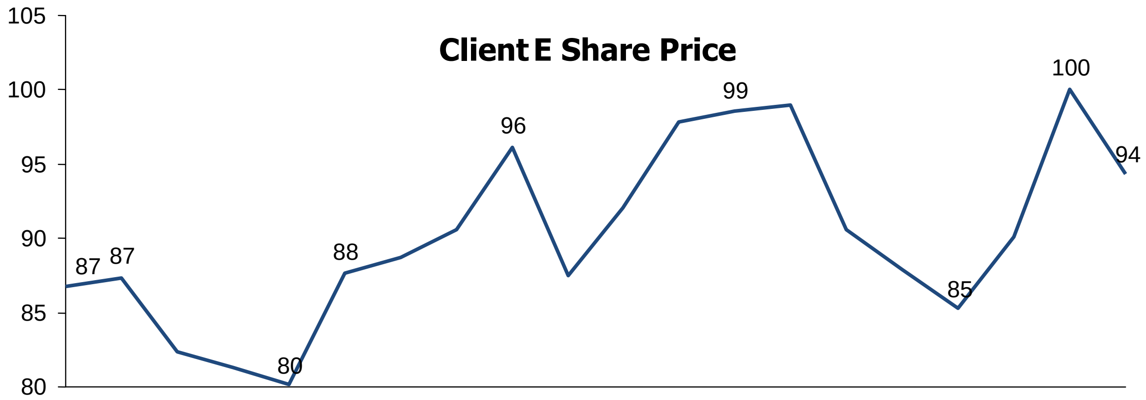


Figure 5.4 Client E Share Price Evolution
Source: Bloomberg

The investment proposal for the purchase of Rig O was a response to Client E's strategy for the future development of its fields in Colombia. Client E was one of the largest global oil companies with a long presence in the region. The project intended to purchase a state-of-the-art drilling rig, which would drill multilaterally[4], in an initial 18-month pilot program. The project was expected to have a high success rate, and therefore commitment to this rig would be at least 5 years time. In this project the client was to pay for all fuel used in the operation reducing the project risk. Fuel costs amount for 20% of the total cost of a drilling operation. Table 5.1 illustrates the initial investment analysis.

[4] It is a new technology to create wells with multiple branches that can target widely spaced reservoir compartments provides engineers unlimited options in optimizing economic extraction of oil and gas.

Table 5.1 Original Investment Analysis for Rig O Project[5]

Growth Project	0	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5
PROJECT NET INCOME STATEMENT											
Total Revenues		8,472	11,944	11,944	11,944	11,944	11,944	11,944	11,944	11,944	11,944
Operating Costs		4,441	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930
Gross Margin		**4,031**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**
Gross Margin		***48%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***
SG&A Expenses		0	0	0	0	0	0	0	0	0	0
EBITDA		**4,031**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**
EBITDA		***48%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***	***50%***
Depreciation & Amortization		2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Earnings from Operations		**1,631**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**
Total Other Income and (Expense)											
Earnings Before Taxes		**1,631**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**	**3,614**
Total Income Taxes		538	1,193	1,193	1,193	1,193	1,193	1,193	1,193	1,193	1,193
Net Income		**1,093**	**2,421**	**2,421**	**2,421**	**2,421**	**2,421**	**2,421**	**2,421**	**2,421**	**2,421**
Net Income		***13%***	***20%***	***20%***	***20%***	***20%***	***20%***	***20%***	***20%***	***20%***	***20%***
PROJECT FREE CASH FLOW STATEMENT											
EBITDA	**0.0**	**4,031**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**	**6,014**
+/- Working Capital											
- Capex	-24,000										
+ Tax benefits	-2,416	5,584									
- Income Tax	0	-538	-1,193	-1,193	-1,193	-1,193	-1,193	-1,193	-1,193	-1,193	-1,193
+ Salvage Value											23,000
FCF	**-26,416**	**9,531**	**4,821**	**4,821**	**4,821**	**4,821**	**4,821**	**4,821**	**4,821**	**4,821**	**27,821**
ACCUMULATED FCF	**-26,416**	**-16,885**	**-12,064**	**-7,243**	**-2,421**	**2,400**	**7,222**	**12,043**	**16,864**	**21,686**	**49,507**
VALUATION SUMMARY											
NPV @ 10%	16,358.1										
IRR	21%										
Payback Period	4.5 years										

Source: OFS Information

5.3 Rig O Project Business Case Assumptions

The 2008 original business case included operational assumptions very similar to the company's average operations for the last twelve months (2007 and 2008). Although the historical data did not represent the exact rigs (the company did not have a rig as automatic and new as this one) it clearly represented a floor in terms of efficiency and margins (see Table 5.2). It also assumed that the rig would be contracted for the next ten years with the same operational assumptions. It is a very bold assumption considering that the industry is very cyclical and the client's initial contract was only for a period of 18 months. The investment project consisted in a 26.4 million investment on the rig and import duties. In 2008, Colombia had a tax rebate that totaled almost 5.5 million for the purchase of such capital good item.

[5] The original business case discounted cash flow consider nominal prices and costs in US$ dollars and it also considerers a nominal discount rate.

Table 5.2 Operational Assumptions Benchmark for Project O

	LTM Operational Assumptions		
	OFS Comparable Rigs		Proposed
	Rig B1	Rig B2	Business Plan
Day Rate	33,925	44,038	35,296
Day Cost	17,617	24,319	17,524
Utilization %	96%	96%	94%
Direct Margin %	49%	46%	50%

Source: OFS Information

5.3.1 Business Case Standardization

In order to make the investment analysis comparable, the original business case assumptions were translated into a standard monthly DCF model. It used the same WACC. Some assumptions were revised in the eyes of the timeframe in which the investment analysis was performed, correcting some gross simplifications and conceptual mistakes. In the case of Rig O investment analysis, the following adjustments and revisions were required:

- The DCF analysis was previously only annual; it was adapted for a monthly projection. The monthly projection was used in order to facilitate the breakdown of the total project into several contracts that are not necessarily multiples of 12 months. The monthly projection also facilitates the identification of trends and impacts within the year.
- The original model considered the depreciation as an annual charge even though it considered only a half-year of operations (revenues and costs).
- The original model did not consider any working capital investments. Using the April 2008 average Days of Sales Outstanding (DSO) and average Days of Payables Outstanding (DPO), the total working capital investment was almost $1 million.
- Maintenance time and time lost within contracts: The original case considered the Rig working for almost 10 years without any contractual or maintenance stop. It did not consider any additional CAPEX in the following years for maintenance overhaul and technological updates. It was adjusted to reflect the following assumptions:
    - One month stop (without revenues) every beginning of new contract;
    - $200,000 maintenance CAPEX every beginning of new contract;
    - 24 months contracts after the initial contract;
    - $1 million CAPEX after 5 years for technological update.

- The salvage value for the Rig at the end of year ten in the original analysis was unrealistic: it was 87% of the initial investment. It was adjusted for a more realistic value, the liquidation value or forced sale value. The liquidation value was estimated based on the real useful life of the rig, 30 years, and that a forced sale would be 32% of the original investment plus any refurbishment and technological updates, depreciated in 30 years. The 32% value was calculated based on recent appraisal for the company assets.
- For taxes purposes was used a 10 year depreciation for the rig. The depreciation reduces the net income from the project consequently reducing the amount of taxes paid.

Table 5.3 contains the revised discounted cash flow analysis after the adjustments that was the base for the Real Option analysis.

Table 5.3 Revised NPV Evaluation of Rig O Investment Project[7]

	2008 (7M)	2009 (12M)	2010 (12M)	2011 (12M)	2012 (12M)	2013 (12M)	2014 (12M)	2015 (12M)	2016 (12M)	2017 (12M)	2018 (12M)
P&L											
Total Revenue	**8.338**	**12.110**	**11.082**	**12.110**	**11.181**	**12.110**	**11.082**	**12.110**	**11.148**	**12.110**	**-**
Total Revenue Growth %	-	45%	-8%	9%	-8%	8%	-8%	9%	-8%	9%	-100%
Revenue	5.838	12.110	12.110	12.110	12.143	12.110	12.110	12.110	12.143	12.110	-
Day Rate / Tariff	35	35	35	35	35	35	35	35	35	35	-
Days Worked	165	343	343	343	344	343	343	343	344	343	-
Utilization Rate %	90%	94%	94%	94%	94%	94%	94%	94%	94%	94%	-
Days Available	184	365	365	365	366	365	365	365	366	365	-
Other Revenues or Cost Avoidance	2.500	-	(1.029)	-	(962)	-	(1.029)	-	(995)	-	-
Day Margin (without Moblization)	17,8	17,8	17,8	17,8	17,8	17,8	17,8	17,8	17,8	17,8	-
Total Operating Costs	**(4.374)**	**(6.012)**	**(6.012)**	**(6.012)**	**(6.029)**	**(6.012)**	**(6.012)**	**(6.012)**	**(6.029)**	**(6.012)**	**-**
Direct Cost	(2.898)	(6.012)	(6.012)	(6.012)	(6.029)	(6.012)	(6.012)	(6.012)	(6.029)	(6.012)	-
Direct Gross Margin %	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	-
Other Direct Costs	(1.476)	-	-	-	-	-	-	-	-	-	-
Direct Gross Margin	**3.963**	**6.098**	**5.069**	**6.098**	**5.152**	**6.098**	**5.069**	**6.098**	**5.119**	**6.098**	**-**
Gross Margin %	48%	50%	46%	50%	46%	50%	46%	50%	46%	50%	-
SG&A Expenses / Indirect Costs	-	-	-	-	-	-	-	-	-	-	-
EBITDA	**3.963**	**6.098**	**5.069**	**6.098**	**5.152**	**6.098**	**5.069**	**6.098**	**5.119**	**6.098**	**-**
EBITDA%	48%	50%	46%	50%	46%	50%	46%	50%	46%	50%	-
EBITDA Growth %	-	54%	-17%	20%	-16%	18%	-17%	20%	-16%	19%	-100%
Depreciation & Amortization	(1.200)	(2.400)	(2.418)	(2.420)	(2.437)	(2.440)	(2.530)	(2.560)	(2.573)	(2.580)	-
Earnings Before Taxes	**2.763**	**3.698**	**2.651**	**3.678**	**2.715**	**3.658**	**2.539**	**3.538**	**2.546**	**3.518**	**-**
Income Taxes	(912)	(1.220)	(875)	(1.214)	(896)	(1.207)	(838)	(1.167)	(840)	(1.161)	-
Tax Rate %	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%	#DIV/0!
Net Income	**1.852**	**2.477**	**1.776**	**2.464**	**1.819**	**2.451**	**1.701**	**2.370**	**1.706**	**2.357**	**-**
Net Income %	22%	20%	16%	20%	16%	20%	15%	20%	15%	19%	-
Project Valuation											
Free Cash Flow											
EBITDA	3.963	6.098	5.069	6.098	5.152	6.098	5.069	6.098	5.119	6.098	-
Income Taxes	(912)	(1.220)	(875)	(1.214)	(896)	(1.207)	(838)	(1.167)	(840)	(1.161)	-
Operating Cash Flow	**3.052**	**4.877**	**4.194**	**4.884**	**4.256**	**4.891**	**4.231**	**4.930**	**4.279**	**4.937**	**-**
Δ NWC	(999)	-	-	-	-	-	-	-	-	-	999
Gross Capex	(26.416)	-	(200)	-	(200)	-	(1.200)	-	(200)	-	-
Salvage Value	5.584	-	-	-	-	-	-	-	-	-	6.754
Total Investments (Net Salvage Value)	**(21.831)**	**-**	**(200)**	**-**	**(200)**	**-**	**(1.200)**	**-**	**(200)**	**-**	**7.753**
Free Cash Flow	**(19.040)**	**4.877**	**3.994**	**4.884**	**4.056**	**4.891**	**3.031**	**4.930**	**4.079**	**4.937**	**7.753**
NPV of FCF (USD)	**9.254,9**										
IRR of Project (Yearly)	**19,8%**										
Payback (Months / Years)	**58,0**	**4,8**									
Discounted Payback (Months)	**80,0**										

Source: Author's review based on OFS information

[7] The same nominal prices and costs in US$ dollars assumption of the original business case was maintained. It assumes that the company will not pass to the tariffs the US$ inflation and will also keep its cost structure controlled in US$ terms.

5.3.2 OFS contract with client E:

Most investment analyses and decisions are made before any contract or formal arrangement with the client is made. In the case of a large investment, it is recommended that the contractual terms be fully reflected in the investment analysis and consequently in the decision. This allows for avoidance of a very common trap, which results when the decision is approved under certain assumptions and the project is implemented under different and more relaxed assumptions. However, in most cases, it is not practical to negotiate the terms of both the contract and the investment decisions together and the investments are approved under assumptions that should reflect the future contractual structure and terms. Most of the contractual terms of a drilling rig contract in the industry are standard, taking it into consideration, the original investment decision should have reflected those clauses. However, this was not the case of the original investment decision:

- The contract specified that the client could cancel the contract at any time, paying only the demobilization tariff estimated at $2.5 million. The contract clearly includes a put option for client E at no additional charge. The value of this option should be discounted from the NPV analysis for the decision-making.
- Payment terms: The contract stipulates a 30-day payment after the client has certified all of the services. On average, it takes a total of 60 days to receive the services, which is a significant working capital investment that was not considered in the original analysis. The contract also stipulates that it may take longer if the client requests additional information and the company is delaying answering.
- The contract also stipulates penalties from 5% to 20% of the regular tariff if the company does not comply with a long list of contractual requirements.

  The contract stipulated an 18-month contracted service with the option for the client to contract again under the same terms. In fact, this option does not have a lot of value for the analysis as the investment project already considers that the contract will be renewed for 10 years with similar terms which is not appropriate.

