St. Petersburg State University

Graduate School of Management

Master in Corporate Finance Program

**REAL OPTIONS THEORY APPLIED TO OIL AND GAS**

**INVESTMENT PROJECTS IN RUSSIA**

Master’s Thesis by the 2nd year student

Concentration – Master in Corporate Finance

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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ

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| Описание цели, задач и основных результатов | Нефтегазовая отрасль важна для российской экономики. Инвестиционные проекты в ней подвержены многим рискам, обладают некоторой гибкостью и активно управляются в течение их срока. Эти проекты чаще всего оцениваются с помощью метода дисконтированных денежных потоков, который предполагает пассивное управление и недооценивает гибкие проекты в условиях неопределенности. Анализ реальных опционов позволяет учесть ценность встроенной гибкости и активного менеджмента в условиях неопределенности.  Цель этой работы – исследовать применение метода реальных опционов к российским инвестиционным проектам в нефтегазовой отрасли и привести пример возможного применения метода. Для достижения этой цели описаны часто используемые модели оценки проектов, отличия метода реальных опционов от традиционных методов, проанализирована специфика инвестиционных проектов в нефтегазовой отрасли в России и показано, как метод реальных опционов может влиять на оценку проекта, на конкретном примере.  Результаты анализа подтверждают, что проекты нефтегазовой отрасли зависят от многих факторов неопределенности. По сравнению с рынками развитых стран, российский рынок обладает большей неопределенностью. Применение анализа реальных опционов на конкретном примере позволило оценить гибкость проекта, и оказало значительное влияние на ценность проекта для инвестора, позволило разработать рекомендации по управлению рисками. |
| Ключевые слова | Реальные опционы, нефтегазовая отрасль, неопределенность, гибкость, риск |

**ABSTRACT**

|  |  |
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| Master Thesis Title | “Real Options Theory Applied to Oil and Gas Investment Projects in Russia” |
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| Description of the goal, task and main results | Oil and gas industry is very important for Russia’s economy. Investment projects experience wide range of uncertainties, include flexibilities and are actively managed during their lifespan. These projects are mostly evaluated with DCF, which assume passive management and tend to undervalue flexible projects under uncertainty. Real options analysis allows to capture the value of built-in flexibilities and fulfill the assumption of active management under uncertainty and adjust the initial NPV estimation with this value.  Consequently, the *goal* of this thesis is to investigate application of real options analysis to Russian oil and gas investment projects and provide an illustrative example of possible application. To achieve this, we describe commonly used project valuation models, analyze how real options analysis differs from traditional valuation techniques, describe specific features of real options analysis for oil and gas investment projects in Russia and analyze how taking into account real options can influence decision making process on example of a specific case.  Results of the analysis confirm that projects in oil and gas depend on numerous factors of uncertainty: economic, political, technical. All types of uncertainties are stronger in Russian market if compared to developed countries. Application of real options analysis to a specific case allowed to estimate the built-in flexibilities that turn out to have a significant influence on project value. It also contributed to formulation of risk management recommendations that increase the expected value of the project and decrease its risk. |
| Keywords | Real options, oil and gas, valuation, risk management, uncertainty, flexibility, risk analysis, decision analysis |

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# Introduction

Russia is the world’s largest hydrocarbon producer, producing 15% of total hydrocarbons on a combined oil and gas basis. Russia produces 12.8% of global oil ranking second in terms of global production after Saudi Arabia and 17.6% of global gas, making it the world’s second-largest gas producer after the US.

Oil and gas industry is very important for Russia’s economy. Before Ukrainian crisis of 2014, the sector accounted for 28% of Russia’s GDP, 67% of the country’s exports and 56% of total revenues of the federal budget. (Nazarov, Khromushin, Dorokhov, Zinovyeva, et al. 2014)

*Investors face problem of valuation of oil and gas projects, which is connected to the decision making process on participating or rejecting the project* *and is more-in-detail described below.*

Oil and gas investment projects are capital intensive and usually have a planning horizon of several decades. Due to long lifespan oil and gas investment projects experience severe *uncertainties* in external environment (regulatory, economic, technical and environmental, etc.) and are actively managed during their lifespan. They also widely include *flexibilities*, such as ability to postpone the start of the project, expand capacity, abandon the project for salvage value, etc.

These projects are mostly estimated with traditional valuation techniques, based on idea of discounted cash flows. However, due to their deterministic nature, DCF methods assume passive management and tend to undervalue *flexible* projects under *uncertainty*, even when extended with analytic methods, i.e. sensitivity analysis. (Cesena 2012)

Real options analysis allows to capture the value of built-in flexibilities and fulfill the assumption of active management under uncertainty and adjust the initial NPV estimation with this value. At the same time real options analysis allow to account for both positive and negative outcomes of the factors of uncertainty and adopt the project to capture maximal value from those outcomes. Therefore, usage of real options analysis and linked to it active management lead to both decrease of volatility of the project’s value for investor and increase of the mean value of the expected cash flows.

Consequently, the *goal* of this thesis is to investigate application of real options analysis to Russian oil and gas investment projects and provide an illustrative example of possible application.

This primary goal can be achieved through the following specific objectives:

1. Describe commonly used project valuation models
2. Analyze how real options analysis differs from traditional valuation techniques
3. Describe specific features of real options analysis for oil and gas investment projects in Russia
4. Analyze how taking into account real options can influence decision making process on example of a specific case.

Thereby, the thesis describes main existing valuation models for investment projects and place of real options analysis among these models. Real options are compared to the traditional valuation techniques, their advantages and disadvantages are analyzed. Specifics of oil and gas investment projects, and specifics of their implementation in Russia are described with real options analysis perspective. Real options analysis algorithm is formulated and applied to an illustrative case of shelf oilfield development project.

The first chapter covers theoretical background of real options analysis, describes its place among other valuation techniques, advantages and disadvantages, link with risk management and main valuation approaches.

Second chapter addresses specifics of Russian market, specifics of oil and gas investment projects: main features, typical built-in flexibilities and linked uncertainties. It describes 7-step algorithm of real options analysis adopted from (Mun 2002), which include project description and qualitative analysis, time series forecasting, base case NPV modeling, Monte Carlo simulation, description of real options, valuation of real options and adjustment of the base case NPV, and formulating risk management recommendations.

Third chapter provides illustrative example of real options analysis applied to a case of shelf oilfield development project. It covers project description and follows the algorithm stated above to estimate adjusted value of NPV and formulate some recommendations on risk management.

The data used for the research was mainly collected from open sources. Data on the illustrative example, including project CAPEX, OPEX, required cost of capital and other project-related inputs for the model, were adopted from independent analysis of the Russian shelf oilfield development project (Lunden and Fjaertoft 2014). Modeling and simulation were performed in Excel statistic add-in Palisade @Risk.

# Real options as a tool of investment project valuation

*This chapter provides theoretical background on real options analysis and consist of 4 parts. The 1st part covers traditional valuation approach, describes its benefits and drawbacks. The 2nd part is a more-in-depth information on real options. It provides insight about advantages and disadvantages of real options compared to traditional approach. The 3rd part describes applications of real options: their link with risk management and utilization in industry. 4th part provide summary of the chapter.*

## Traditional valuation approach

Techniques based on discounted cash flow (DCF) methods are the most widely used for the assessment of investment projects. These methods provide sound assessments and allow the identification of robust investment alternatives. However, due to their deterministic nature, DCF methods tend to undervalue flexible projects under uncertainty, even when extended with analytic methods, i.e. sensitivity, decisions, and risk analyses. (Cesena 2012)

DCF methods are based on the idea of time value of money; that is, money has a greater value in the present than in the future. An investor prefers to receive money in the present than to be promised the same amount of money in the future because money in the present can be invested to produce additional revenues, the capital is devalued with time due to inflation, and there is a risk that the amount of money promised in the future will vary as it is subject to risk. Therefore, in order for an investor to sacrifice money in the present in exchange for a promised return in the future, the expected return must offer a premium that compensates for the time value of money

#### Net Present Value

In an NPV approach, the cost of an investment is compared to the future free cash flows that the investment is expected to generate. The NPV of a project is therefore the sum of the discounted expected cash flows, *CFt*, that occur at times *t* with *t* = 1, 2, …, *n*, (1.1)

|  |  |
| --- | --- |
|  | (1.1) |

where *r* is the discount rate.

A positive cash flow is a cash inflow and a negative cash flow is a cash outflow to a project. To account for the time value of money and the declining value of future cash flows, the expected cash flows are discounted at a specific rate. When comparing several alternative projects, the most common discount rate employed by an NPV analysis is the weighted average cost of capital (WACC) (Kobari 2014).

The WACC is the weighted average of the after-tax marginal cost of equity, *kE*, and cost of debt *kD*, and it is weighted by the market value of the firm's debt, D, and equity E: (1.2)

|  |  |
| --- | --- |
|  | (1.2) |

Where *t* is the marginal tax rate.