5.4 Real Option analysis for Rig O Project – Indentifying the Uncertainties

To apply the methodology of Real Options to evaluate the project for Rig O, a combination of the five-step process proposed by COPELAND, T. E.; ANTIKAROV (2005) and the adjustment used by BRANDÃO *et al.* (2005) was implemented. Different from the COPELAND, T. E.; ANTIKAROV (2005) approach, this method uses most of the binomial lattice methodology in terms of cash flow already discounted by the risk-free rate. This approach facilitates results analyses and the modeling of the variables.

5.4.1 Step1: Calculate NPV to estimate the market value for the project

Step 1a: Our revised version of the original business case was the base DCF used to estimate the project value. To facilitate the analysis, the discounted cash flow was divided into 5 contracts: One base contract for 18 months, according the investment proposal with Client E, and 4 contracts for 24 months each.

Step 1b: Estimate the cost of capital. To facilitate the comparison with the original investment analysis the same nominal WACC was used, 10%. This figure was the company-estimated nominal WACC at the time of the investment.

Step 1c: During the application of the methodology, separating the different "flows" was found to facilitate analysis and the binomial lattice approach, thus in the NPV analysis, they can be mixed together. I separated all flows related to investment or divesture decisions (CAPEX, salvage value, margin lost between contracts) from other flows related to the regular operation activity (direct margin and working capital from rigs operations).

Step 1d: After separating the flows, each piece can be discounted by the same WACC and added together in the NPV.

Table 5.4 Project O NPV Breakdown

	Rig O
PV Cash Flows (operation)	29,480
PV Investments	(22,892)
PV Salvage Value	2,667
NPV	**9,255**

Source: Author's calculation

5.4.2 Step 2: Analyze Uncertainties: Define the main uncertainties

This was the most complex part of the analysis. In this step, it is necessary to decide what the most important uncertainties that affect the project value are and the options that are incorporated in the project. It is tricky because there is no single methodology that will produce the answers; only a deep understanding of the reality of the project, the complexity and dynamics of the industry will yield the answers. After defining these elements, it is necessary to go back to the methodology to determine whether it can be modeled to analyze the real impact (sensibility analysis) for the relevance of the variable and if it really should be incorporated in a day-to-day evaluation after a standard model has been developed.

In this case, the first step is to recognize that unlike the original investment analysis, the project is not a single series of cash flows from a single client. In fact, it is a combination of several sets of cash flows from various contracts, which may or may not come from a single client. Here we have to assume some distribution of the contracts in order to be able to model:

The base contract is the first; it is an 18-month cash flow that has already been contracted with Client E and has most of the value drivers defined, lowering uncertainties.

The second set of contracts are three 25-month contracts, including one month in the beginning of the contract for rig up (perform maintenance) without revenues, and one additional 21-month contract;

After the last contract, it was determined that three additional months were required to recover the working capital (receivables) and to sell the rig for the liquidation value, totaling a 114-month projection plus 3 months to recovery the working capital equal to the revised NPV calculation.

Table 5.5 Project O Contract Breakdown Assumptions and CAPEX

	Months	Capex
Base Contract (Client E)	18	21.09
New contract 1	25	0.20
New contract 2	25	0.20
New contract 3	25	1.00
New contract 4	21	0.20
Total 5 Contracts	**114**	**22.7**

Source: Management estimates

Table 5.6 PV of Cash Flow Breakdown Per Contract

	PV Cash Flow
Base Contract (Client E)	6.4
New contract 1	7.6
New contract 2	6.3
New contract 3	5.2
New contract 4	4.0
Total 5 Contracts	**29.5**

Source: Author's calculation

Step 2a: Map the uncertainties

After reframing the project, it was easier to define the main uncertainties involved in the contracts and the options involved. The main uncertainties involved can be divided into two main groups:

OFS company Uncertainties or Technical Uncertainties:

Rig Efficiency: Total days/hours worked and billed divided by the total days/hours contracted. A drilling rig such as the one described operates 24 hours per day 7 days per week and generates revenue according to the amount of hours or days it is ready to operate. A stable operation generally requires high levels of efficiency, around 98%; however, a rig could have several operational problems such as personnel strikes, difficulties in moving the rig between wells, mechanical problems or even human errors in the drilling activity. This uncertainty affects the base contract as well the new contracts.

Rig utilization: Rig utilization is a similar to the former variable, total days/hours worked and billed divided by the total days/hours available, but it also considers the impact of an idle rig between contracts. It is important as the project has only one contract guaranteed. After the first contract was finished, the OFS was back to the market and susceptive to the market forces to get a new contract.

Tariff and Day Rate: Once the rig is engaged, this variable is mostly fixed as all tariffs are calculated according to the contract with little space for renegotiation. Except by the mix of different tariffs under which the rig may operate. However, as the contract is renewed or the rig is available for a new contract, it will have to take the new “market” tariff. The oil price has an important influence on OFS tariffs. However, as it encompasses a 10-year timeframe, abrupt price changes could be mean reverting, reducing this impact in the model. Other variables also affect the tariffs such as government stimulus for the industry, the complexity of the drilling services, the availability of competitors’ rigs in the region. For this analysis the day rate variable is used, formed by all revenues generated during the month (from several type of tariffs) divided by the total days it worked and billed.

Costs and Day Cost: Differently from the tariffs that are mostly defined as the contract is signed, the operational costs involved in the operation are not; foreign exchange variations and demand shocks could significantly influence the costs and the overall profitability of the project. A very active drilling market affects the whole supply chain, increasing the price for trucks, cranes, specialized labor, maintenance services, as well as for OFS services. For this analysis the day cost variable is used, formed by all costs generated during the month (most tend to be variable regarding activity or days worked/billed) divided by the total days it worked and billed.

Client / Operator Uncertainties or Market Uncertainties:

Oil Price and Economic downturn: The OFS’s clients are the ones who bear the direct impact of drastic fluctuations in the oil prices or an economic downturn; they are the ones who will sell oil at a lower price and at a lower volume. The drilling service they contract is only a part of the initial investment they have to incur to be able to sell their products; it is only one part of a more complex value chain. The practical implication of these uncertainties for the OFS investment project is:

- If the oil price drops substantially with no expectation of recovery, the client's project (in which the rig is being used) may not be viable any more (in light of the new expected price of oil). In this case, the client could cancel the contract for a specified penalty (generally the demobilization costs).
- In a downturn or in a lower oil price environment, the clients will be less willing to contract new rigs, depressing the tariffs and the utilization.

Step 2b: Keep separate those uncertainties that evolve discretely

According to Copeland and Antikarov (2005) there are three important things to keep in mind when modeling uncertainties:

- It is possible to combine uncertainties provided they evolve more or less continuously over time and you capture the covariances among them as well as their autocorrelation over time. In the case we combined the efficiency, utilization with the day margin risks.
- When a source of uncertainty is resolved all at once and therefore is discontinuous over time, it should be kept separate from uncertainties that evolve continuously. In the case we separated the risk of the client canceling the contract from the one related to the company efficiency and day margin.

Using the previous division of uncertainties it becomes clear that part of the first group has a direct impact on the OFS cash flow as it may manage and mitigate most of the risks. They are directly involved in the cash flow projections, for instance: the total revenue will depend on the day rate and the efficiency, and the EBITDA and the working capital will depend on them and the day cost.

The impact of the second group on OFS will depend on the economics of the operator project as the total investment it will require, expected lifting cost (cost to extract the oil after the well is complete), type of oil it will produce and the price it is expected to sell. The impact on the OFS cash flow will only be applicable if the operators cancel the contract or if they hire the OFS for a new contract with a lower tariff.

The Real Option analysis model treats the two cases separately as the underlying risks' volatilities are different as well as the options involved for OFS.

Step 2c: Combine those risks that evolve continuously through time using Monte Carlo techniques

In order to define the appropriate volatility for the options involved in the first group of uncertainties discussed above, the MAD approach discussed previously was used with a Monte Carlo simulation.

Using this approach, I assumed that there was no perfectly correlated "twin security" for the investment in the drilling rig. I used the NPV as the most accurate estimate of the value of the project without flexibility, substituting for the value of the twin security. According to Copeland and Antikarov (2005), although this practice has been questioned, the assumption in the MAD approach is the same one that corporate executives routinely make when using the NPV of projects as estimates of the market price of projects. It is consistent with the practical approach used in this study.

For modeling and conceptual proposes I combined two uncertainties, day rate and day cost, into one variable, day margin. As the dynamics of this variable are strongly correlated to each other since some costs increase as labor costs are passed to the tariffs (in some contracts) and the market dynamic of lower activity generating lower tariffs also reflects on lower operational costs of the whole market contracts, showing that this assumption is valid.

To capture the effects of the uncertainties that were discussed on project risk, the day margin and utilization rate were used to drive the Monte Carlo simulation of changes in project value.

Step 2d: Use either historical data or subjective forward-looking management estimates to drive the Monte Carlo Simulation[8]

Using historical data and management estimates, considering the information available at the time. In the case of the investment project on Rig O, one might be tempted to identify the risk of the investment project with the volatility of the efficiency benchmark, 4.6% (Figure 5.5), or the day margin of a benchmark rig, 16% (Figure 5.6).

[8] As in most of the cases in with there is no complete and reliable information to take a decision, we utilized management estimates. These estimates are mostly based on past performance adjusted by the management expectations of the future. It generates an immense field biased decisions being behavioral economics the best approach to deal with them.

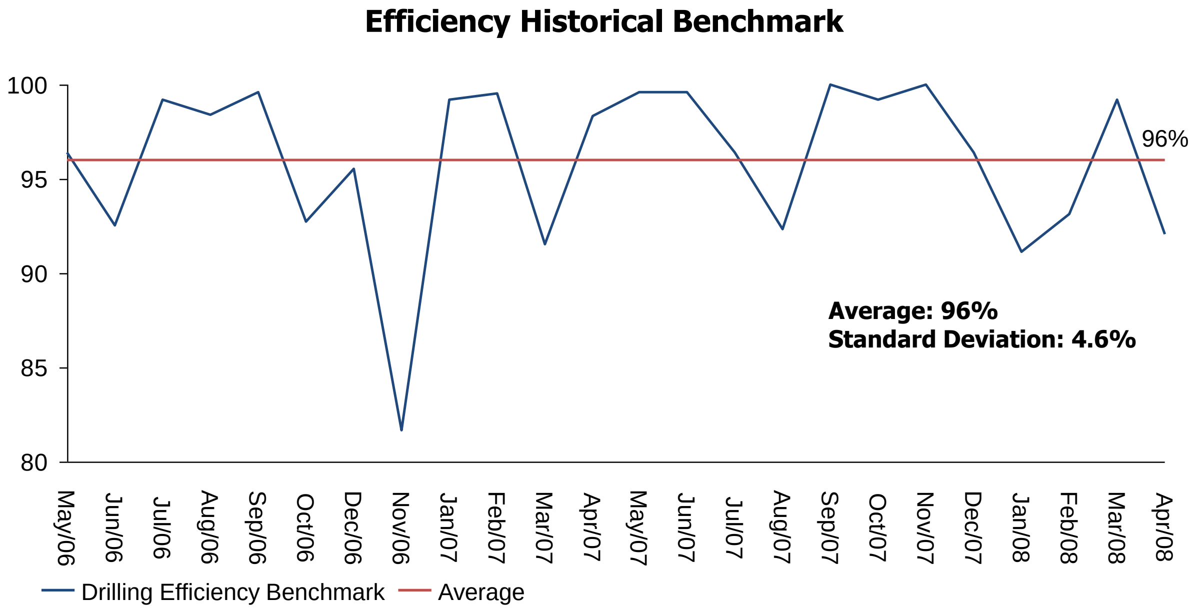


Figure 5.5 Efficiency Evolution of Benchmark rig
Source: OFS internal data

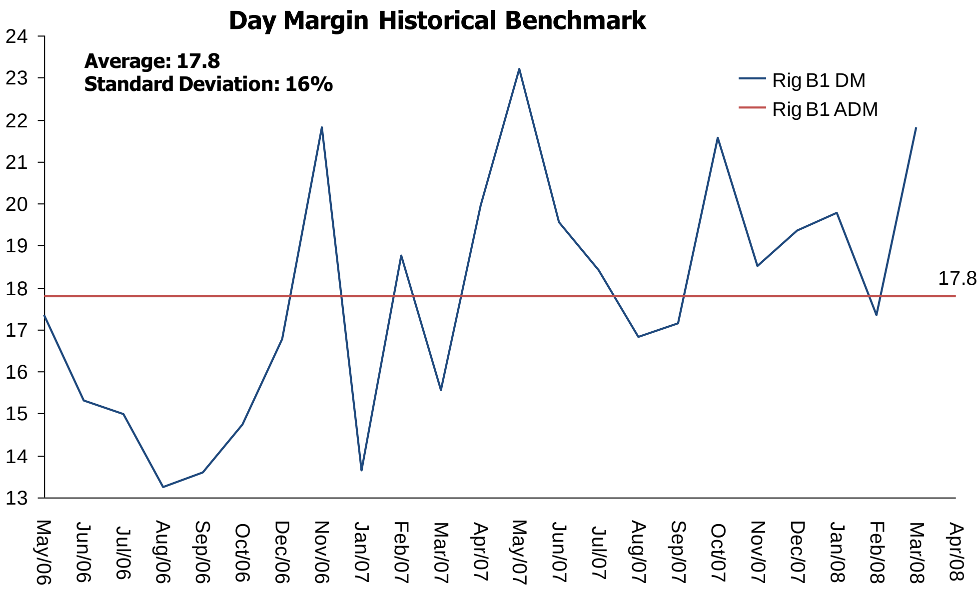


Figure 5.6 Day Margin Evolution for Benchmark rig
Source: OFS internal data

However, it is important to recognize that although efficiency and day margin uncertainties drive the risk of the project, it is not equivalent to that risk (as many Real Options applications seem to assume), and thus it is not a twin security. To incorporate these two risks into the Monte Carlo Simulation based on the original PV model, a combination of historical data and management estimates for both risks was used.

Efficiency uncertainty:

As illustrated in Figure 5.5, efficiency may behave as a mean reverting variable. Using the procedure described by Copeland and Antokarov (2003), the formula for this variable should be:

$Vt=V_{t-\Delta t}+\alpha\,(V - V_{t-\Delta t}) +\sigma dz$, where:

V is the average level in which the uncertainty fluctuates, in the case was used 94% as the original business case; the same assumption for the original case and a little lower than the benchmark in Figure 5.5. α is the speed of the efficiency return to average after every deviation, in this case it was assumed 3 periods or 100% ÷3 = 33% according to management estimates and supported by Figure 5.5. The value of uncertainty in the previous period $V_{t-\Delta t}$ was already determined. The random variable for the Monte Carlo simulation will be dz, which is normally distributed with expected value zero and standard deviation of 1. The volatility for each period is constant, σ, defined by:

$$\sigma_t = \frac{V-V_{(lower)T}}{2\sqrt{\sum_{n=2}^{T}[(1-\alpha)^{T-t}]^2}} = \frac{V_{(upper)T}-V}{2\sqrt{\sum_{n=2}^{T}[(1-\alpha)^{T-t}]^2}}$$

Source: Copeland and Antokarov (2003)

Applying the formula for a 24-month period, considering management estimates of lowest possible value with a 95% confidence rate in 24 months (period of contracts) is 40%; the value of σ is 20.0%. With these parameters, we can incorporate the formula:

$Vt=V_{t-\Delta t}+\alpha\,(V - V_{t-\Delta t}) +\sigma dz$ into the Monte Carlo simulation.

Day Margin Uncertainty:

Observing Figure 5.6, the day margin may also be a mean reverting variable during the 18-month period and should also be in the long run to guarantee the profitability of the industry and the availability of the services. However, in the short period under a contracted tariff, the volatility should be significantly smaller. Using the procedure described by Copeland and Antokarov (2003) , I performed the same analysis of the efficiency, but considering one range for the 18-month contract and another for the remaining 98 months.

The average level around the uncertainty fluctuates; in the case it is 17.7, the same assumption of the original case and a little lower than the benchmark in Figure 5.6. α is the speed the efficiency return to average after every deviation, in this case it was assumed that 2 periods or 100% ÷2 = 50% according to management estimates and supported by Figure 5.6 for the 18-month period and 12 periods or 100% ÷12 = 8.3% for the remaining 98 months. Applying the volatility formula for the 18-month period considering management estimanates of lowest possible value with a 95% confidence in 18 months (period of the base contract) is $10,000; the value of σ is 3.37 or 18.9%. Using the same volatility formula for the 98-month period considering management estimates of the lowest possible value with a 95% confidence in 98 months (period of the base contract) is negative 10.0; the value of σ is 5.5 or 31.2%.

In order to check the modeling of the uncertainties in the Monte Carlos simulation I performed the Monte Carlo simulation for the two variables to check whether they are converging to the expected mean (that showed be very close from the ones in the PV analysis).

Summary Statistics				
Average	93.8%	%	1000	repetitions
SD	5.5%	5.9%	43	seconds
Max	109.1%			
Min	77.4%			

Summary Statistics				
Average	17.721	%	1000	repetitions
SD	5.1814	29.2%	42	seconds
Max	33.316			
Min	-0.280			

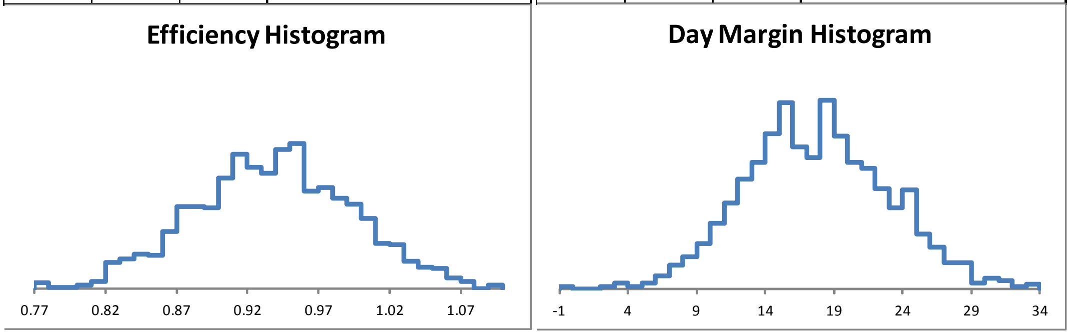


Figure 5.7 Efficiency and Day Margin Histograms from Monte Carlo Simulation

Source: Author’s Calculations

<u>Step 2e</u>: Estimate the volatility of the return based on value

This simulation in turn allows for estimation of the volatility of the rate of return on the project (which, as we shall show later on, is 24.3%)—a number that is different from the volatility of the efficiency (5.9%) and from the volatility of the day margin (29.2%), calculated directly from the Monte Carlo simulation. In fact, the project volatility is a combination of the volatilities from these two risks combined with the economics of the projected defined by the remaining assumptions. Even though the other assumptions were not randomly simulated in the Monte Carlo model, they can influence the project volatility. For instance, if the project had no working capital requirements the project volatility would be only 0.8% higher; on the other hand, if it had a monthly fixed cost of $100, regardless of reducing the PV of the project it would have increased the volatility of the project in 22.4%.

As much market information as possible was used in order to estimate the volatility of the rate of return on the project. In the absence of a traded twin security that represents the project (not merely the oil price), the proposed method assumed that the PV of the project without flexibility, as calculated using classical techniques, is the best estimate of the market price of a hypothetical twin security—one whose cash flows are perfectly correlated with the project itself. However, it is important to recognize that the inputs, even if subjective in some respects, are based on management estimates based on actual data of comparable projects. Perhaps even more important for managers is that the use of the MAD approach makes it far easier to perform the "reality check" of ensuring that the total project value is equal to the implied value of managerial flexibility plus the value of the project without flexibility. The search for a "twin security" in such a case, without a solid PV analysis and the understanding of the value of the underlying project it provides, is likely to turn the Real Options method into the "black box" that puts off practitioners (Copeland; Antikarov, 2005).

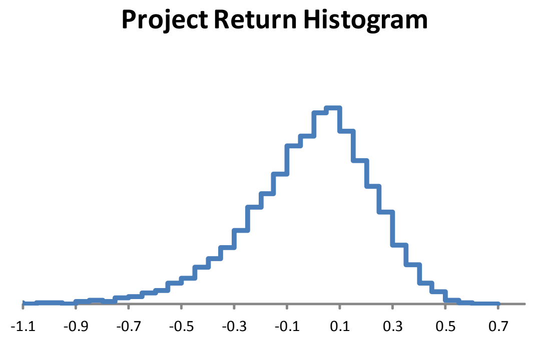
The Monte Carlo simulation of the project return was accomplished by running 10,000 random draws of the two risks, efficiency and day margins, as described before in the spreadsheet. The project return is defined by the formula: $\ln((PV_1+FCF_1)/PV_0)$. In this case, PV_1 is the present value of future cash flow generated by the operation without investments and salvage value (as described in Step 1d) in Year 1 discounted at WACC (from the Monte Carlo simulation). FCF_1 is the nominal cash flow generated in the first month without any investment, rather than working capital, from the Monte Carlo simulation. PV_0 is the cash flow generated by the operation at Year 0 from the standard PV analysis without the Monte Carlo simulation.

In order to perform the Monte Carlo simulation efficiently, the add-in program for Excel developed by Barreto; Howland [s.d.] was used. The program adds optional simulation commands and features to Microsoft Excel.

The volatility of the project calculated by this methodology was 24.3%, Figure 5.8. A simulation of the NPV of the project was also performed, and it was close to the original NPV values, Figure 5.8, reinforcing the believe in the model integrity.

Summary Statistics			
Average	-1.9%	10000	repetitions
SD	24.3%	843	seconds
Max	67.7%		
Min	-194.0%		

Summary Statistics				
Average	9,260	%	10000	repetitions
SD	7,068	76%	1946	seconds
Max	30,629			
Min	- 11,760			



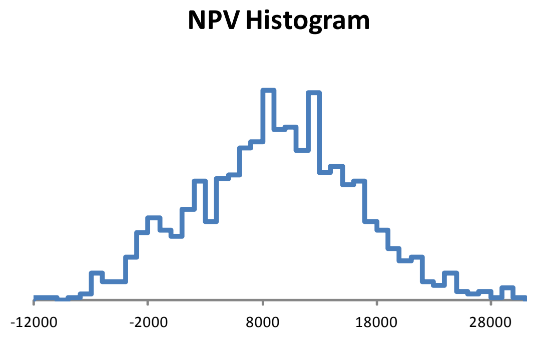


Figure 5.8 Project Return and NPV Histograms from Monte Carlo Simulation
Source: Author's Calculations

As mentioned in Step 2b, the uncertainties were separated. The volatility for the first group was already calculated by using the Monte Carlo simulation. For the second group, based on the operator's economics, the risk of an economic downturn would make the operator's project unfeasible, also requiring a volatility estimation. In this case, the OFS cash flow is the operator's CAPEX and if the operator's project becomes unfeasible because of a drop in oil prices, an analysis will be performed to determine if it is worth exercising its put option to cancel the contract and pay the contract penalty.

This thesis does not intend to discuss the operators' economics and rationale for exercising this option. On the other hand, it is a relevant option that the OFS gives away to the operators by the time the contract is signed and should be discounted in the original PV calculation of the project. To calculate this option we will use a simplified approach and consider as the volatility driver the oil prices' standard deviation for a similar period, in this case the last 20 months previous the project approval as we believe that this periods will captures the expected volatility going forward.

Steps 3 to 5 will be applied twice: first for the second type of uncertainty related to the OFS client, the company that hired the OFS and can cancel the contract any time if it faces difficulties, and then for the sets of uncertainties related to OFS-related operations (efficiency and day margin). This order is important because to model the former type of uncertainties it the project value is necessary, and the project value should be calculated after discounting the embedded put option that the OFS company gives to its clients. This is a cost that reduces the project value that will be the base to calculate the impact of the other uncertainties in the total project value. The annual risk free discount rate used in both cases was 3.4% in $ dollars equivalent to a 0.28% monthly rate.

5.5 Real Option analysis for Rig O Project – Operator Perspective

5.5.1 Step 3 Operator: Build Event Tree Based on the Binomial Lattice

<u>Step 3a</u>: Construction of the underlying asset event tree**:** Estimate the volatility of the return based on value

The underlying asset in the first case is the OFS client project value. The project value is composed by the expected net cash flow the client will receive from oil sales after the wells are drilled and operational. This value should be net from the extracting and selling costs and discounted by the initial investment in drilling the wells. This initial investment, CAPEX, is the OFS expected cash flow from the contract. To calculate the operator's project value it would require a lot of information from the project that the OFS company does not have. In this thesis I proposed a simplification that is only possible because what we really want is not the operators project value; we want the impact of the operator project's value variation on the OFS cash flow. It is known that the operator's project value is strongly correlated to the oil prices, and that at the time the operators decide to contract the project they take into consideration the current oil price and the investment required to implement the project. It is assumed that if the project's expected value substantially fell during the drilling phase due to a sharp drop in the expected oil price the operator will reevaluate if it should continue to invest or not. In the case that it stops investing it means that it will cancel the OFS contract and pay eventual penalties.

It is assumed that at the time the operator contracts the OFS the expected project value is 100. Based on that and the estimated volatility of this project, the oil price standard variation, (24%), the binomial event tree for the first contract (18 months) is calculated in Table 5.7. The up and down movements at each step are u $=e^{\sigma \sqrt{\Delta t}}$ and d=1/u, where σ is the volatility of asset returns, oil price, per time increment in the tree and $\sqrt{\Delta t}$ is the length of the time increment, in this case is one (Hahn; Brandao; Dyer, 2010).

Table 5.7 Operators (Client E) Project Valuation Binomial Tree

1-Up Movement	1.2712269
2-Down Movement	0.7866416

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0	867.0	1,102.1	1,401.1	1,781.1	2,264.1	2,878.2	3,658.9	4,651.2	####	7,516.5
1		78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0	867.0	1,102.1	1,401.1	1,781.1	2,264.1	2,878.2	####	4,651.2
2			61.9	78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0	867.0	1,102.1	1,401.1	1,781.1	####	2,878.2
3				48.7	61.9	78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0	867.0	1,102.1	####	1,781.1
4				-	38.3	48.7	61.9	78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0	867.0	1,102.1
5				-	-	30.1	38.3	48.7	61.9	78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0	536.5	682.0
6				-	-	-	23.7	30.1	38.3	48.7	61.9	78.7	100.0	127.1	161.6	205.4	261.2	332.0	422.0
7				-	-	-	-	18.6	23.7	30.1	38.3	48.7	61.9	78.7	100.0	127.1	161.6	205.4	261.2
8				-	-	-	-	-	14.7	18.6	23.7	30.1	38.3	48.7	61.9	78.7	100.0	127.1	161.6
9				-	-	-	-	-	-	11.5	14.7	18.6	23.7	30.1	38.3	48.7	61.9	78.7	100.0
10				-	-	-	-	-	-	-	9.1	11.5	14.7	18.6	23.7	30.1	38.3	48.7	61.9
11				-	-	-	-	-	-	-	-	7.1	9.1	11.5	14.7	18.6	23.7	30.1	38.3
12				-	-	-	-	-	-	-	-	-	5.6	7.1	9.1	11.5	14.7	18.6	23.7
13				-	-	-	-	-	-	-	-	-	-	4.4	5.6	7.1	9.1	11.5	14.7
14				-	-	-	-	-	-	-	-	-	-	-	3.5	4.4	5.6	7.1	9.1
15				-	-	-	-	-	-	-	-	-	-	-	-	2.7	3.5	4.4	5.6
16				-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	2.7	3.5
17				-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	2.1
18				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3

Source: Author's Calculation

What we are really interested in is the impact on the OFS project value; we also build the event tree for the first contract, which has an PV of $6,437.