*kE* can be estimated by the capital asset pricing model (CAPM). The CAPM, developed primarily by (Malkiel and Fama 1970) and (Sharpe 1970), started with the idea that individual investment contains two types of risk:

*1.* *Systematic risk* (or market risk), that cannot be diversified away, such as interest rates, recessions, and wars

*2.* *Unsystematic risk* (or private risk, company specific risk, idiosyncratic risk), that is specific to individual stocks and can be diversified away as the investors increase the number of stocks in their portfolio. Unsystematic risk represents the component of a stock's return that is not correlated to the general market moves.

Modern portfolio theory shows that although unsystematic risk can be hedged through diversification, systematic risk cannot be eliminated, and must be accounted for, when calculating a deserved return. The CAPM, evolved as a way to measure this systematic risk (Sharpe 1970). The CAPM states that if the market portfolio, *M*, is efficient, the expected return of any asset *i*, equals the risk-free interest rate, *rf* , plus an added premium to the investor for taking the risk, as presented below: (1.3)

|  |  |
| --- | --- |
|  | (1.3) |

Where: *ri* is the expected return of the asset *i*,

*rM* is the expected return of the market portfolio,

*βi* coefficient is a measure of the level of systematic risk between the market portfolio and the traded equity,

*ρiM* is the correlation between the return of asset i and the return of the market portfolio,

*σi* is the variance of return of asset i,

*σM* is the variance of return of the market portfolio.

As was mentioned earlier, DCF models are popular in industry and used to evaluate vast majority of projects. According to (Mun 2002) discounted cash flow models have several *advantages*:

* Clear, consistent decision criteria for all projects.
* Same results regardless of risk preferences of investors.
* Quantitative, decent level of precision, and economically rational.
* Not as vulnerable to accounting conventions (depreciation, inventory valuation, etc.).
* Factors in the time value of money and risk structures.
* Relatively simple, widely taught, widely accepted.
* Simple to explain to management.

However, Mun claims that underlying assumptions of DCF models do not depict real life problems and become major *drawback* of the model, as shown in Figure 1.

|  |  |
| --- | --- |
| DCF Assumption | Realities |
| Decisions are made now, and cash flow streams are fixed for the future. | Uncertainty and variability in future outcomes. Not all decisions are made today, as some may be deferred to the future, when uncertainty becomes resolved. |
| Projects are “mini firms,” and they are interchangeable with whole firms. | With the inclusion of network effects, diversification, interdependencies, and synergy, firms are portfolios of projects and their resulting cash flows. Sometimes projects cannot be evaluated as stand-alone cash flows. |
| Once launched, all projects are passively managed. | Projects are usually actively managed through project life cycle, including checkpoints, decision options, budget constraints, and so forth. |
| Future free cash flow streams are all highly predictable and deterministic. | It may be difficult to estimate future cash flows as they are usually stochastic and risky in nature. |
| Project discount rate used is the opportunity cost of capital, which is proportional to non-diversifiable risk. | There are multiple sources of business risks with different characteristics, and some are diversifiable across projects or time. |
| All risks are completely accounted for by the discount rate. | Firm and project risk can change during the course of a project. |
| All factors that could affect the outcome of the project and value to the investors are reflected in the DCF model through the NPV or IRR. | Because of project complexity and so-called externalities, it may be difficult or impossible to quantify all factors in terms of incremental cash flows. Distributed, unplanned outcomes (e.g., strategic vision and entrepreneurial activity) can be significant and strategically important. |
| Unknown, intangible, or immeasurable factors are valued at zero. | Many of the important benefits are intangible assets or qualitative strategic positions. |

Figure 1. Flaws of DCF models. Source: (Mun 2002)

Traditional methods do not account for risks and uncertainty abound when decisions have to be made and that management has the strategic flexibility to make and change decisions as these uncertainties become known over time. According to (Mun 2002) in such a stochastic world, using deterministic models like the discounted cash flow may potentially grossly underestimate the value of a particular project. Same idea can be found in (Trigeorgis 1996; Cesena 2012; Kobari 2014) and many more.

The traditional valuation methodology relying on a discounted cash flow series does not get at some of the intrinsic attributes of the asset or investment opportunity. Traditional methods assume that the investment is an all-or-nothing strategy and do not account for managerial flexibility that exists such that management can alter the course of an investment over time when certain aspects of the project’s uncertainty become known.

Discounted cash flows models perform well in a deterministic environment, when there are no fluctuations of market factors over time, and managers do not change the project to adopt to external factors (i.e. development path of the project is predetermined). If this is the case, then the discounted cash flow model is correctly specified as there would be no fluctuations in business conditions that would change the value of a particular project. In fact, there would be no value in flexibility or active management.

However, the actual business environment is highly volatile, and if management has the flexibility to make appropriate changes when conditions differ, then there is indeed value in flexibility, a value that will be grossly underestimated using a discounted cash flow model.

Next section provide description of how real options can capture the value of this flexibility and enhance the DCF method.

## Real Options

### Financial options

Real options analysis can be described as the application of the ideas behind the valuation of financial options to the assessment of real assets. (Kobari 2014) This section describes main ideas of financial option theory, according to (Hull 2009)

A financial option is a contract that gives the owner the right, but not the obligation, to buy or sell an underlying risky asset at a future date (maturity) and at a specified price (strike). Financial options can be traded on both exchanges and over the counter markets. Since the value of these instruments is driven by their underlying asset value – such as commodities, stocks, futures, foreign currencies, and indices – they are referred to as derivatives. An important feature of an underlying asset is that its current price is known at the present but liable to change in the future. The main applications of financial options are hedging and speculation. Hedging is an act of mitigating the risk should the underlying asset yield an unfavorable outcome, whereas speculating is an act of betting on the future underlying prices, by taking a position in the market.

In an option contract, two parties are involved: a party with a long position who has the right to purchase the underlying asset, and a party with a short position who has the right to sell/write the underlying asset. Financial options are commonly categorized in two manners. In the first classification, options are categorized as call or put options. A call option is an option to buy the underlying asset, whereas a put option is an option to sell the underlying asset. In the first classification, options are categorized as European and American options. The holder of a European option has the right to exercise the option only at the maturity, whereas the holder of an American option may exercise its right any time before or on the maturity date.

The payoff of a call option, *c(St; t),* which gives an option holder the right but not an obligation to purchase the underlying asset, is (1.4)

|  |  |
| --- | --- |
|  | (1.4) |

where St is the underlying stock price at time t and K is the strike price. Similarly, the payoff of a put option, *p(St; t),* which gives an option holder the right but not an obligation to sell the underlying asset, is (1.5)

|  |  |
| --- | --- |
|  | (1.5) |

Myers recognized the analogy between financial options and project decisions, because of the similarities in their risk structure and payoffs. (Myers 1977) The following two sections describe how real options analysis is linked to the ideas of financial options.

### Defining real options

(Myers 1977) suggested that option-based valuation used in quantifying the flexibility in financial instruments can be applied to quantify the value of flexibility in real-world opportunities, and proposed the term “real options”. As the owner of an American call option on a financial underlying asset has the right, but not the obligation, to purchase the asset by paying the exercise price on or before the maturity date, the holder of a real option has the right, but not the obligation, to carry out managerial decisions in order to receive the present value of expected cash flows net of related investment costs until the opportunities associated with that decision disappear (Trigeorgis 1996).

*“Real option”* is thereby the right, without obligations, to adjust a project in response to the evolution of uncertainty.

Real options are by definition directly linked to the managerial flexibilities built into the project, such as postponing the construction of the project, a change in the manner the project operates, exiting for salvage value and many others.

Flexibility can be defined as the capacity of project managers to adopt the project to the changing environment when the uncertainty is resolved. Without flexibility, there would be no feasible options to adjust the project, and real option theory could not be applicable. Same is true in case of deterministic environment: real options do only have value (and sense) in case future remains unknown and unpredictable (Бухвалов 2004).

Just like financial options, real options are not obligations; that is, even if an option is available, it should not be exercised unless its execution adds value for the project. Therefore, it is normal to have some real options that are never used. Moreover, real options are not generally stated in project description in advance and thus do usually exist only in managers’ imagination. (Бухвалов 2006)

### Real options theory

Following logic of previous section, *“real option theory”* can be determined as an area of research focused on assessing the value of flexibility within projects under uncertainty.