Table 5.8 OFS Project Valuation Binomial Tree for Base Contract with Client E and Monthly % of Cash Flow of Remaining Project Value

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	6,437	8,183	7,700	9,650	12,075	17,135	20,255	23,698	27,462	31,823	36,217	40,841	45,178	49,162	51,775	52,298	49,894	41,922	26,906
1		5,064	4,765	5,971	7,472	10,603	12,534	14,665	16,993	19,692	22,411	25,273	27,956	30,421	32,039	32,362	30,874	25,941	16,650
2	-	-	2,949	3,695	4,624	6,561	7,756	9,075	10,516	12,186	13,868	15,639	17,300	18,825	19,826	20,026	19,105	16,053	10,303
3	-	-	-	2,287	2,861	4,060	4,799	5,615	6,507	7,541	8,582	9,677	10,705	11,649	12,268	12,392	11,822	9,933	6,375
4	-	-	-	-	1,770	2,513	2,970	3,475	4,027	4,666	5,310	5,988	6,624	7,208	7,592	7,668	7,316	6,147	3,945
5	-	-	-	-	-	1,555	1,838	2,150	2,492	2,887	3,286	3,706	4,099	4,461	4,698	4,745	4,527	3,804	2,441
6	-	-	-	-	-	-	1,137	1,331	1,542	1,787	2,033	2,293	2,537	2,760	2,907	2,936	2,801	2,354	1,511
7	-	-	-	-	-	-	-	823	954	1,106	1,258	1,419	1,570	1,708	1,799	1,817	1,733	1,457	935
8	-	-	-	-	-	-	-	-	590	684	779	878	971	1,057	1,113	1,124	1,073	901	578
9	-	-	-	-	-	-	-	-	-	423	482	543	601	654	689	696	664	558	358
10	-	-	-	-	-	-	-	-	-	-	298	336	372	405	426	431	411	345	222
11	-	-	-	-	-	-	-	-	-	-	-	208	230	250	264	266	254	214	137
12	-	-	-	-	-	-	-	-	-	-	-	-	142	155	163	165	157	132	85
13	-	-	-	-	-	-	-	-	-	-	-	-	-	96	101	102	97	82	52
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62	63	60	51	32
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39	37	31	20
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	19	12
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	8
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
FCF as a % of PV OFS	0%	26%	1%	2%	-12%	7%	8%	9%	9%	10%	11%	13%	14%	17%	21%	25%	34%	50%	100%

Source: Author's Calculation

Unlike the operators project value lattice, which does not "pay divided" along the first 18 months of investment, the OFS contract pays them and the up and down formula should applied to the present value of the project after the dividend payment. To get to the present value of the project after the dividend payment, we multiplied the current project value by 1- % of the monthly cash flow to the current value of the project. See section 3.6.5 for more details.

<u>Step 3b</u>: Models dividends payment

According to Brandão; Dyer; Hahn (2005), to simplify the binomial tree and allow for an easier understanding of the variables that are being modeled, we separate the dividend payments of the project; in this case the expected monthly cash flow from the project value. We also discount the dividend payment using the risk-free interest rate.

Table 5.9 OFS Discounted Cash Flow (Dividends Payments) Binomial Tree for Base Contract.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	-	2,120	108	150	-1,389	1,186	1,586	2,055	2,374	3,250	3,977	5,141	6,290	8,132	10,227	12,513	16,175	19,791	25,584
1	-	1,312	67	93	-860	734	981	1,272	1,469	2,011	2,461	3,181	3,893	5,032	6,328	7,743	10,009	12,247	15,831
2	-	-	42	58	-532	454	607	787	909	1,245	1,523	1,969	2,409	3,114	3,916	4,791	6,194	7,578	9,796
3	-	-	-	36	-329	281	376	487	563	770	942	1,218	1,491	1,927	2,423	2,965	3,833	4,690	6,062
4	-	-	-	-	-204	174	232	301	348	477	583	754	922	1,192	1,499	1,835	2,372	2,902	3,751
5	-	-	-	-	-	108	144	186	215	295	361	466	571	738	928	1,135	1,468	1,796	2,321
6	-	-	-	-	-	-	89	115	133	183	223	289	353	457	574	703	908	1,111	1,436
7	-	-	-	-	-	-	-	71	82	113	138	179	219	283	355	435	562	688	889
8	-	-	-	-	-	-	-	-	51	70	86	111	135	175	220	269	348	426	550
9	-	-	-	-	-	-	-	-	-	43	53	68	84	108	136	166	215	263	340
10	-	-	-	-	-	-	-	-	-	-	33	42	52	67	84	103	133	163	211
11	-	-	-	-	-	-	-	-	-	-	-	26	32	41	52	64	82	101	130
12	-	-	-	-	-	-	-	-	-	-	-	-	20	26	32	39	51	62	81
13	-	-	-	-	-	-	-	-	-	-	-	-	-	16	20	24	32	39	50
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	15	20	24	31
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	12	15	19
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	9	12
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author's Calculation

Step 3c: Ensure no arbitrage with underlying and risk-free bonds; event tree should reduce to PV

At this point, we are still modeling the binomial tree without any flexibility. Using the same backward induction technique that will be used to determine a correct price for the option on the asset at time zero, we return to the PV of the OFS first contract by starting from the last branch (18,0) and (18,1) (Table 5.10) returning to (0,0) by using the appropriated risk-neutral probability as discussed in section 3.6.1.

Table 5.10 OFS Project Valuation Binomial Tree for Base Contract Backward Induction

Risk Neutral Prob (up)	44.6%
Risk Neutral Prob (Down)	55.4%

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	6,437	8,161	7,657	9,569	11,940	16,897	19,917	23,238	26,853	31,031	35,217	39,602	43,685	47,404	49,785	50,147	47,707	39,973	25,584
1	-	5,050	4,738	5,922	7,389	10,456	12,325	14,380	16,617	19,202	21,792	24,506	27,033	29,334	30,807	31,031	29,522	24,735	15,831
2	-	-	2,932	3,664	4,572	6,470	7,627	8,898	10,283	11,883	13,485	15,164	16,728	18,152	19,064	19,202	18,268	15,306	9,796
3	-	-	-	2,267	2,829	4,004	4,719	5,506	6,363	7,353	8,345	9,384	10,351	11,233	11,797	11,882	11,304	9,472	6,062
4	-	-	-	-	1,751	2,478	2,920	3,407	3,937	4,550	5,164	5,807	6,405	6,951	7,300	7,353	6,995	5,861	3,751
5	-	-	-	-	-	1,533	1,807	2,109	2,437	2,816	3,195	3,593	3,964	4,301	4,517	4,550	4,329	3,627	2,321
6	-	-	-	-	-	-	1,118	1,305	1,508	1,742	1,977	2,224	2,453	2,662	2,795	2,816	2,679	2,244	1,436
7	-	-	-	-	-	-	-	807	933	1,078	1,224	1,376	1,518	1,647	1,730	1,742	1,658	1,389	889
8	-	-	-	-	-	-	-	-	577	667	757	851	939	1,019	1,070	1,078	1,026	859	550
9	-	-	-	-	-	-	-	-	-	413	469	527	581	631	662	667	635	532	340
10	-	-	-	-	-	-	-	-	-	-	290	326	360	390	410	413	393	329	211
11	-	-	-	-	-	-	-	-	-	-	-	202	223	241	254	255	243	204	130
12	-	-	-	-	-	-	-	-	-	-	-	-	138	149	157	158	150	126	81
13	-	-	-	-	-	-	-	-	-	-	-	-	-	92	97	98	93	78	50
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	61	58	48	31
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	36	30	19
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	18	12
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	7
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author’s Calculation

In Table 5.10, the last column, 18, is the same as Table 5.8, reflecting that in this kind of project, in month 18 the project value is the same as the expected cash flow in the 18^{th} month. This will be our starting point for the backward induction. The yellow cell (17,0) reflects the backward movement that will continue until cell (0,0). The yellow cell is: 25,584 x Risk Neutral Prob (up)+15,831 x Risk Neutral Prob (down) + the dividend paid in (17,0) (Table 5.9), 19,791. Cell (0,0) is the final result; as expected, it is the same as the original project value from Table 5.8 reflecting the binomial tree without flexibility.

5.5.2 Step 4 Operator: Create Decision Tree

Step 4a: Understand the type of option being modeled: Modeling the value of operator put option to cancel the OFS contract.

As discussed before, we assumed that the operator project value on T_0 is 100. We also assumed that its value would change according the oil price volatility. The weakest assumption that will have to be considered in order to calculate the option value is that the operator project will be unfeasible if it reduces its value by 50%. When this happens, the operators will choose between continuing the contract and paying the remaining contract value or canceling the contract and paying the contractual penalty; it will choose the lowest value and make its decision. Once the decision is made, it will generate a new binomial tree for the OFS company. The difference between the binomial tree without flexibility (Table 5.10) and the one with the operator's flexibility to cancel the contract (Table 5.12) will be the put option value that OFS gives to the client.

Table 5.11 Operator (Client E) Decision Tree Based on Oil Price and Remaining Cash Flow to be Paid to OFS

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Remaining Cash Flow to be paid to the OFS contract	19,966	20,022	16,693	15,785	14,869	13,879	12,920	11,925	10,927	10,026	9,022	8,050	7,041	6,062	5,048	4,031	3,044	2,021	1,029
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
0	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
1	-	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
2	-	-	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
3	-	-	-	cancel	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
4	-	-	-	-	cancel	cancel	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
5	-	-	-	-	-	cancel	cancel	cancel	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue	continue
6	-	-	-	-	-	-	cancel	cancel	cancel	cancel	continue	continue	continue	continue	continue	continue	continue	continue	continue
7	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	continue	continue	continue	continue	continue	continue	continue
8	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	cancel	continue	continue	continue	continue	continue
9	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	cancel	cancel	continue	continue	continue
10	-	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	cancel	cancel	continue	continue
11	-	-	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	cancel	continue	continue
12	-	-	-	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	cancel	continue	continue
13	-	-	-	-	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	cancel	continue	continue
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	cancel	cancel	cancel	continue	continue
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	cancel	cancel	continue	continue
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	cancel	continue	continue
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	continue	continue
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	continue

Source: Author's Calculation

According the OFS contract with Client E, the penalty for early cancelation of the contract is the mobilization revenue, about $2.5 million. Once the operator decision is modeled, we have to reflect this decision on the OFS project value to calculate the option value.

<u>Step 4b:</u> Can have multiple decisions at one node

Depending on the opportunities, the decision node could have multiple alternatives such as:

- Operators would try to renegotiate the tariffs; or
- Operators could simply cancel the contract and look for one of the several fine print clauses in the contract that gives it the right to postpone payment or apply fines to minor operational problems common in a contract like this.

However, most of the alternatives would generate a similar impact for the OFS and would not justify a more complex modeling to account for them.

5.5.3 Step 5 Operator: Estimate Value of RO

<u>Step 5a</u>: Solution provides decisions as well as a value.

Using the similar backward induction technique described previously, the project value with operators' flexibility was calculated. However, instead of only using the backward induction with risk neutral probabilities, in the case that the operators "cancel" the project, OFS receives only the difference between the mobilization revenue and the mobilization cost to return the rig to the base, about $1.1 million. This means that it will receive this value instead of the remaining cash flow that it would have received had the project continued. The difference from the two projects is $0.53 million or 8% of the project value. This is the value of the option to cancel that OFS gives to the client and should be seen as a cost to be subtracted from the original contract PV. The value of this option is entirely owned by the operators as OFS gives it own its contract and its real value to the operator will depend on its own economics. In fact the value that was calculated is the OFS cost on giving this option to the operator.

Table 5.12 OFS Project Valuation Binomial Tree Backward Induction with Client E Flexibility to Cancel the Contract.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	5,907	7,876	7,562	9,557	11,950	16,904	19,919	23,238	26,853	31,031	35,217	39,602	43,685	47,404	49,785	50,147	47,707	39,973	25,584
1	-	4,322	4,301	5,760	7,359	10,468	12,336	14,383	16,617	19,202	21,792	24,506	27,033	29,334	30,807	31,031	29,522	24,735	15,831
2	-	-	1,970	3,004	4,305	6,407	7,638	8,917	10,289	11,883	13,485	15,164	16,728	18,152	19,064	19,202	18,268	15,306	9,796
3	-	-	-	1,062	1,852	3,572	4,597	5,513	6,391	7,364	8,345	9,384	10,351	11,233	11,797	11,882	11,304	9,472	6,062
4	-	-	-	-	1,062	1,062	2,240	3,181	3,926	4,591	5,184	5,807	6,405	6,951	7,300	7,353	6,995	5,861	3,751
5	-	-	-	-	-	1,062	1,062	1,062	2,036	2,763	3,252	3,630	3,964	4,301	4,517	4,550	4,329	3,627	2,321
6	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,836	2,297	2,520	2,662	2,795	2,816	2,679	2,244	1,436
7	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	1,596	1,768	1,730	1,742	1,658	1,389	889
8	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	1,062	1,289	1,078	1,026	859	550
9	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	1,062	1,062	635	532	340
10	-	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	1,062	1,062	329	211
11	-	-	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	1,062	204	130
12	-	-	-	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	1,062	126	81
13	-	-	-	-	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	1,062	78	50
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,062	1,062	1,062	48	31
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,062	1,062	30	19
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,062	18	12
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	7
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author's Calculation

A similar approach was taken to obtain the amount required to cancel the new contracts. The other four contracts are longer (24 months), generating an option to cancel, or cost to the OFS, valued at $1.2 million or 14% of the project value.

More central than calculating the cost of the option was the understanding of the risk involved in the project caused by a contractual clause[9]. By agreeing to such a clause, OFS is more exposed to the market uncertainty (oil price). By understanding this dynamic, the company could be more prepared to negotiate with clients as such drastic events occur.