Real options theory is based on the ideas of financial option theory. Figure 2 presents the analogy between a financial call option and a real option.

|  |  |  |
| --- | --- | --- |
| Variable | Financial option | Real option |
| Underlying asset | Current value of stock | PV of expected cash flows |
| Strike price | Stock price | Investment cost |
| Time to expiration | Stated in the contract | Until the opportunity disappears |
| Risk-free rate | Risk-free interest rate | Risk-free interest rate |
| Volatility | Variation of stock returns | Variation of project cash flows |
| Dividends | Cash flows from stock | Project cash flows |

Figure 2. Analogy between a call option and a real option on a project adopted from. Source: (Trigeorgis 1996)

Based on real option theory, flexibility can be modelled and quantified with real options. If these options are detected and properly implemented, they can increase the expected value of the project and decrease associated risks.

Increase in expected value of flexible projects is achieved by managing uncertainties associated with the projects – adjusting the project to the environment, i.e. expanding the capacity if sales turned out to be higher than forecasted and contracting if those are lower. Those actions do not only increase mean expected value, but also reduce its volatility, making inflows more certain.

According to (Trigeorgis 1996), when incorporating flexibility to modify future actions in response to changing environment, a positive asymmetry is introduced to the probability distribution of NPV[[1]](#footnote-1). Similar to financial option theory, the upside potential of the value of the investment opportunity improves, but the downside loss becomes limited relative to initial expectations, leading to an overall increase in the real value of the investment opportunity.

Trigeorgis defines the “expanded NPV”, *NPV\**, as: (1.6)

|  |  |
| --- | --- |
|  | (1.6) |

Where:

*NPV* is the traditional (or static) net present value of the expected future cash flows under a passive management,

*“option premium”*, also called real-options value, is the value of managerial flexibility under an active management.

However, some limitations may apply to the option analogy, including the non-tradability of the underlying asset of a real option, non-exclusiveness of ownership and competitive interactions, non-tradability of a real option, and strategic interdependencies and option compoundness across time (Trigeorgis 1996)

### Types of real options

Idea of real option is directly connected to the flexibilities which are available to the management of a specific project. This section describes common real options built into long-term investment according to (Kobari 2014)

##### 1. Option to defer the investment

According to (Cesena 2012) this are the most common real options found in the literature. They concern the alternative to delay investment decisions with the objective of gathering additional information to better assess the projects.

This option exists when investor have an opportunity to wait and see how the uncertainties connected with the project will resolve. It can be movement of currency exchange rates, prices of goods, etc. Than if market conditions are favorable the management will continue and participate in the project. Otherwise, they will reject the project and save on the planned costs. This option will entitle management to receive (1.7)

|  |  |
| --- | --- |
|  | (1.7) |

Therefore, the option to defer or invest is analogous to an American call option on the gross present value of the completed project's expected operating cash flows, *V*, with a strike price of the required investment, *I.*

The option to wait is particularly valuable in such resource extraction industries, as well as in farming, paper products, and real estate development, due to high uncertainties and long investment horizons.

##### 2. Option to stage investment

According to (Kobari 2014), in most real-life projects, the required investment is not performed at one stage. Staging capital investment as a series of outlays over time creates valuable options to continue with the project or abandon it at any given stage. Each stage involving a small investment and the reassessment of the project.

This provides an opportunity similar to option to abandon the project if necessary before the whole capital needed to build it has been compromised. These sequential options can be valued as compound options.

The option to stage investment is valuable in R&D-intensive industries (particularly in biotechnology and pharmaceuticals), in highly uncertain, long development capital-intensive industries (such as energy-generating plants or large-scale construction acquisition or market entry strategies), in high-tech startups, and in venture capital.

##### 3. Option to expand (or grow) the investment

If market or any other external conditions turn out to be more favorable than expected, management has the option to expand the scale of production, by *e*%, by incurring a follow-up cost of *IE*. Increase in capacity may require non-proportionally lower increase in investment due to some infrastructural investments made earlier.

This flexibility is similar to a call option to acquire an additional share *ωe* of the base-scale project with a strike price of *IE*. Therefore, an investment opportunity with the option to expand can be viewed as a base-scale project plus a call option on future investment. This option will entitle management to receive *(1.8*)

|  |  |
| --- | --- |
|  | *(1.8)* |

When having an initial design choice, management may deliberately choose a more expensive technology with a built-in flexibility to expand production when desirable. The option to expand may also have strategic importance, particularly if it enables the firm to capitalize on new or future growth opportunities.

For example, when the firm buys a piece of undeveloped land, or when it builds a flexible plant in a new geographic location to position itself to take advantage of a developing potentially large market, it essentially acquires an expansion option. This option will be exercised only if future developments turn out to be favorable. Although this type of investment project often seems unprofitable based on passive NPV, it is worth undertaking based on real options analysis.

##### 4. Option to contract

In unfavorable conditions management can choose to operate at a rate below the maximum capacity of the plant or reduce the scale of operations by share *ωc*, thereby saving part of the planned investment costs, *IC*. The flexibility to mitigate loss is analogous to a put option on *ωc* of the base-scale project with a strike price of the potential cost savings, *IC*. This option will entitle management to receive (1.9)

|  |  |
| --- | --- |
|  | (1.9) |

Similar to the option to expand, the option to contract is valuable in the case of new product introductions in uncertain markets. The option to contract may also be important in choosing among technologies or alternative plants with a different construction-to-maintenance cost mix, where it may be preferable to build a plant with lower initial construction costs and higher maintenance expenditures in order to acquire the flexibility to contract operations by cutting down on maintenance when conditions turn out to be unfavorable.

##### 5. Option to temporarily shut down (and re-start) operations

In the real-world, the project does not have to operate and extract the oil in each and every period of the project life. If uncertainty resolved into conditions which are not sufficient to cover variable operating costs, it might be better to temporarily stop the operation. Operations can once start up again, if uncertainty will lead to positive changes. Therefore, operation in each specific period (i.e. year) can be seen as a call option to acquire the revenues of the period, *R*, by paying the variable costs of operating, *IV*, as the strike price. This option will entitle management to receive (1.10)

|  |  |
| --- | --- |
|  | (1.10) |

It should be noted that there might be some switching costs between the operating and idle modes. When switching costs are substantial, delays in switching may arise. Options to expand, contract, or shut down are typically found in natural resource industries, such as mine operations, facilities planning and construction, fashion apparel, consumer goods, and commercial real estate.

##### 6. Option to abandon for salvage value

If environmental factors lead to significant decrease of inflows compared to initial forecast after the investment was made, management does not have to continue incurring fixed costs. Management has the option to permanently abandon the project in exchange for its salvage value. This option can be valued as an American put option on the current project value with a strike price of the salvage or best alternative use value *A*. This option will entitle management to receive (1.11)

|  |  |
| --- | --- |
|  | *(1.11)* |

Commonly, more general-purpose capital assets would have a higher salvage value and thus will have higher value of option to abandon, compared to special purpose assets. Valuable abandonment options are generally found in capital-intensive industries (such as in airlines and railroads), in financial services, and in new product introductions.

##### 7. Option to switch inputs or outputs

Option to switch inputs (or outputs) allow management to switch from the current input to the cheapest future input, or from the current output to the most profitable future product mix, as the relative prices of the inputs and/or outputs fluctuate over time. Therefore, the firm should be willing to pay a certain premium for such a flexible technology over a rigid alternative with no or less flexibility. A firm which can develop more uses for its assets in this way may have a significant competitive advantage.

*Process* flexibility can be achieved either by technology, as in the example, or by maintaining relationships with a variety of suppliers. Subcontracting policies may provide even more flexibility to contract the scale of future operations at a low cost, when faced with unfavorable conditions.

Another example would be a multinational company that may locate its production facilities in various countries in order to acquire the flexibility to shift production to the lowest-cost producing facilities as the relative costs, other local market conditions, or exchange rates change over time.

Process flexibility is also valuable in feedstock-dependent facilities such as oil and minerals, electric power, chemicals, crop switching, and supplier relationships.

*Product* flexibility, which enables the firm to switch among alternative outputs, is more valuable to industries in which product differentiation and diversity are important and/or product demand is volatile.

Examples of such industries are automobiles, consumer electronics, toys, or pharmaceuticals. In such cases, it may be worthwhile to install a more expensive flexible capacity to acquire the ability to alter product mix or production scale in response to changing market demands.

The lower the correlation between the alternative outputs, the higher the value of the option to switch.

##### 8. Corporate growth options

(Kobari 2014) refers to corporate growth options as to a special case of the option to expand, explained above.

In a broader context, many early investment projects – such as R&D projects, a lease on undeveloped land or a site with potential oil reserves, a strategic acquisition, or an information technology network – can be viewed as purchase of corporate growth option. In this case, the value of the project may depend not on directly measurable cash flows, but rather on unlocking future growth opportunities – such as a new-generation product or process, related oil or mineral reserves, access to a new or expanding market, strengthening of the firm's core capabilities, or strategic positioning.

For example, an opportunity to invest in a first-generation high-tech product is analogous to an option on options, or an inter-project compound option. Even though the initial investment may have a negative passive NPV, the infrastructure, experience, and potential by-products generated during the development of the first-generation product may result in development of lower-cost or improved-quality future generations of that product, and encourage the generation of new applications in other areas. Unless the firm makes the initial investment, subsequent generations or other applications would not even be feasible. The infrastructure and experience gained can be proprietary and can place the firm at a competitive advantage, which may even reinforce itself if learning cost curve effects are present.

Growth options exists in all infrastructure-based or strategic industries, especially in high tech, R&D, and industries with multiple product generations or applications – such as semiconductors, computers, pharmaceuticals – in multinational operations, and in strategic acquisitions. In a more general context, such operating and strategic adaptability represented by such a set of corporate real options can be achieved at various stages during the value chain, such as switching the factor input mix among various suppliers and subcontracting practices, rapid product design and modularity in design, or shifting production among various products or countries rapidly and cost efficiently in a flexible system or multinational network.

### Valuation of real options

According to (Cesena 2012) the main existing approaches used for the assessment of financial options and real options are based on trees, and partial differential equations (e.g. the Black Scholes formula). All of them has advantages and drawbacks, and can be used to properly address certain types of options and projects. This section provides a description of real options valuation approaches.

#### Partial differential equations: The Black Scholes formula

Partial differential equations are sets of equations derived for the modelling and assessment of specific real options under particular assumptions. These equations can be formulated using dynamic programming and contingent claims analysis. The most widely used partial differential equation found in real options literature is the Black Scholes formula. (Cesena 2012)

The Black Scholes (Black and Scholes 1973) formula was the first equation that allowed a straightforward calculation of the value of a financial option. The formula offers the following approach for estimation the call option premium C (1.12)

|  |  |
| --- | --- |
|  | (1.12) |

*where:*

is the cumulative distribution function of the standard normal distribution

is the time to maturity (expressed in years)

is the spot price of the underlying asset

*K* is the strike price

*r* is the risk free rate (annual rate, expressed in terms of continuous compounding)

is the volatility of returns of the underlying asset

Correct estimation with Black Scholes equation requires understanding of underlying premises. The equation is based on two main assumptions, which are more-in-detail described below, following (Cesena 2012):

1. The financial option is traded in a market with no arbitrage opportunities, which allows the use of the risk free interest rate.
2. The price of the product that is addressed by the financial option is uncertain and it follows a geometric Brownian motion.

##### No arbitrage opportunities

It is said that there is arbitrage when an investor can use a set of transactions to guarantee obtaining a risk free profit. In practice, it can be reasonable to assume no arbitrage for stock prices, as arbitrage opportunities do not last long due to the forces of supply and demand. That is, investors would start securing products at low prices, increasing the demand of the product and causing a price increase; and would sell it in another market at higher prices, increasing the supply and causing a price decrease. This would balance the price of the product in both markets.

The no arbitrage assumption facilitates the assessment of financial options. Under no arbitrage conditions, uncertainty affects equally the product price and any financial options associated with it. As a result, a portfolio of products and financial options can be made in such a way that their value becomes certain, which allows the use of the risk free interest rate. Once such a portfolio is found, the value of the options must be such that the risk free value of the portfolio becomes zero.

##### Geometric Brownian motion

No arbitrage cost of a financial option can be easily determined for a small amount of scenarios for the price of the product. However, in practice, the evolution of the price of a product has to be modelled with more complex processes, such as the geometric Brownian motion. (Cesena 2012)

The model assumes that:

1. the future changes of the variable are independent of its previous values,
2. the probability of occurrence of any given percentage change of the variable is independent of its current value, and
3. the variable is always positive.

These assumptions can be included in the model by making the random variable *πt+t2*/*πt* independent of previous prices and making ln (*πt+t2*/ *πt*) follow a normal distribution. Accordingly, a geometric Brownian motion process can be modelled as (1.13):

|  |  |
| --- | --- |
|  | (1.13) |

*where:*

*π* is the price of the asset,

is the cumulative distribution function of the standard normal distribution,

*σ* is the standard deviation,

Δ*t* is a time step.

#### The tree model

The trees allow modelling of different types of uncertainty sources and options in discrete scenarios. These scenarios can provide information about the performance of the option in different conditions. The downside of these methods is that their accuracy depends on the amount of scenarios considered throughout the tree; too few scenarios reduce the accuracy of the approach, whereas considering too many scenarios can be computationally expensive.

Under assumption of Black Scholes following equations describe a tree for option estimation (Hull 2009) (1.14)

|  |  |
| --- | --- |
|  | (1.14) |

*where:*

*up* and *down* are respectively an increase and decrease in the price of the product,

*σ* is the standard deviation,

*∆t* is the length of a discrete period,

*p* is the probability of an increase in the price of the product,

*d* is the interest rate.

The probabilities of occurrence of a price increase *(p)* and decrease *(1 – p)* are set to guarantee a zero expected gain from trading the underlying asset.

## Application of real options

#### Real options and risk management

Risks of the project are directly connected to the underlying uncertainties that drive the financial outcomes. Those uncertainties (factors) can vary project to project and this volatility is mostly inevitable due to the time between investment and cash inflows. As the key idea of any investment is to spend money at period “0” and gain money back later, any investor faces the uncertainty which is resolved only at the end of the project life span.

Buhvalov (2004) determines two main approaches for defining risk. The first is understanding of risk as a synonym of the dangers linked to the project and risk management as actions to avoid these dangers, to achieve safe and stable outcomes. However, this approach does not capture the possibilities brought by the uncertain environment. In an attempt to reach certain, guaranteed outcomes a company cannot successfully compete with rivals in dynamic environment.

The second approach accounts for both positive and negative outcomes linked with the risk. It describes risks of the project as volatility (variance) of the financial inflows, connected to their expected value. This approach allows risk management to concentrate not only on dangers but also on possible positive outcomes linked with the uncertainty and therefore perform active management of the project throughout its lifespan.

Real options allow to handle possible negative outcomes and understand if those actions are reasonable at all in terms of money. Active management of negative outcomes is one of the most important applications of real options in risk management. However, it is not the only application. Real options allow to account for positive outcomes of the factors of uncertainty and adopt the project to capture maximal value from those outcomes.

Therefore, usage of real options analysis and linked to it active management lead to both decrease of volatility of the project’s value for investor and increase of the mean value of the expected cash flows.

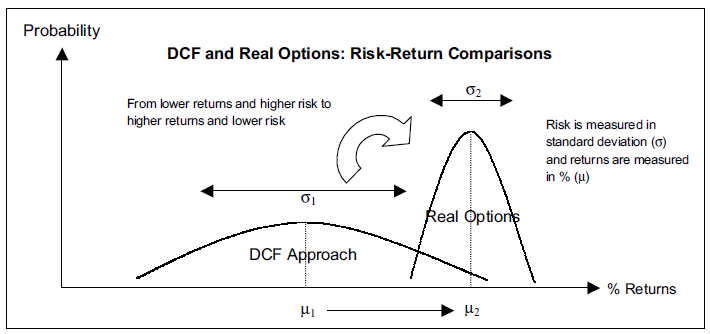


Figure 3. Application of real option reduce risk and increase return of the project. Source: (Mun 2002)

#### Utilization of Real Options Analysis in Industry.

In spite of being broadly studied, the topic of real options is not covered or scores poorly by industrial practitioners, in terms of utilization (Block 2007). For example, as reported in (Teach 2003), Bain and Company conducted a survey of 451 senior executives covering 30 industries regarding their views of management techniques, and only 9% reported using real options. Also, a survey of 208 CFOs found real options trailing the list of 13 supplementary capital budgeting techniques with a utilization rate of 11.4% (Ryan and Ryan 2002).