5.6 Real Option analysis for Rig O Project – OFS Perspective

5.6.1 Step 3 OFS: Build Event Tree Based on the binomial lattice

Now we are going to apply the methodology to the other uncertainties taking into consideration the original PV reducing the put option cost that was given to the client.

<u>Step 3a</u>: Construction of the underlying asset event tree

The underlying asset now is the combination of all contracts' expected cash flows. The up and down movements at each step are $u = e^{\sigma\sqrt{\Delta t}}$ and $d=1/u$ as before, where σ is the volatility of asset returns calculated using the Monte Carlo simulation.

[9] As described previously in section 2.2 and 5.3.2, the standard drilling contract between a Oil Field Company and an Operator contains clauses that allow the Operator to cancel the contract paying no or a lower penalty.

Table 5.13 OFS Project Valuation Binomial Tree without Flexibility

Up Movement	1.279655
Down Movement	0.781461

	0	**1**	**...**	**18**	**19**	**20**	**...**	**43**	**44**	**45**	**...**	**68**	**69**	**70**	**...**	**93**	**94**	**95**	**...**	**116**	**117**
0	**29.5**	38	46	1,981	2,496	3,194	4,030	633,134	795,048	1,017,387	1,277,463	179,960,736	224,852,605	287,733,739	358,848,868	38,243,846,457	46,613,703,314	59,649,453,984	72,578,193,384	695,149,427,123	460,349,127,603
1	-	23	28	1,210	1,524	1,951	2,461	386,643	485,521	621,299	780,122	109,898,567	137,313,170	175,713,471	219,142,116	23,354,782,978	28,466,093,910	36,426,776,635	44,322,109,633	424,514,412,434	281,126,376,278
...	-	-	17	739	931	1,191	1,503	236,115	296,498	379,415	476,406	67,112,946	83,854,517	107,304,844	133,825,884	14,262,317,693	17,383,697,172	22,245,133,315	27,066,661,633	259,242,803,537	171,678,482,048
3	-	-	-	451	569	728	918	144,191	181,066	231,702	290,932	40,984,588	51,208,344	65,529,009	81,724,899	8,709,723,664	10,615,890,200	13,584,675,942	16,529,090,742	158,314,604,209	104,840,753,787
18	-	-	-	0	0	0	1	88	111	142	178	25,109	31,373	40,146	50,069	5,336,032	6,503,849	8,322,683	10,126,585	96,991,803	64,230,926
19	-	-	-	-	0	0	0	54	68	87	109	15,334	19,159	24,517	30,576	3,258,612	3,971,776	5,082,503	6,184,111	59,231,032	39,224,594
20	-	-	-	-	-	0	0	33	41	53	66	9,364	11,700	14,972	18,672	1,989,972	2,425,487	3,103,787	3,776,518	36,171,255	23,953,707
...	-	-	-	-	-	-	0	20	25	32	41	5,718	7,145	9,143	11,403	1,215,238	1,481,199	1,895,423	2,306,247	22,089,091	14,628,069
43	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	24	29	37	45	429	284
44	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	14	18	22	27	262	173
45	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	9	11	14	17	160	106
...	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	5	7	8	10	98	65
68	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
69	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
70	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

PV	29.5
Capex + Cancel Options	(6.6)
Liquidation value	4.8
Total Project Value	27.7

Source: Author's Calculation

As it pays "divided" throughout the 117 months of the contract, the up and down formula should be applied to the present value of the project after the dividend payment. To ascertain the present value of the project after the dividend payment, we multiplied the current project value by the % of the month cash flow to the current value of the project. See section 3.6.4 for details.

Step 3b: Models dividends payment

According to Brandão; Dyer; Hahn (2005), to simplify the binomial tree and allow a easier understanding of the variables that are being modeled, we separate the dividend payment of the project; in this case the expected monthly cash flow from the project value. We also discount the dividend payment using the risk-free interest rate (Table 5.14).

Step 3c: Ensure no arbitrage with underlying and risk-free bond; event tree should reduce to PV

At this point, we are still modeling the binomial tree without any flexibility. Using the same backward induction technique that will be used to determine a correct price for the option on the asset at time zero, we return to the PV of the OFS PV of cash flow by starting from the last branch (117,0) and (117,1) of Table 5.13 and returning to (0,0) by using the appropriated risk-neutral probability as discussed on section 3.5.2.

In Table 5.15, the last column, 117, is the same as in Table 5.14, reflecting that in this kind of project in Month 117 the project value is the same as the expected cash flow in the 117th month, which will be our starting point for the backward induction.

Table 5.14 OFS Discounted Cash Flow (Dividends Payments) Binomial Tree for the Project.

	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	-	2	0	29	-	42	59	10,492	-	16,839	20,741	3,510,818	-	6,006,657	7,813,860	1,400,444,366	-	2,247,461,932	2,769,044,168	242,376,759,102	331,736,293,266
1	-	1	0	18	-	26	36	6,408	-	10,283	12,666	2,143,989	-	3,668,150	4,771,774	855,224,494	-	1,372,481,864	1,691,002,124	148,014,834,600	202,584,986,946
...	-	-	0	11	-	16	22	3,913	-	6,280	7,735	1,309,293	-	2,240,069	2,914,031	522,269,183	-	838,148,331	1,032,662,540	90,389,818,491	123,714,763,108
18	-	-	-	0	-	0	0	1	-	2	3	490	-	838	1,090	195,399	-	313,581	386,355	33,817,993	46,286,021
19	-	-	-	-	-	0	0	1	-	1	2	299	-	512	666	119,327	-	191,498	235,940	20,652,000	28,265,985
20	-	-	-	-	-	0	0	1	-	1	1	183	-	313	407	72,870	-	116,944	144,084	12,611,780	17,261,494
...	-	-	-	-	-	-	0	0	-	1	1	112	-	191	248	44,501	-	71,415	87,989	7,701,772	10,541,263
42	-	-	-	-	-	-	-	0	-	0	0	0	-	0	0	1	-	2	3	245	335
43	-	-	-	-	-	-	-	0	-	0	0	0	-	0	0	1	-	1	2	149	205
44	-	-	-	-	-	-	-	-	-	0	0	0	-	0	0	1	-	1	1	91	125
45	-	-	-	-	-	-	-	-	-	0	0	0	-	0	0	0	-	1	1	56	76
...	-	-	-	-	-	-	-	-	-	-	0	0	-	0	0	0	-	0	0	34	47
68	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	0	-	0	0	0	0
69	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	-	0	0	0	0
70	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	-	0	0	0	0
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	0	0	0
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	0	0
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Source: Author's Calculations

Table 5.15 OFS Project Valuation Binomial Tree Backward Induction without Flexibility.

Risk Neutral Prob (up) 44.4%
Risk Neutral Prob (Down) 55.6%

0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
29.5	38	45	1,884	2,367	3,020	3,800	561,306	702,880	896,928	1,123,062	148,756,783	185,344,947	236,514,311	294,145,376	29,475,135,550	35,825,450,628	45,716,011,772	55,469,190,237	**502,342,616,470**	331,736,293,266
-	23	28	1,150	1,445	1,845	2,321	342,779	429,235	547,737	685,832	90,842,912	113,186,602	144,434,750	179,628,935	17,999,899,534	21,877,915,064	27,917,890,915	33,873,969,801	306,770,993,906	202,584,986,946
-	-	17	702	883	1,126	1,417	209,328	262,126	334,492	418,825	55,476,023	69,120,885	88,203,530	109,695,943	10,992,193,155	13,360,422,804	17,048,920,125	20,686,183,180	187,339,157,811	123,714,763,108
-	-	-	0	0	0	1	78	98	125	157	20,756	25,861	33,000	41,041	4,112,564	4,998,602	6,378,597	7,739,425	70,090,133	46,286,021
-	-	-	-	0	0	0	48	60	76	96	12,675	15,793	20,152	25,063	2,511,464	3,052,550	3,895,287	4,726,318	42,802,699	28,265,985
-	-	-	-	-	0	0	29	37	47	58	7,740	9,644	12,307	15,305	1,533,703	1,864,134	2,378,777	2,886,272	26,138,787	17,261,494
-	-	-	-	-	-	0	18	22	29	36	4,727	5,890	7,515	9,347	936,603	1,138,391	1,452,673	1,762,591	15,962,455	10,541,263
-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	18	22	28	34	310	205
-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	11	13	17	21	189	125
-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	7	8	11	13	116	76
-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	4	5	6	8	71	47
-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0

Source: Author's Calculations

5.6.2 Step 4 OFS: Create Decision Tree

<u>Step 4a</u>: Understand the type of option being modeled: Modeling the several options that OFS has along the contracts.

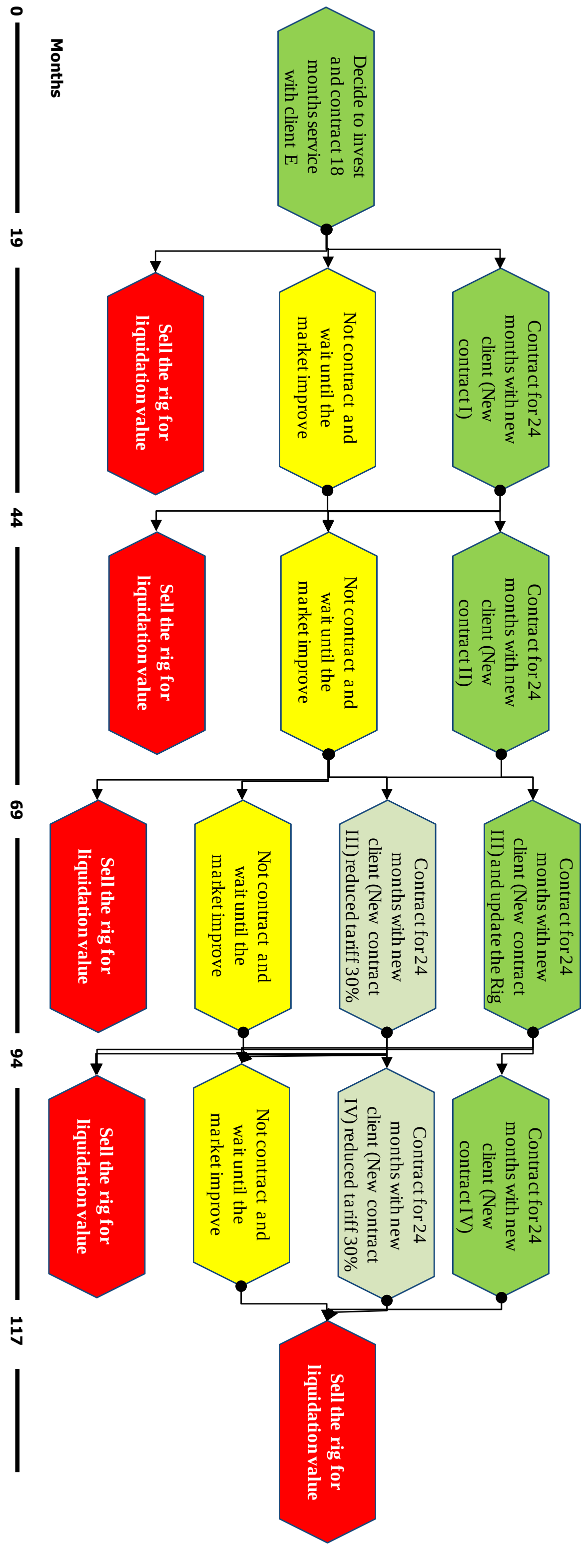


Figure 5.9 Decision Tree for OFS after Each Contract
Source: Author

The decision tree was modeled as several European options that OFS has at the end of each contract. At the end of the contract with Client E, after Contracts I and II the OFS has the option to enter into a new contract with the same or a new client, and either wait until the market improves or sell the rig for the current liquidation value. If the OFS decides to enter into a new contract, it has a small maintenance CAPEX to incur. After almost five years the OFS has an additional option of investing in addition of the maintenance CAPEX $1 for updating the rig or accepting a reduction of 30% on the day margin and consequently the cash flow. At the end of Contract III if it did not choose to update it will have to continue with lower margins. After almost 10 years, if the O rig was not sold yet it will be sold for a liquidation value similar to the original business case. Using this approach, we are able to obtain the total project value during the period of the projections without the need to calculate any terminal value for cash flow projections.

<u>Step 4b:</u> Can have multiple decisions at one node

The fourth step adds the options to the event tree, transforming it into a decision tree like the one shown in Figure 5.9 This is the case of a compound option; there are as many decision trees as there are compound options. To calculate the value of each option, different binomial lattice trees were calculated:

Flexibility to do not contract (A) at the end of each contract and wait for better margins; in this case it is not necessary to invest in maintaiance CAPEX;

Flexibility to do not contract (A) + To be able to continue contracting with lower margins and without incurring the update CAPEX (B);

A+B+ To sell the rig for liquidation value at the end of each contract (C).

In addition to this binomial lattice, one lattice more was performed only with the option to sell for liquidation value.

5.6.3 Step 5 OFS: Estimate Value of Real Option

<u>Step 5a</u>: Solution provides decisions as well as a value

Using the similar backward induction technique described before, first it was calculate the option to do not contract Table 5.16. This option should be exercised when the expected cash flow from the current client is lower than the required investment (maintenance CAPEX) added to the option to cancel that OFS awards its clients. As OFS has the option to offer service latter if the market improves it is also necessary to model this contract separately.