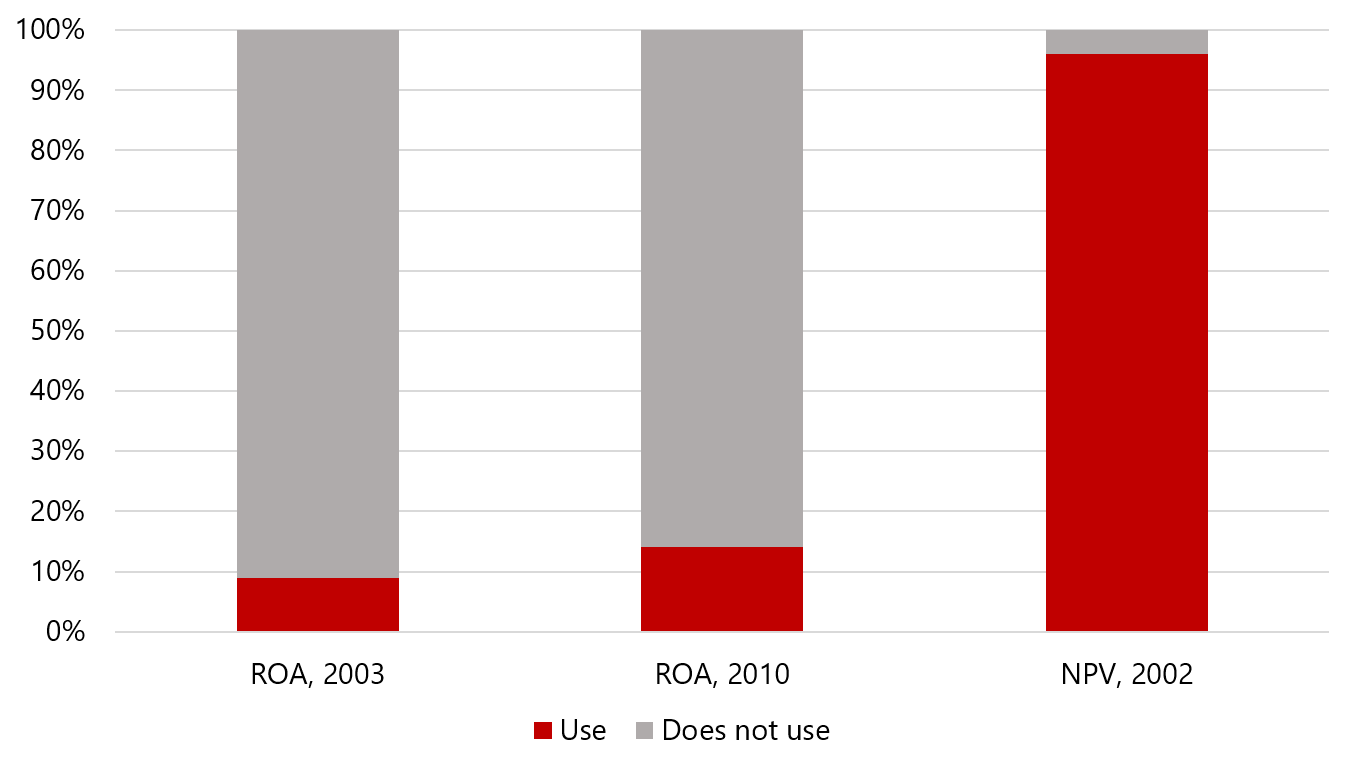


Figure 4. Utilization of Real Options Analysis in Industry. Source: Author´s figure, (Block 2007), (Bennouna, Meredith, and Marchant 2010), (Ryan and Ryan 2002), (Teach 2003).

In contrast, 85.1% of the respondents used sensitivity analysis and 96% used traditional net present value analysis for basic capital budgeting. In a more recent survey, (Block 2007) surveyed Fortune 1,000 companies to see if the companies were employing ROA to complement traditional analysis. Out of 279 respondents, 40 were using real options (14.3%). Based on a survey by (Bennouna, Meredith, and Marchant 2010) of large Canadian corporations, only 8.1% of the firms used or were using ROA. Overall, traditional NPV analysis continues to be described as a normative approach, and the use of ROA in industry is limited.

## Chapter summary

Real options analysis is one of the numerous investment project valuation technics, which can be generally categorized into two main groups: static and dynamic (Brennan and Trigeorgis 2000).

Static, or the traditional valuation approach assumes that an investment project can be evaluated using a series of its expected future cash flows. This approach includes all the methods of estimation which are based on the idea of discounted cash flows, such as net present value, internal rate of return and many more.

NPV is widely used and well known in the industry (which will be discussed later in this chapter), however it has its drawbacks. Traditional valuation techniques are unable to quantify *managerial flexibility*, which is adapting and changing the project during its lifespan in response to the uncertain environment (Trigeorgis 1996).

In contrast with static valuation techniques, dynamic valuation techniques account for managerial flexibilities in responding to future events as uncertainty is resolved (Trigeorgis 1993). According to Trigeorgis, real options analysis is computationally complicated, but consistent with economic theory. In the same time, it outperforms (Trigeorgis 1996) other dynamic approaches and is therefore in the focus of this thesis.

Real options are an instrument of valuation, that captures managerial flexibility and makes estimation of capital intensive projects with long life span more precise. However real options analysis is not just a tool for valuation but also a powerful tool of risk management. Application of real options analysis reduce risk of the investment and increase the returns of the project at the same time.

This goal is achieved through two ways. First is active management of the project and its adjustment to the environment, which makes NPV distribution asymmetrical and reduce probability of negative outcomes. (Trigeorgis 1996) Second is intentional change of project design to include flexibilities from the very beginning. (Cesena 2012)

# Real options theory applied to oil and gas projects

*This chapter provides insight on specifics of oil and gas investment projects in Russia and methodology of real options analysis. The 1st part covers specifics of oil and gas projects and related underlying uncertainties and flexibilities. It later offers a review of how Russian specifics influence oil and gas projects. The 2nd part describes 7-step approach of real options analysis adopted from* (Mun 2002) *in line with topic of oil and gas.*

## Oil and gas projects in russia

This section describe main specifics of projects in oil and gas industry according to (Badiru and Osisanya 2013) and gives some insight on Russian market.

Oil and gas business differs from other industries in many ways. Trends in oil and gas affect almost all other projects in consumer market. According to (Badiru and Osisanya 2013) The influence sphere of oil and gas has grown dramatically over the years. A big decline in distributor costs of oil and gas directly drives a large portion of wholesale prices. Thus, it should be of interest to the general public to manage oil and gas projects so as to lower operating costs that can spread positively to consumer marketplace.

Projects in the oil and gas industry are characterized by huge investments, massive interfaces, and complex engineering efforts. The size and complexity of these projects require special attention in the project management process. Risks are a big part of oil and gas projects. Many aspects of the oil and gas business can benefit from better valuation and risk management practices.

Investments in oil and gas projects imply a wide range of economic, social, and environmental impacts on many parties over a long lifespan. Evaluation of such projects is therefore a crucial task before construction. To a great extent, the willingness of investors looking to make a reasonable rate of return on their investment in such projects is related to the legal and regulatory framework. (Bagh 2015)

Risk is also an inherent part of the oil and gas industry. Factors of uncertainty in world oil prices, technology, conditions of economy, currency exchange rates affect financial results of projects in oil and gas. Risks can be managed, but not eliminated. In fact, risk is the essence of any enterprise. Long lifespan makes forecasting key economic variables extremely difficult. Actual level of extractable reserves is usually known only after the beginning of the project. In spite of government regulations designed to reduce accident risks in the energy industry, accidents will occasionally happen.

According to (Badiru and Osisanya 2013) the span of projects of interest in the oil and gas industry includes the selected sample below:

|  |  |  |
| --- | --- | --- |
| General operations | Processing | Exploration and development |
| Economics of the market | Refining | Forecasting |
| Financing | Operations | Geological research |
| Product marketing | Construction | Discoveries |
| Government relations | Petrochemicals | Reserves |
| Regulations | Gas processing | Area drilling |
| Inspections | New plants | **Drilling and production** |
| Regulatory oversight | Capacities | Drilling operations |
| Quality checks | Liquefied petroleum gas (LPG) | Production operations |
| Compliance assessment | **Transportation** | Field start-ups |
| Corporate alliances | Tankers | Unconventional resources |
| Human resources | Liquefied natural gas (LNG) |  |
| Hardware and software infrastructure | Pipelines |  |

Figure 5. Operations in oil and gas. Source: (Badiru and Osisanya 2013)

Large scale projects face massive regulatory, technical and social challenges (physical distance, cultural diversity, language barriers and technological differences). Constructing such projects therefore requires pervasive management of economic, political and environmental risks. Next section describes main sources of uncertainty in oil and gas investment projects.

### Sources of uncertainty

Uncertainty is the lack of exact knowledge of a project and one cannot tell the possible events and outcomes of the future concerning the venture. Uncertainty can be good or bad for a project. For a long time, the state where the uncertainty is likely to yield an undesired, bad results or a significant loss is called risk. However, now we can address both positive and negative outcomes as risk (Бухвалов 2004). When analyzing projects concerning oil and gas, one is likely to encounter many uncertainties which include economic, technical and political.

Uncertainties determine the value of the real options built into the project. Under certain environment flexibility has no value, as both managerial decisions and project outcomes are predetermined. Due to long lifespan projects in oil and gas experience severe uncertainties in external environment. The situation is worsening by volatile world oil prices and for Russian players, state of Russian economy plays a major role (which will be discussed later).

Though uncertainties make it very difficult to undertake a project using traditional valuation approach, the investor and management can develop strategies, flexibilities, and options to minimize all risks and take advantage of favorable upside uncertainties.

#### Economic Uncertainty

Oil and gas investment projects have very long lifespan that can last for decades. It is impossible to make viable forecasts for this period, while state of market, including world oil price dynamics, currency exchange rates, interest rates, and other uncertainties impact the cash inflows of the project.

According to (Murphy 2009) there are four major factors that determine oil prices – supply, consumption, financial markets, and government policies. Supply and consumption have historically been the fundamental factors in pricing the barrel. However, those are no longer the main determinants. In 2009, for example, there has been abundant supply and slowing demand, but prices have doubled.

Oil prices are extremely volatile and are therefore responsible for significant share of overall risk of oil and gas projects. (Carver and Ennis 2011). From 1999 to 2004, the biggest difference between the high and low price in any given year was $16; from 2005 on, the average variance was $52 – but in 2008 it was $115. In 2014 same variance was about $60.

Uncertainty in prices is not necessarily harmful for the project. Price fluctuation can be favorable when the price of oil and gas increases and the corresponding increase in purchasing power generates higher cash inflow. Same logic refers to other economic variables like interest rate on debt or the currency exchange rates which can both increase the project’s value or lead to loss.

Oil and gas projects in Russia include significant economic uncertainty, connected to URALS oil price, Russian ruble exchange rate and debt interest rates that fluctuated from 5.5% to 17% from 2013 to 2017. Those factors apart from oil price are more volatile in Russia than in developed countries. There are numerous reasons for that that include a weak governance, large share of oil and gas sector in economy and federal budget income, large share of government in economy, and many more. However, the main reason of volatility since Ukrainian crisis of 2014 is political uncertainty which is more-in-details described later in this section.

#### Technical Uncertainty

The most difficult aspect of any oil and gas production project is the prediction of the amount of the resource available in the formation. Level of extractable reserves depend on the geologic nature of the formation and used technology. It contributes significant part of overall volatility since it directly influences cash inflows of the project. (Suslick, Schiozer, and Rodriguez 2009) Geologic uncertainties can be favorable for the project if preliminary estimations reveal expected volumes lower that actual results.

The technical uncertainties include oil spill and blowout which lead to environmental risks and extra costs for the company. Russian legislation requires oil and gas manufacturers to develop a strategy of environmental risk management, but cases of oil spills still occur (Greenpeace Russia 2014) and influence profitability of investment projects.

#### Political Uncertainty

According to (Laaksonen 2010) a foreign investment project needs to be analyzed in the context of its political, legal, economic, social, and cultural environments. These aspects create the investment climate of a host country. The investment climate further comprises features such as general political stability, government policies toward foreign investment, other government policies and legal factors, macroeconomic environment, and international payments. Author notes that all these items depend directly or indirectly on the behavior of the political system in the host country, and that changes in the investment climate will proceed mainly from changes in the behavior of the host government or from general political instability. As a consequence, political risk arises from uncertainty about the host country’s political conditions and government policies that are critical to the profitability of an actual or proposed business arrangement.

According to (Assis, Burcham, and Perrine 2014) geopolitics is a central concern for the oil and gas sector and can be viewed as a source of both risk and opportunity. The trend toward more nationalistic and assertive political behavior indicates global instability is on the rise. So it is no coincidence that one of the top risks facing oil and gas companies, as identified by EY in our most recent risk study, was geopolitics.

The term “geopolitics” encompasses a broad range of frequently interconnecting issues, including diplomacy and security, global economics, financial and supplier market uncertainty, commodity constraints and pricing, exchange rate fluctuations, and civil and workforce disruption. Because geopolitics is complex and volatile, with unpredictable players who have conflicting agendas and disparate motivations, it is tempting to see geopolitics as impossible to control or prepare for.

While the fundamental nature of geopolitics is volatile, there is an opportunity to mitigate the impact of these forces on the industry. However, when companies are unable to foresee emerging trends or react to rapid, unforeseeable geopolitical change, the potential impacts on corporate and capital project performance can be significant.

### Managerial flexibility in oil and gas projects

This section describes common flexibilities built into long-term oil and gas investment projects and connected real options through an illustrative example of an oil extraction and refinement facility. It follows logic of “Types of Real Options” section in Chapter 1 and is mostly adapted from (Kobari 2014) to be in line with oil and gas industry aspect.

Consider a large oil and gas company with a one-year option to start extracting oil on undeveloped land with potential reserves. Initiating the project may require certain exploration costs, to be followed by infrastructure investments, such as construction of roads, pipelines, etc.

Extraction can begin only after construction is completed, so cash flows are generated only during the operating stage that follows the last investment outlay. *Flexibilities* associated with the project include following:

* During construction, if market conditions worsen, management can forego future planned costs past the current stage.
* Management also has the possibility to reduce (contract) the scale of operation by share *ωc* by saving a portion, *IC*, of the last outlay investments if the market is weak.
* The plant is also designed in advance such that if gas prices (or the quantity of reserves) turn out to be unexpectedly high, the rate of production can be enhanced by share *ωe* with a follow-up cost of *IE* to install extra capacity.
* At any time, management may get back a portion of its investment by selling the plant and equipment for their salvage value (i.e., the resale value of its capital equipment and other assets in second-hand markets) or switch them to an alternative use value, *At*.
* An associated refinery plant, which may be designed to operate with alternative sources of energy inputs, can convert crude oil into a variety of refined by-products.

These flexibilities add value to the project through introducing connected real options. The *real* *options* embedded in this type of project are enumerated as follows.

#### 1. Option to defer the investment

The lease enables management to defer investment for up to a year, thus benefit from the resolution of uncertainty about oil prices during this period. Management would exercise its option to extract crude oil and invest *I1 (*the investment in roads and other infrastructure in the first period) only if world oil prices are high enough. Conversely, management would not participate in the project and would save the planned costs, if prices are low. Therefore, just before the expiration of the lease contract, the value*[[2]](#footnote-2)* of the project will be the greater of the net value, *V1 – I1*, and $0.

#### 2. Option to stage investment

If after exploration the reserves or oil prices turn out to be very low, management can abandon the project. It means that management does not necessarily need to continue the project in case of negative uncertain outcomes come in place. In this case each stage of project, like exploration or building the necessary infrastructure can be viewed as an *option on the value of subsequent stages*. These sequential options can be valued as compound options.

#### 3. Option to expand (or grow) the investment

If world oil prices (or the quantity of the reserves, or any other environment conditions) turn out to be *more* favorable than expected, management has the *option to expand* the scale of production, by ω*e,* by incurring a follow-up cost of *IE*. In that case management deliberately maximize the expected inflows and fully captures favorable market conditions in order to increase expected NPV of the project. It worth noting that due to economy on scale increase of capacity by e% will require non proportional increase in associated costs *IE* due to some “fixed” costs lice investment in infrastructure or exploration which were made in advance.

This flexibility is similar to a call option to acquire an additional *e*% of the base-scale project with a strike price of *IE*. Therefore, an investment opportunity with the option to expand can be viewed as a base-scale project plus a call option on future investment.

#### 4. Option to contract

If market conditions turn out weaker than originally expected, management of illustrative project can operate at a rate below the maximum capacity of the plant or even reduce the scale of operations by ω*c*, thereby saving part of the planned investment costs, *IC*.

The flexibility to mitigate loss is analogous to a put option on ω*c* of the base-scale project with a strike price of the potential cost savings, *IC*.

#### 5. Option to temporarily shut down (and re-start) operations

In the real-world, the project does not have to operate and extract the oil in each and every period of the project life. In fact, if world oil prices are such that cash revenues are not sufficient to cover variable operating costs, it might be better to temporarily stop the operation. Operations can start up again, if prices increase sufficiently. Therefore, operation in each specific period (i.e. year) can be seen as a call option to acquire the revenues of the period, *R*, by paying the variable costs of operating, *IV*, as the strike price.

#### 6. Option to abandon for salvage value

If world oil prices suffer a sustainable decline or if the quantity of reserves turns out to be significantly less, management does not have to continue incurring fixed costs. Management has the option to permanently abandon the project in exchange for its salvage value. This option can be valued as an American put option on the current project value with a strike price of the salvage or best alternative use value *A*.

Value of this option highly depends on the salvage value of the related assets. If the equipment can be sold or reused on another oilfield or plant, the value of option to abandon will significantly increase net present value of the project.

#### 7. Option to switch inputs or outputs

The associated oil refinery operation of this example can be designed to use alternative forms of energy inputs – such as oil, gas, or electricity – to convert the crude oil into a variety of output by‑products.

This valuable built‑in flexibility provides options to switch from the current input to the cheapest future input, or from the current output to the most profitable future product mix, as the relative prices of the inputs and/or outputs fluctuate over time. Therefore, the firm should be willing to pay a certain premium for such a flexible technology over a rigid alternative with no or less flexibility. A firm which can develop more uses for its assets in this way may have a significant competitive advantage.