Note that at this point it was incorporated the following variables in the binomial lattice:

- At the last nodes, column 117 considers the dividend paid on 117 month (cash flow generated by the operation) and the proceeds from the sale of the rig for liquidation valued estimated on 4.8 million at month 117;
- In the white cells, consideration of the regular backward induction mechanism is illustrated: e.g., (116,0) = (117,0) x Risk Neutral Prob (up) + (117,1) x Risk Neutral Prob (down) + the dividend paid in Table 5.14 (116,0);

In the green cells, the months in which the European option can be exercised, the option was modeled as:

- Month 94: the maximum between investing the required CAPEX, less the put option that OFS offered the client (option to cancel the contract) plus the backward induction representing the value of future cash flows (enter in a new contract), and doing nothing and selling for liquidation value the rig in Month 117. Note that by entering into a new contract the backward induction in the last nodes guarantee that it will also receive the liquidation value of the rig.
- Month 69: the maximum between investing the required CAPEX, less the put option that OFS offered the client (option to cancel the contract) plus the backward induction representing the value of future cash flows (enter in a new contract), and doing nothing during the following 24 months but having the option to enter into a new contract in Month 94. Note that the impact of being able to contract again is calculated by using the same formula of the previous choice but subtracting the value of the binomial tree from Table 5.20, which is the same binomial tree but without the new Contract IV cash flow.
- Month 44: the maximum between investing the required CAPEX, less the put option that OFS offered the client (option to cancel the contract) plus the backward induction representing the value of future cash flows (enter in a new contract), and doing nothing during the next 24 months, but having the option to enter in a new contract in Month 69. Note that the impact of being able to contract again is calculated by using the same formula of the previous choice but subtracting the value of the binomial tree from Table 5.21 that is the same binomial tree but without new Contracts III and IV.
- Month 19: the maximum between investing the required CAPEX, less the put option that OFS offered the client (option to cancel the contract) plus the backward induction representing the value of future cash flows (enter in a new contract), and doing

nothing during the next 24 months, but having the option to enter in a new contract in Month 44. Note that the impact of being able to contract again is calculated by using the same formula of the previous choice but subtracting the value of the binomial tree from Table 5.22 that is the same binomial tree but without new Contracts II, III and IV.

The result was exhibited in Table 5.16, \$30.3 million. Comparing this value with the value of the project without flexibility in Table 5.13 27.7 million. The value of the option of not entering into new contracts if the situation is not favorable is calculated to be \$2.6 million.

A this point a new variable was added to the option calculation: the option not to invest in updating the rig in Month 69. Table 5.17 shows the new binomial tree. The only differences from the tree in Table 5.16 is that in the Month 69 column in blue, the maximum formula should also contain the option to reduce the investment by \$1 million with the value that comes from the backward induction representing the future cash flows from the subsequent contracts being reduced by 30%. Comparing this value with the value of the project with flexibility only to not enter into a new contract in Table 5.16, \$30.3 million, the additional value of the option of reducing tariffs (reducing the day margin) but not to invest on updating the rig is calculated, resulting in an additional value of \$0.4 million.

Finally the most valuable option was incorporated, which, as we will see, is the option to sell the rig for its liquidation value at the end of each contract. The same formulas from the previously binomial lattice were used, but incorporating the value of the liquidation value as an additional option in the maximum formula, in the green or blue columns, at end of each contract. This value is compared with the previous project in Table 5.17: \$30.7 million. The additional value of the option of selling the rig for liquidation value is calculated to be \$1.2 million. However, unlike the previous option that was built on the option of not entering into a new contract, this option and decision is independent from the others and has the potential to offset the flexibility added by the other option. In order to better understand its dynamics we implemented an additional binomial lattice only with the flexibility to sell the rig for liquidation value. As we can see on Table 5.19, it has the same value of the project with all of the other options. The option to sell Rig O for liquidation value is dominant over the other options. From a numerical perspective of this framework, all other options could be eliminated, but in the last one, the project would have the same numerical value. However, if you take into consideration the business perspective it is very different: the option of selling the rig could not be accessible for instance if it were pledged in a credit agreement or any other restriction appears. The liquidation value could also be misestimated or the market for this kind of rig could become less liquid. Another import aspect of having additional options even though it does not represent any additional value for the project value is the fact that by having the option mapped, managers could be more aware of the project value drivers and act on the levers in order to maximize the project value throughout its life.

Table 5.16 OFS Project Valuation Binomial Tree Backward Induction with Flexibility to Not Enter in a New Contract.

Required Investment					(1.6)				(1.5)				(2.2)				(1.3)				
	0	**1**	**...**	**18**	**19**	**20**	**...**	**43**	**44**	**45**	**...**	**68**	**69**	**70**	**...**	**93**	**94**	**95**	**...**	**116**	**117**
0	**30.3**	38	46	1,882	2,365	3,020	3,800	561,306	702,880	896,930	1,123,063	148,756,784	185,344,949	236,514,315	294,145,379	29,475,135,554	35,825,450,631	45,716,011,777	55,469,190,242	502,342,616,475	331,736,293,271
1	-	24	28	1,149	1,444	1,844	2,321	342,778	429,235	547,738	685,833	90,842,914	113,186,603	144,434,754	179,628,939	17,999,899,538	21,877,915,068	27,917,890,920	33,873,969,806	306,770,993,911	202,584,986,950
...	-	-	18	701	881	1,126	1,417	209,328	262,126	334,494	418,826	55,476,024	69,120,887	88,203,533	109,695,946	10,992,193,159	13,360,422,808	17,048,920,130	20,686,183,185	187,339,157,815	123,714,763,113
18	-	-	-	5	5	5	5	78	98	127	158	20,757	25,862	33,004	41,045	4,112,568	4,998,605	6,378,602	7,739,430	70,090,138	46,286,026
19	-	-	-	-	5	5	5	48	60	78	97	12,676	15,794	20,156	25,067	2,511,467	3,052,554	3,895,292	4,726,323	42,802,704	28,265,990
20	-	-	-	-	-	5	5	30	37	48	60	7,742	9,646	12,310	15,309	1,533,706	1,864,137	2,378,782	2,886,277	26,138,792	17,261,499
...	-	-	-	-	-	-	5	19	23	30	37	4,728	5,891	7,519	9,350	936,606	1,138,394	1,452,678	1,762,596	15,962,460	10,541,268
43	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	22	26	33	39	315	209
44	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	15	17	22	26	194	130
45	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	10	12	15	18	120	81
...	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	8	9	11	13	75	51
68	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	5	5
69	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	5
70	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author’s Calculation

Table 5.17 OFS Project Valuation Binomial Tree Backward Induction with Flexibility to Not Enter in a New Contract and to Reduce Tariffs instead of Investing on Updating (CAPEX)

	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	**30.7**	39	46	1,882	2,365	3,020	3,800	561,306	702,880	896,930	1,123,063	148,756,784	185,344,949	236,514,315	294,145,379	29,475,135,554	35,825,450,631	45,716,011,777	55,469,190,242	502,342,616,475	331,736,293,271
1	-	24	29	1,149	1,444	1,844	2,321	342,778	429,235	547,738	685,833	90,842,914	113,186,603	144,434,754	179,628,939	17,999,899,538	21,877,915,068	27,917,890,920	33,873,969,806	306,770,993,911	202,584,986,950
...	-	-	19	701	881	1,126	1,417	209,328	262,126	334,494	418,826	55,476,024	69,120,887	88,203,533	109,695,946	10,992,193,159	13,360,422,808	17,048,920,130	20,686,183,185	187,339,157,815	123,714,763,113
18	-	-	-	5	5	6	6	78	98	127	158	20,757	25,862	33,004	41,045	4,112,568	4,998,605	6,378,602	7,739,430	70,090,138	46,286,026
19	-	-	-	-	5	5	6	48	60	78	97	12,676	15,794	20,156	25,067	2,511,467	3,052,554	3,895,292	4,726,323	42,802,704	28,265,990
20	-	-	-	-	-	5	5	30	37	48	60	7,742	9,646	12,310	15,309	1,533,706	1,864,137	2,378,782	2,886,277	26,138,792	17,261,499
...	-	-	-	-	-	-	5	19	23	31	38	4,728	5,891	7,519	9,350	936,606	1,138,394	1,452,678	1,762,596	15,962,460	10,541,268
43	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	22	26	33	39	315	209
44	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	15	17	22	26	194	130
45	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	10	12	15	18	120	81
...	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	8	9	11	13	75	51
68	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	5	5
69	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	5
70	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5	5	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	4	-	5	5	5	5	5	5	5
93	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	5	5	5	5	5	5
94	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	5	5	5	5
95	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	-	5	5	5
116	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	-	-	5	5
117	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	5	-	-	-	5

Source: Author's Calculation

Table 5.18 OFS Project Valuation Binomial Tree Backward Induction with Flexibility to Not enter into a New Contract, to Reduce Tariffs instead of Investing on Updating (CAPEX) and to Sell the Rig for Liquidation Value.

Liquidation Value				8.4	8.4	8.3	8.3	7.3	7.3	7.2	7.2	6.6	6.6	6.5	6.5	5.7	5.7	5.6	5.6	4.9	4.8
	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	31.9	40	47	1,882	2,365	3,020	3,800	561,306	702,880	896,930	1,123,063	148,756,784	185,344,949	236,514,315	294,145,379	29,475,135,554	35,825,450,631	45,716,011,777	55,469,190,242	502,342,616,475	331,736,293,271
1	-	26	30	1,149	1,444	1,844	2,321	342,778	429,235	547,738	685,833	90,842,914	113,186,603	144,434,754	179,628,939	17,999,899,538	21,877,915,068	27,917,890,920	33,873,969,806	306,770,993,911	202,584,986,950
...	-	-	20	701	881	1,126	1,417	209,328	262,126	334,494	418,826	55,476,024	69,120,887	88,203,533	109,695,946	10,992,193,159	13,360,422,808	17,048,920,130	20,686,183,185	187,339,157,815	123,714,763,113
18	-	-	-	8	8	7	7	79	98	127	158	20,757	25,862	33,004	41,045	4,112,568	4,998,605	6,378,602	7,739,430	70,090,138	46,286,026
19	-	-	-	-	8	7	7	49	60	78	97	12,676	15,794	20,156	25,067	2,511,467	3,052,554	3,895,292	4,726,323	42,802,704	28,265,990
20	-	-	-	-	-	7	7	30	37	49	60	7,742	9,646	12,310	15,309	1,533,706	1,864,137	2,378,782	2,886,277	26,138,792	17,261,499
...	-	-	-	-	-	-	7	19	24	31	38	4,728	5,891	7,519	9,350	936,606	1,138,394	1,452,678	1,762,596	15,962,460	10,541,268
43	-	-	-	-	-	-	-	7	7	7	7	7	7	6	6	22	26	33	39	315	209
44	-	-	-	-	-	-	-	-	7	7	7	7	7	6	6	15	17	22	26	194	130
45	-	-	-	-	-	-	-	-	-	7	7	7	7	6	6	10	12	15	18	120	81
...	-	-	-	-	-	-	-	-	-	-	7	7	7	6	6	8	9	11	13	75	51
68	-	-	-	-	-	-	-	-	-	-	-	7	7	6	6	6	6	5	5	5	5
69	-	-	-	-	-	-	-	-	-	-	-	-	7	6	6	6	6	5	5	5	5
70	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	6	6	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	6	5	5	5	5
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	5	5	5	5
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	5	5	5	5
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author’s Calculation

Table 5.19 OFS Project Valuation Binomial Tree Backward Induction Only with the Flexibility to Sell the Rig for Liquidation Value.

Liquidation Value				8.4	8.4	8.3	8.3	7.3	7.3	7.2	7.2	6.6	6.6	6.5	6.5	5.7	5.7	5.6	5.6	4.9	4.8
	0	**1**	**...**	**18**	**19**	**20**	**...**	**43**	**44**	**45**	**...**	**68**	**69**	**70**	**...**	**93**	**94**	**95**	**...**	**116**	**117**
0	**31.9**	40	47	1,882	2,365	3,020	3,800	561,306	702,880	896,930	1,123,063	148,756,784	185,344,949	236,514,315	294,145,379	29,475,135,554	35,825,450,631	45,716,011,777	55,469,190,242	502,342,616,475	331,736,293,271
1	-	26	30	1,149	1,444	1,844	2,321	342,778	429,235	547,738	685,833	90,842,914	113,186,603	144,434,754	179,628,939	17,999,899,538	21,877,915,068	27,917,890,920	33,873,969,806	306,770,993,911	202,584,986,950
...	-	-	20	701	881	1,126	1,417	209,328	262,126	334,494	418,826	55,476,024	69,120,887	88,203,533	109,695,946	10,992,193,159	13,360,422,808	17,048,920,130	20,686,183,185	187,339,157,815	123,714,763,113
18	-	-	-	8	8	7	7	79	98	127	158	20,757	25,862	33,004	41,045	4,112,568	4,998,605	6,378,602	7,739,430	70,090,138	46,286,026
19	-	-	-	-	8	7	7	49	60	78	97	12,676	15,794	20,156	25,067	2,511,467	3,052,554	3,895,292	4,726,323	42,802,704	28,265,990
20	-	-	-	-	-	7	7	30	37	49	60	7,742	9,646	12,310	15,309	1,533,706	1,864,137	2,378,782	2,886,277	26,138,792	17,261,499
...	-	-	-	-	-	-	7	19	24	31	38	4,728	5,891	7,519	9,350	936,606	1,138,394	1,452,678	1,762,596	15,962,460	10,541,268
43	-	-	-	-	-	-	-	7	7	7	7	7	7	6	6	22	26	33	39	315	209
44	-	-	-	-	-	-	-	-	7	7	7	7	7	6	6	15	17	22	26	194	130
45	-	-	-	-	-	-	-	-	-	7	7	7	7	6	6	10	12	15	18	120	81
...	-	-	-	-	-	-	-	-	-	-	7	7	7	6	6	8	9	11	13	75	51
68	-	-	-	-	-	-	-	-	-	-	-	7	7	6	6	6	6	5	5	5	5
69	-	-	-	-	-	-	-	-	-	-	-	-	7	6	6	6	6	5	5	5	5
70	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	6	6	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	6	5	5	5	5
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6	5	5	5	5
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	5	5	5	5
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	5
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5

Source: Author’s Calculation

Table 5.20 Backward Induction without Flexibility and Without New Contract IV.