#### 8. Corporate growth options

(Kobari 2014) refers to corporate growth options as to a special case of the option to expand, explained above. Corporate growth options set the path of future opportunities. For example, assume that the proposed refinement facility in this example is based on a new, technologically superior process, which has been tested internally on a pilot plant basis.

Even though the proposed facility in isolation may appear unattractive, it could be the first facility in a series of similar facilities if the process is successfully developed. The initial facility may even lead to production of entirely new oil by-products.

### Russian specifics

Russia is the world’s largest hydrocarbon producer, producing 15% of total hydrocarbons. Russia produces 12.8% of global oil and 17.6% of global gas, making the country the world’s top oil and gas producer on a combined basis. In 2013, Russia produced 10.5 mln bpd of oil, ranking second in terms of global production after Saudi Arabia. In 2013, Russia also produced 684 bcm of gas, making it the world’s second-largest gas producer after the US. (Nazarov, Khromushin, Dorokhov, Zinovyeva, et al. 2014)

Oil and gas industry – the most important for Russia’s economy. Russia’s significant weight in the global economy has historically been underpinned by the country’s strong oil and gas sector. Before Ukrainian crisis, the sector accounted for 28% of Russia’s GDP, 67% of the country’s exports and 56% of total revenues of the federal budget. (Nazarov, Khromushin, Dorokhov, and Zinovyeva 2014)

Due to specifics of natural resources Russian oil producers have extremely low lifting costs and CAPEX comparing to the world market. As Russian oil companies continue to develop conventional onshore oil and gas resources, it is still cheaper to produce oil in Russia compared to oil produced by international oil companies that have a significant proportion of offshore deepwater and unconventional oil production in total output. However, the lower production costs of Russian integrated oil companies are partly offset by higher transportation costs and a heavier tax burden. (Nazarov, Khromushin, Dorokhov, and Zinovyeva 2014)

Russia has complicated taxation system, aimed to capture excess returns on oil and gas projects to the federal budget. Payments for mineral resources extraction, and specifically for oil and gas, depend on Russian ruble exchange rate, price of Russian oil URALS and production volumes of the company, location of the oil field, extractable resources, cumulative production volume and some other factors. Total taxation of crude oil sold on export account for 50 to 60 % of revenues, and depends mostly on produced volume rather than on profit of a tax payer. (Ernst & Young Global Limited 2014)

Political situation of the latter years contributes to overall level of uncertainty in the industry. Sanctions from European countries, United States and allies lead to decline in economy and rapid depreciation of Russian ruble, supported by the decline of world oil prices.

Sanctions also lead to limited access to market of capitals as well as complications with obtaining new technologies, crucial for oil and gas projects.

(Laaksonen 2010) summarize risks associated with operating in Russia from the viewpoint of an international investor:

1. The investment climate in Russia is ambivalent – foreign investors are needed because of capital and technology, but the state wants to retain control over large investment projects, especially in the strategic sectors.

2. In the Russian oil and gas industry top level of government play major role. As a consequence, the political risk in this sector stems from the top level of governance, not from issues at the regional level.

3. International relations between the investor’s home and host country can affect the political risk faced by the investor, particularly in the gas business, where deals are made at the top level of governance.

4. In the gas sector, European companies do not have many alternatives where to invest, and this enables Russia to behave arbitrarily, relying on its current position as a global energy power.

5. The area claims might increase tensions in the Arctic. This may have an impact on the international relations between the Arctic states, for instance between Norway and Russia.

6. Technology and know-how enhance the bargaining power of foreign partners of Russia.

7. The political risk could more likely be realized in operational issues such as taxation, import or export licenses, changes in legislation, and price controls.

To summarize, Russian players in oil and gas market enjoy competitive conditions of Russian oilfields, which require minimal level of upstream CAPEX. However, main oil and gas reserves are located in the very north of Russia and their development require both massive infrastructural investment and profound technology, which Russian players lack. Participation of foreign players is limited due to political risks and sanctions implied in recent years, however major projects started earlier continue development.

## Real options analysis algorithm

This section describes application of real options analysis through a 7-step algorithm and follows logic of (Mun 2002). Real options analysis can be performed using the following algorithm:

1. Project description and qualitative analysis
2. Time series forecast
3. Base case NPV model
4. Monte Carlo simulation
5. Description of real options
6. Valuation of real options and adjustment of the base case NPV
7. Formulating risk management recommendations

### Project description and qualitative analysis

Project description and qualitative analysis is a vital part of real options analysis process. It includes detailed description of factors which influence cash flows of the project. This stage allows to determine main uncertainties that influence the financial outcome value and find built in managerial flexibility – essential part of real options identification.

### Forecasting

Forecasting is essential for discounted free cash flow modeling. It includes statement of all assumptions for the forecast, which will later be used for base case net present value analysis. Forecasting allows to get the average values of factor variables and model random processes, which can be used for the future steps, specifically for Monte Carlo simulation.

Forecasting approaches usually fall into one of several categories (Mun 2002)

1. Regression
2. Time series
3. Simulation
4. Qualitative

#### Regression

Regression forecasts results using historical data on past values several variables. Performing regression forecasting requires assuming that historical data describe future relationship between dependent and explanatory variables that might influence it. According to (Mun 2002) this works best for situations where the goal is to identify the different effects of different variables. This category includes multiple linear regression.

#### Time-series

Time-series analysis on past patterns of historical data is performed to forecast results according to their expected values. This type of forecasting works best for stable situations where conditions are expected to remain the same. In other words, time series can usually be forecasted assuming they are stationary both in mean and in variance.

Time series forecasting can be applied to model such factors as oil price or currency exchange rate. An important class of time series models is the family of autoregressive integrated moving average (ARIMA) models, usually associated with Box and Jenkins (Box and Jenkins 1970).

Non-seasonal ARIMA models are generally denoted ARIMA(p,d,q) where parameters p, d, and q are non-negative integers, p is the order (number of time lags) of the autoregressive model, d is the degree of differencing (the number of times the data have had past values subtracted), and q is the order of the moving-average model. (2.1)

|  |  |
| --- | --- |
|  | (2.1) |

where:

*εt* is stationary time series,

*φi, θj* are parameters of the model,

Δ*d* is difference *d* operator,

is the cumulative distribution function of the standard normal distribution.

Although the existence of ARMA models predates them, Box and Jenkins were the first to approach the task of estimating an ARMA model in a systematic manner. Their approach was a practical and pragmatic one, involving three steps:

1. Identification
2. Estimation
3. Diagnostic checking.

These steps are now explained in greater detail according to (Brooks 2008)

##### Step 1

1st step involves determining the order of the model required to capture the dynamic features of the data. Graphical procedures like plotting the data over time and plotting the autocorrelation function (ACF) and partial autocorrelation function (PACF) are used to determine the most appropriate model specification – specifically number of lags *p* and *q* and degree of differencing.

##### Step 2

2nd step involves estimation of the parameters of the model specified in step 1. This can be done using least squares or more often with maximum likelihood function, depending on the model.

##### Step 3

This involves model checking – i.e. determining whether the model specified and estimated is adequate. Box and Jenkins suggest two methods: overfitting and residual diagnostics. Overfitting involves deliberately fitting a larger model than that required to capture the dynamics of the data as identified in stage 1. If the model specified at step 1 is adequate, any extra terms added to the ARMA model would be insignificant. Residual diagnostics imply checking the residuals for evidence of linear dependence which, if present, would suggest that the model originally specified was inadequate to capture the features of the data. The ACF, PACF or Ljung-Box tests could be used.

Also, such approaches to determining the adequacy of the model could only reveal a model that is underparameterised (‘too small’) and would not reveal a model that is overparameterised (‘too big’).

##### Choice of model

It is usually the objective to form a model, which is one that describes all of the features of data of interest using as few parameters (i.e. as simple a model) as possible. (Brooks 2008)

The identification stage would now typically not be done using graphical plots of the ACF and PACF. The reason is that when real data is used, it unfortunately rarely exhibits the simple patterns that are generally used to perform graphical analysis. This makes the ACF and PACF very hard to interpret, and thus it is difficult to specify a model for the data.

Another technique, which removes some of the subjectivity involved in interpreting the ACF and PACF, is to use what are known as information criteria. Information criteria embody two factors: a term which is a function of the residual sum of squares (RSS), and some penalty for the loss of degrees of freedom from adding extra parameters. So, adding a new variable or an additional lag to a model will have two competing effects on the information criteria: the residual sum of squares will fall but the value of the penalty term will increase.

The object is to choose the number of parameters which minimizes the value of the information criteria. So, adding an extra term will reduce the value of the criteria only if the fall in the residual sum of squares is sufficient to more than outweigh the increased value of the penalty term. There are several different criteria, which vary according to how stiff the penalty term is. The three most popular information criteria are Akaike’s information criterion (AIC) (Akaike 1974), Schwarz’s Bayesian information criterion (SBIC) (Schwarz 1978), and the Hannan-Quinn criterion (HQIC) (Hannan and Quinn 1979).