	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	**3.0**	4	6	414	529	676	863	184,761	235,769	300,860	383,922	81,946,775	104,570,346	133,439,753	162,614,365	1,400,444,366	-	-	-	-	-
1	-	2	3	252	322	412	526	112,829	143,979	183,729	234,453	50,043,322	63,859,102	81,489,096	99,305,471	855,224,494	-	-	-	-	-
...	-	-	1	153	196	251	321	68,902	87,924	112,199	143,175	30,560,495	38,997,527	49,763,827	60,643,945	522,269,183	-	-	-	-	-
18	-	-	-	-2	-2	-2	-2	24	31	40	51	11,432	14,588	18,618	22,689	195,399	-	-	-	-	-
19	-	-	-	-	-2	-2	-2	14	18	23	30	6,980	8,908	11,370	13,856	119,327	-	-	-	-	-
20	-	-	-	-	-	-2	-2	7	10	13	18	4,262	5,439	6,943	8,461	72,870	-	-	-	-	-
...	-	-	-	-	-	-	-2	4	5	7	10	2,602	3,321	4,240	5,167	44,501	-	-	-	-	-
43	-	-	-	-	-	-	-	-2	-2	-2	-2	-2	-2	0	0	1	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-2	-2	-2	-2	-2	0	0	1	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-2	-2	-2	-2	0	0	0	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-2	-2	-2	0	0	0	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-2	-2	0	0	0	-	-	-	-	-
69	-	-	-	-	-	-	-	-	-	-	-	-	-2	0	0	0	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Author's Calculation

Table 5.21 Backward Induction without Flexibility and Without New Contract IV and III

	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	**4.8**	7	9	502	641	818	1,045	223,330	284,986	363,666	442,579	3,510,818	-	-	-	-	-	-	-	-	-
1	-	3	5	306	391	499	637	136,383	174,035	222,084	270,274	2,143,989	-	-	-	-	-	-	-	-	-
...	-	-	2	186	238	304	389	83,286	106,279	135,622	165,051	1,309,293	-	-	-	-	-	-	-	-	-
18	-	-	-	1	1	1	1	30	38	51	62	490	-	-	-	-	-	-	-	-	-
19	-	-	-	-	1	1	1	18	23	31	38	299	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	1	1	10	13	19	23	183	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	1	6	8	12	14	112	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	1	1	0	0	0	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	1	0	0	0	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	0	0	0	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-
69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Author's Calculation

Table 5.22 Backward Induction without Flexibility and Without New Contract IV, III and II

	0	1	...	18	19	20	...	43	44	45	...	68	69	70	...	93	94	95	...	116	117
0	**6.0**	8	11	611	781	998	1,220	10,492	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	4	6	373	476	610	745	6,408	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	3	227	290	372	455	3,913	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	- 2	- 2	0	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	- 2	0	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	0	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
43	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
...	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Source: Author's Calculation

5.7 Real Option analysis Results

As described in Figure 5.10, the project valuation with all real options is 8.7 million. This value is formed by:

- All contracts expected cash flow totaling 29.5 million;
- All CAPEX investments (22.9) million;
- The salvage value of the end of the project (rig liquidation value) 2.7 million;

The first components of the tree combined is the project traditional NPV without any flexibility and static, 9.3 million.

Including the real options:

- Cost of the option to cancel the contract awarded to Client E, (0.5) million;
- Cost of the option to cancel the new assumed contracts to be awarded to the new contracts expected to be signed (4.2) million;
- The option to be able to not invest on maintenance and updating CAPEX and not enter in a new contract waiting for better tariffs (expected cash flow) to improve 2.6 million;
- Option to be able to work with lower tariffs in Month 69, before entering in contract 3 and not investing on updating the rig 0.5 million;
- Option to sell the rig for liquidation value that has a marginal impact of 1.2 million considering the previous options; or 4.2 million considering it by itself.

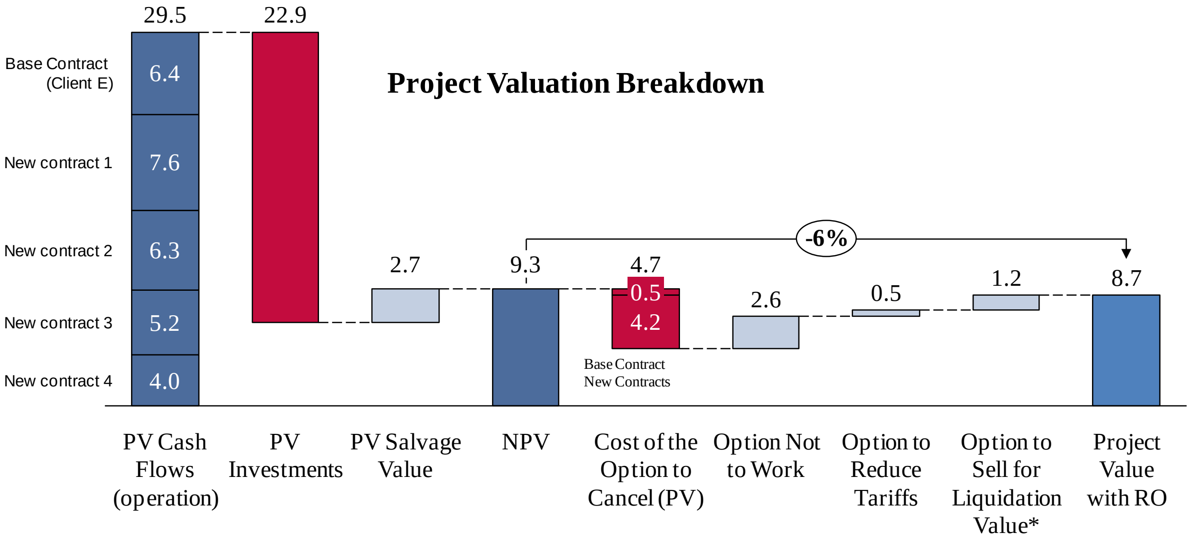


Figure 5.10 Project Valuation Breakdown with all Real Options
Source: Author’s Calculation

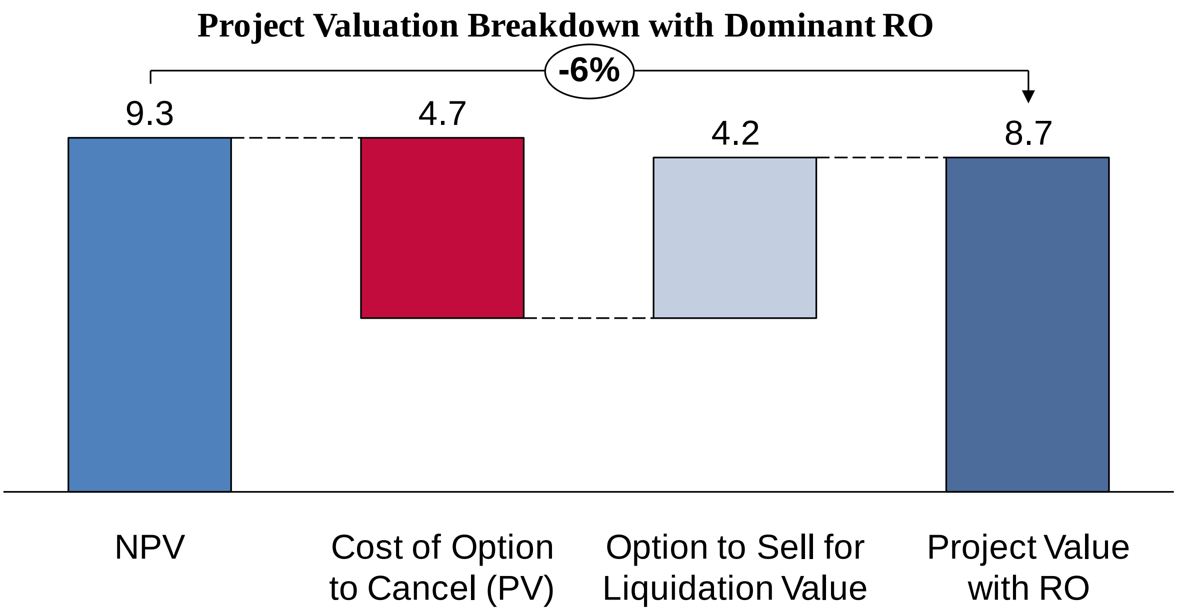


Figure 5.11 Project Valuation Breakdown with Dominant Real Options
Source: Author's Calculation

Unlike several Real Options examples and case studies in which the Real Option analysis increases the project value compared to the NPV approach, this one reduces. By incorporating the cost of the put option that OFS puts forth for the client it reduces the value by giving flexibility to its clients it is a similar impacted described by Copeland and Weston, (1982) on their note on the evaluation of cancellable operating leases. By incorporating some options brought by the OFS management, flexibility to act, it partially offset the project value reduction.

5.8 Retrospective Analysis of Rig O Investment Project

It would be easy to criticize the investment decision having the advantage of hindsight; however, this exercise tried to examine the decisions through the lens of that period. As previously discussed, the original business plan had serious flaws and was revised (Figure 5.12). The Real Options analysis valuation had results similar to those of the original business case; with that in mind, the actual results are presented below.

As it was a 10-year project valuation, and it has only been 4 years and 4 months since the project started, we have to consider the following assumptions:

- 53 months of operation and 14 more months with the latest company projections for the rig O were considered actual results;
- For the remaining months the same projection of the revised business case was used;
- The same discount rate was considered;

- The actual CAPEX, working capital assumption and Ebitda results were considered.

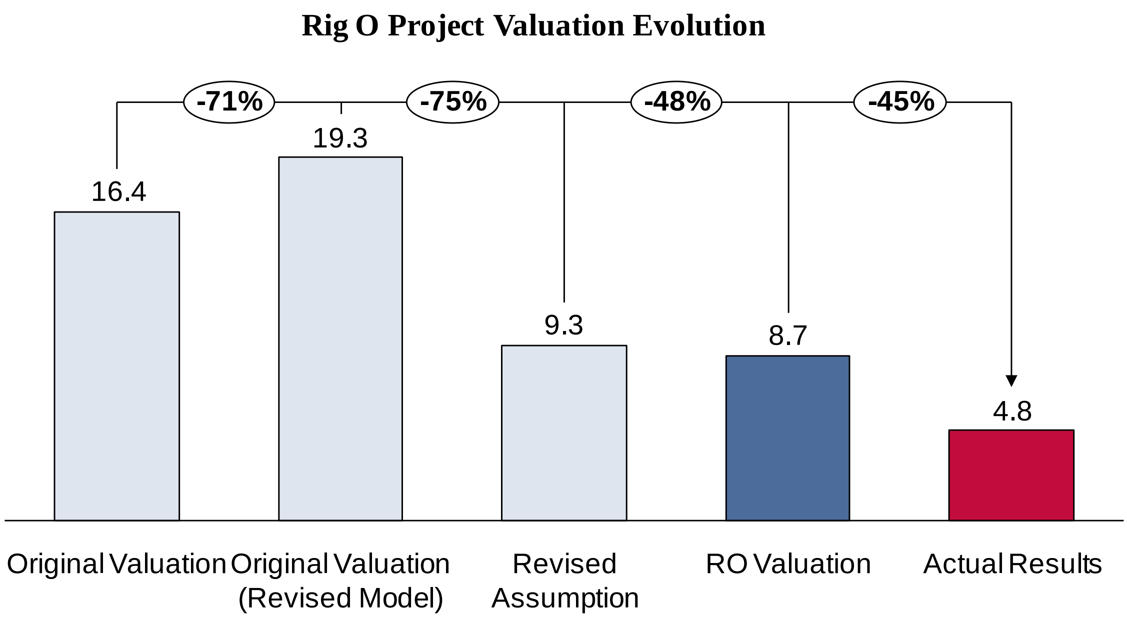


Figure 5.12 Rig O Project Valuations and Actual Results
Source: OFS internal information and author's calculations

Table 5.23 Project Valuation Comparison with Actual Results

	Project Valuation				Var. Actual vs Revised	
	Original	Original (Revised Model)	Revised Assumption	Actual Results	Abs.	%
NPV of FCF	16.4	19.3	9.3	4.8	(4.5)	-48.4%
Payback (Months / Years)	54	50	58	74	16	27.6%
IRR of Project (Yearly)	21.5%	26.5%	19.8%	14.4%	-5.4%	-27.2%
Total Gross Capex	26.4	26.4	28.2	27.6	(0.6)	-2.2%
Maximum NWC Investment	na	na	1.0	2.1	1.1	106.6%
First 12 months NWC Investment	na	na	1.0	0.5	(0.5)	-51.4%
EBITDA 2008 (7M)	4.0	4.1	4.0	(0.8)	(4.8)	-120.5%
EBITDA next 12 months	6.0	6.1	6.1	3.5	(2.6)	-43.1%

Source: OFS internal information and author's calculations

Figure 5.13 shows the difference between the projected results and actual results considering the assumptions discussed.

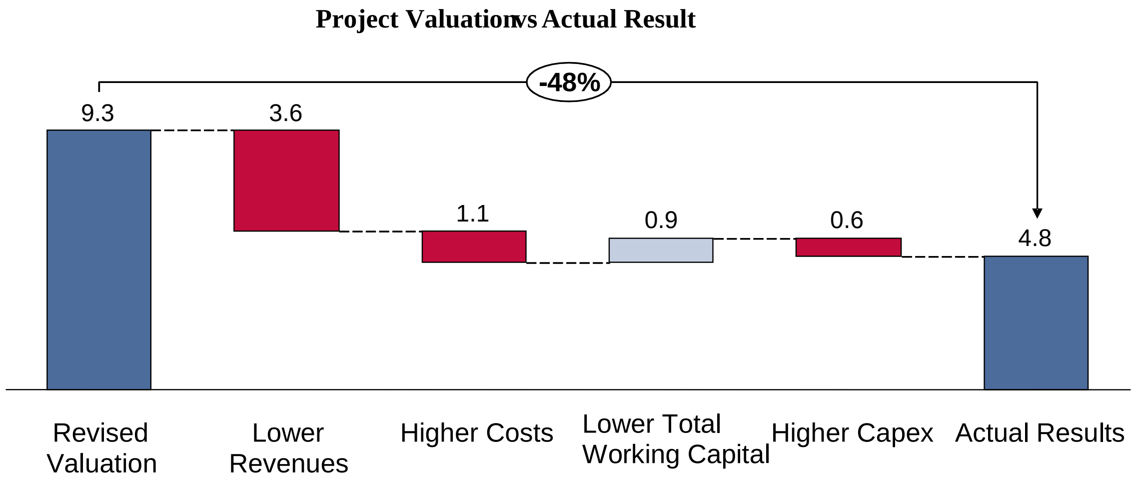


Figure 5.13 Project Valuation vs. Actual Results Variation Per Lever

Source: OFS internal information and author's calculations

So what went wrong? Why is the project generating lower margins than expected? The company and the market were very bullish on this project, thus up to the present moment, the project had not paid back and is worth almost half the value was expected.

Tables 5.24 and 5.25 examine the monthly cash generation and compare it with the projections and the operation assumptions to identify the main problems:

Table 5.24 Monthly Rig O Cash Flow Generation Compared to Projections

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2008						0%	-96%	-4%	-334%	-152%	-43%	216%	2%
2009	-400%	-233%	-21%	8%	-24%	-96%	78%	-224%	-95%	14%	4%	185%	-69%
2010	82%	-73%	-18%	-212%	-21%	6%	223%	5%	-54%	-94%	80%	31%	-23%
2011	-54%	-46%	-25%	-57%	19%	-31%	28%	53%	-83%	21%	-21%	65%	-11%
2012	25%	-83%	-49%	-95%	22%	78%	-18%	49%	-69%	17%	-11%	40%	8%
2013	-21%	-41%	-46%	1%	50%	45%	40%	-137%	-112%	-75%	44%	-11%	-22%

Source: OFS internal information and author's calculations

Table 5.25 Rig O Operational Performance Comparison

	Operational Levers					Actual vs Revised	
	OFS Comparable Rig		Colombian OFS	Proposed	Actual		
	Rig B1	Rig B2	Drilling Average	Business Plan	Results	Δ Abs.	Δ %
Day Rate	33,925	44,038	28,786	35,296	34,212	(1,083.8)	-3.1%
Day Cost	17,617	24,319	16,909	17,524	20,965	3,441.0	19.6%
Utilization / Efficiency	100%	100%	93%	94%	96%	2.4%	2.5%
Direct Margin %	49%	46%	41%	50%	39%	-11.6%	-23.1%
DSO	na	na	58.5	58.5	77.4	18.9	32.2%
DPO (Adjusted)	na	na	57.2	57.2	87.0	29.8	52.1%

Source: OFS internal information and author's calculations

Evaluating first the operational performance, it is clear that the problem was not performance: the actual utilization was higher than expected and the rig was mainly contracted by Client E. In fact, Client E sold its Colombian operation and the new owner continued contracting Rig O.

In terms of cash generation, the first year was close to the projection mainly because of lower working capital requirements. 2009 was a very turbulent year because of the world financial crisis, generating 70% less cash than planned, improving the results for 2010, 2011 and 2012. On aggregate, it is clear that there was a problem of lower tariffs than expected 3.1 million that was partially offset by higher efficiency. The higher costs also affected the value of the project as described in Figure 5.13 but in a bullish market, OFS companies generally are able to pass it through tariffs.

The biggest impact was that the market abruptly changed in the years after the investment was approved in mid 2008.

The global financial crisis led to sharp decreases in oil prices (Figure 5.14), reducing the oil price by 47% from the period the project was approved to the beginning of operations. The financial crisis also decreased the drilling demand and that, combined with the high level of competition in Colombia, generated an oversupply of rigs, resulting in downward pricing pressure on OFS companies' rates.

Even though the client E shares were strongly impacted, at a 44% reduction from the peak (Figure 5.15), the client did not cancel the contract, but pressured OFS to reduce the tariffs.

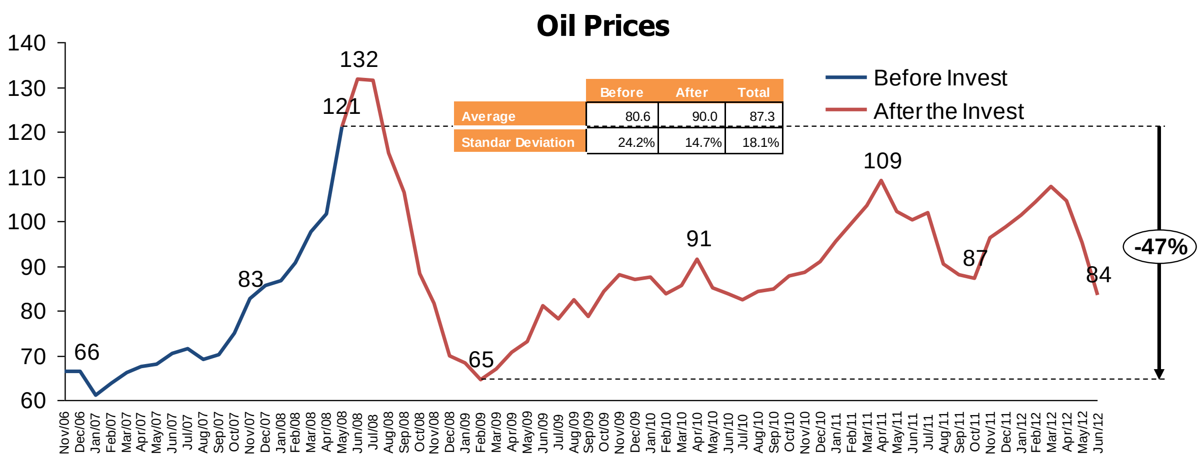


Figure 5.14 Price Evolution: Prior to and after the Investment was Approved.
Source: Bloomberg

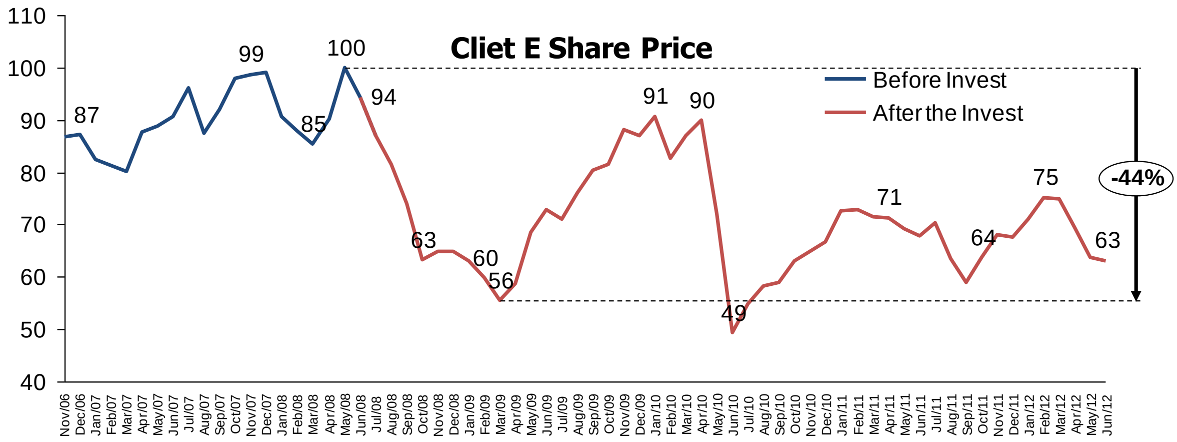


Figure 5.15 Client E Share Price Evolution
Source: Bloomberg

As a whole, the OFS Colombian results degraded from the peak right after the investment was approved (Figure 5.16). This supports the argument that the project's unsuccessful results were due much more to external problems that a specific operational problem of the project execution.

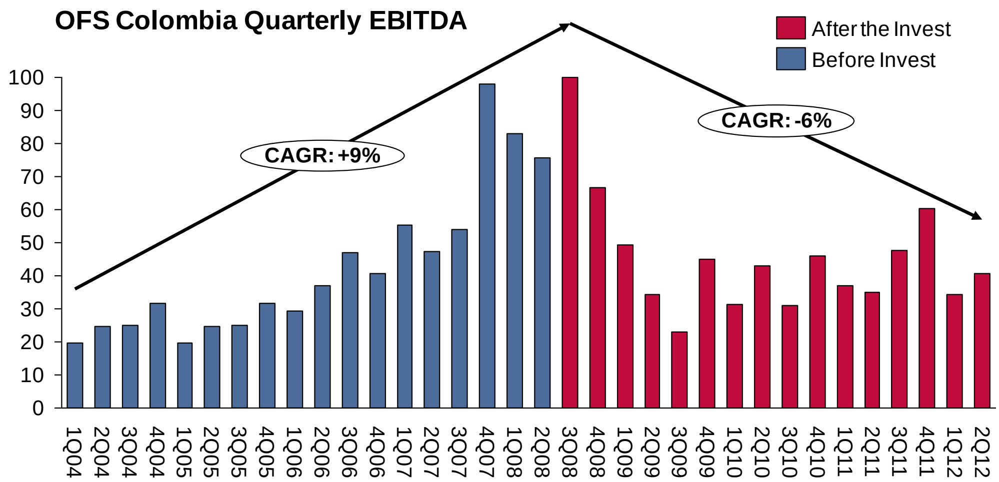


Figure 5.16 OFS Colombian EBITDA Evolution
Source: Bloomberg

In conclusion, the revised assumptions mostly aligned with historical results and actual results in terms of efficiency and utilization, as the rig was fully contracted for the period. However, the unanticipated economic crisis severely affected its tariffs and the ability to pass cost increases thought the tariffs. The Real Option approach was not able to capture such changes in the assumptions in full, thus discounting the cost of option to cancel the contract partially reflected the impact of tariffs reduction. The options not to enter into a new contract or to sell the rig for liquidation value are still open and should be exercised if the expected future cash flow further deteriorates.

6 CONCLUSION

6.1 Challenges of the Real Option Methodology

According to Block (2007), in the survey with 279 Fortune 1000 companies, only 14.3% used Real Options in the capital budget process in contrast with the majority using NPV analysis. Thus, despite being recommended by academics and experts, the practical application of Real Options in organizations is still meager. According to Lander and Pinches (1998), the main barriers for wider adoption are (1) the types of models are not well known or understood by corporate managers; (2) the required modeling assumptions are often violated in a practical Real Options application; and (3) additional assumptions required limits the scope of applicability. Several authors have also developed simplified approaches and methodologies to try to open the Real Options black box (Copeland; Tufano, 2004). Recent literature, informed by several case studies in different areas, has helped bring together academics and practitioners to overcome these challenges.

However, most companies are still far from the correct application of the traditional NPV methodology. As shown in the case study, important projects are still being approved without comprehensive discussions of their main assumptions. In the case analyzed, the company over-simplified some assumptions or economic dynamics that could be better modeled bringing more precise results. Before going further in the use of Real Options, the company should revise its internal decision-making process and ensure that the results are being calculated with all information available, not only the ones given to the financial analysts.

The Real Option methodology will not solve the problems of poor assumption or overconfident estimates. However, it could better reflect the reality and the flexibility involved in the project: the flexibility of the company acting to solve problems, but at the same time the flexibility for its clients to cancel contracts. This was the situation in case study. By subtracting from the NPV the cost of the put option, it discounted the project value reflecting possible economic downturn as it actually happened.

6.2 "The journey not the arrival matters." – *T. S. Eliot*

As discussed before in section 5.7, the project value with the revised NPV and the NPV added the Real Options had similar values. The option to sell for the liquidation value is dominant to the other two options, so why take the trouble of calculating the all the options?

The answer lies on the understanding that the most important point of Real Option valuation is not the results, but how one arrives at them. Unlike a static NPV analysis in which after the project value is calculated and the project is approved or not, the Real Option valuation requires and supports the monitoring of the project. By understanding how the options are created, management can make better decisions about the project after it was approved, exercising its option or not. Even the projects that were not approved might be feasible if certain circumstances change. By performing the analysis, the option dynamics are mapped and its values drivers explored, helping to identify possible opportunities and threats for the project and allow management to act in time to increase the project value.

As a finance professional, I answer yes to the research question. Real Options can be used in real-world organizations, not only in academia. The case study showed how valuable it can be especially to price contractual clauses that typically companies give to clients at no charge. However, there is still a long way to go in making the methodology more practical to use. The case study also showed that there was no single framework that fits all organizations' needs or types of investment projects. The framework should be customized to calculate a specific option or investment project. It is still far from being a simple framework for all organizations.

6.3 Future Studies

Future studies could explore the following approaches of this theme:

- Analyze the case through the lens of Behavioral Economics and the common biases of capital budgeting process as overconfidence of managers' projection and hindsight;
- Retroactively evaluate if one of the options (not to enter into the contract or sell for salvage value) should have been exercised;
- Perform the same analysis for Rig G project, a similar project approved during the same time period

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8 APPENDIX

8.1 Appendix A: Data Collection Procedures

	Case Rig O	
Information	**Source**	**Concluded?**
Projects Data		
Original Projects Business Plans (with Investment Analysis)	Former Operations Controller	Yes
Client Contract	Commercial Area	Yes
Contractual fees and conditions	Commercial Area	Yes
Historic Operational Performance	Company Information System	Yes
Historic Financial Performance	Company Information System	Yes
Historic Benchmark Projects Performance	Company Information System	Yes
Projects Operational Insights	Operations - Interview	No
Market Data		
Historic Interest Rate and Country Risk	Bloomberg	Yes
Historic Clients Stock performance	Bloomberg	Yes
Historic Exchange Rate	Bloomberg - Colombian Pesos	Yes
Historic Options Values (Clients)	Bloomberg	Yes
Historic Oil Prices	Bloomberg	Yes
Historic Market Utilization (Rigs)	Internal Commercial Information	No