#### Qualitative

Qualitative forecasting uses subjective judgment and expert opinion to forecast results. Qualitative forecasting is widely used in industry, relying on experts in estimation of inputs for the models. Applied for oil and gas project this type of forecasting is used widely for estimation of the extractable resources of an oil field. These methods work best for situations for which there are no historical data or models available.

#### Simulation

Simulation provides insight not only on expected value of the forecasted variable, but also on its distribution and probabilities. (Mun 2002) determines simulation as one of the forecasting types, but for logic of this thesis simulation is considered also an enhancement of linear regression forecasting, which is fully described later.

Simulation in general is any analytical method that is meant to imitate a real-life system. It is usually used when analytical methods cannot be applied to the problem due to its complexity or lack of the methodology. This method works best where historical data is not available or not enough, but it is possible to build the model of the situation to analyze its behavior.

Monte Carlo simulation randomly generates many different scenarios for a model to forecast the possible outcomes by repeatedly picking values from the probability distribution for the uncertain variables and using those values for the event through a predetermined model. Latin hypercube – a more profound analogue of Monte Carlo method is used in this thesis.

As all those scenarios produce associated results, each scenario can have a single forecast. Forecasts are events (usually with formulas or functions) that are defined as outputs of the model. These usually are events such as totals, net profit, or gross expenses. However, in real options analysis it is used in order to determine the value of real options through modelling the *volatility* of an underlying asset. It will be described in details in the following section on Monte Carlo simulation.

### Base case NPV model

Base case NPV model transforms inputs from previous two steps into an estimation of expected net present value of the project. It accounts for the riskiness in terms of WACC, however, it cannot capture the flexibilities. This is the last step of traditional valuation approach.

Discounted cash flow model serves as the base case analysis, where a net present value is calculated for the project. This net present value is calculated using the traditional approach of forecasting revenues and costs, and discounting the net of these revenues and costs at an appropriate discounting rate.

The data for the model is obtained from time series forecasting, in case it is possible, or management assumptions may have to be used if environment is extremely unpredictable or there is no developed methodology that could describe the external factors of the project.

NPV approach cannot capture managerial flexibilities built into the project. It assumes passive management in static and predictable environment. In other words, management follows the predefined plan of the project, which was developed before the realization and is not to be changed to adopt actual realization of underlying uncertainties, such as oil price or currency exchange rate.

Following steps are performed in order to estimate value of managerial decisions and assume active management – changing the actions throughout the project life span.

### Monte Carlo simulation

Because the static discounted cash flow produces only a single-point estimate result, there is often little confidence in its accuracy given that future events that affect forecast cash flows are highly uncertain. To better estimate the actual value of a particular project, Monte Carlo simulation may be employed.

Monte Carlo simulation is the first step of dynamic approach. It uses results of the first three steps as inputs and is conducted in order to estimate riskiness of the project not in terms of discount rate, but as a simulated standard deviation of the returns of project’s cash flows.

The uncertain key variables that drive the net present value and hence the decision are called critical success drivers. According to (Mun 2002) these critical success drivers are prime candidates for Monte Carlo simulation. Because some of these critical success drivers may be correlated – for example, operating costs may increase in proportion to quantity sold of a particular product, or prices may be inversely correlated to quantity sold – a correlated Monte Carlo simulation may be required. Typically, these correlations can be obtained through historical data. Running correlated simulations provides a much closer approximation to the variables’ real-life behaviors.

### Description of real options

After simulation modeling we possess all the necessary data to estimate the value of real options. At this step real options should be identified and linked to the built in flexibilities and uncertainties of the project. The strategic optionalities may include, among other things, the option to expand, contract, abandon, switch, choose, and so forth. Based on the identification of strategic optionalities that exist for each project or at each stage of the project, real options can be described for the later estimation.

### Valuation of real options and adjustment of the base case NPV

Valuation of real options use all the previous steps as inputs in order to estimate the value of managerial flexibility. Black and Scholes formula along with binomial trees are used to get the final estimation.

In real options, we assume that the underlying variable is the future profitability of the project, which is the future cash flow series. An implied volatility of the future free cash flow or underlying variable can be calculated through the results of a Monte Carlo simulation previously performed.

Usually, the volatility is measured as the standard deviation of the logarithmic returns on the free cash flows stream. In addition, the present value of future cash flows for the base case discounted cash flow model is used as the initial underlying asset value in real options modeling.

Real options analysis does not substitute the traditional NPV approach, it rather enhances it through adding the value of managerial flexibilities under assumption of active management. Thus the NPV estimation from the third step is adjusted to the value of real option.

### Formulating risk management recommendations

Real options analysis allows not only to estimate the value of active management under uncertainty but also to formulate recommendations for specific actions, such as leaving the project or expanding the capacity.

Real options analysis assumes that the future is uncertain and that management has the right to make midcourse corrections when these uncertainties become resolved or risks become known; the analysis is usually done ahead of time and thus, ahead of such uncertainty and risks. Therefore, when these risks become known, the analysis should be revisited to incorporate the decisions made or revising any input assumptions. Sometimes, for long-horizon projects, several iterations of the real options analysis should be performed, where future iterations are updated with the latest data and assumptions.

## Chapter summary

Oil and gas industry remains a core part of Russian economy. Specifics of natural resources allow Russian market participants to enjoy favorable upstream cost structure. However, location of oil and gas fields require complex and expansive infrastructural investments and profound technologies, that often require participation of foreign investors.

Projects in oil and gas in general are very capital intensive and differ from many others with their extremely long lifespan. Due to complexity and broad planning horizon projects in oil and gas industry are subject to wide range of uncertainties, which can be grouped into three main categories.

Economic uncertainty includes all market variables that influence the projects inflows. Volatile world oil price is main contributor to overall risk level in oil and gas projects. However, operations in Russia lead to increase in economic uncertainty due to high variance of Russian ruble exchange rate and fluctuations of debt interest rates.

Technical uncertainty includes uncertainty in exploration and extractable reserves forecast and uncertainty connected to accidents. While the second one is purely unfavorable for the project and can lead to environmental threats, the first can be both positive and negative and requires according adjustment of the project.

Political uncertainty contributes to overall volatility of oil and gas investment project and remain one of driving factors in industry development. Russian specifics increase this type of uncertainty if compared to developed countries due to many factors, including the fact that major market players are state owned companies that follow guidance of the top level of government.

An important tool for managing uncertainties is real options analysis. It can offer recommendations for managing economic and partially technical risk, however, political risks are not within the scope of the method.

Real options analysis helps to identify flexibilities built into the projects. Those include ability to defer the investment, to stage investment, to adjust capacity during lifespan, to temporarily shut down, to exit for salvage value, etc.

Identification of real options contribute to both increasing overall expected cash flows and decreasing risk of the investment. Done in advance real options analysis provide valuable insight on how project could be changed in order to increase its flexibility (i.e. managers’ ability to adjust it) and therefore its value for the investor.

Real option analysis can be performed in 7 stages, which include steps of traditional analysis (project description, forecasting, base case NPV) and specific for real options approach (simulation, description of real options, valuation of real options, formulating risk management recommendations).

Application of real options analysis to oil and gas projects allow to evaluate flexibilities under assumption of active management of the project and adjust base case NPV with this value. It provides recommendations on risk management – describe actions that should be undertaken throughout the project, determine conditions when options should and should not be executed.

# Case Study

*This chapter provides an illustrative example of real option analysis applied to a specific case of shelf oil field in Russia. It consists of 8 parts. First 7 follow the 7-step approach of real options analysis adopted from* (Mun 2002) *and described in Chapter 2. They provide detailed description of real option analysis application to a specific project. The 8th part summarize the contents of the chapter and provide conclusions.*

## Project description

The project is an oil field located on the sea shelf 50 kilometers off the shore. Sea depth at the site is about 20 meters. Total recoverable reserves are 74 million tons, i.e., some 540 million barrels. Crude oil will be shipped from the platform year-round with a peak-period production level of around 120,000 barrels per day.

The platform used to develop the field is an Offshore Ice-Resistant Fixed Platform. Production starts three years later. The platform measures 126 by 126 meters and has an un-ballasted weight of 117,000 tons. A total of 40 wells are planned to be drilled from the platform, which has a storage capacity of 855,000 barrels of oil, i.e., just over six days during the peak production period. Oil and gas company owns and operates the field while the contractor for construction of the platform is a government-owned shipyard, which traditionally has constructed military vessels such as nuclear submarines.

Onshore infrastructure includes a base camp and helipad near the oil terminal on the sea shore, an office and amenity compound as well as an offshore supply base.

The platform is reportedly designed to be able to serve other fields in the area and would thus serve as a production hub for the area and consequently provide economic ripple effects for other fields.

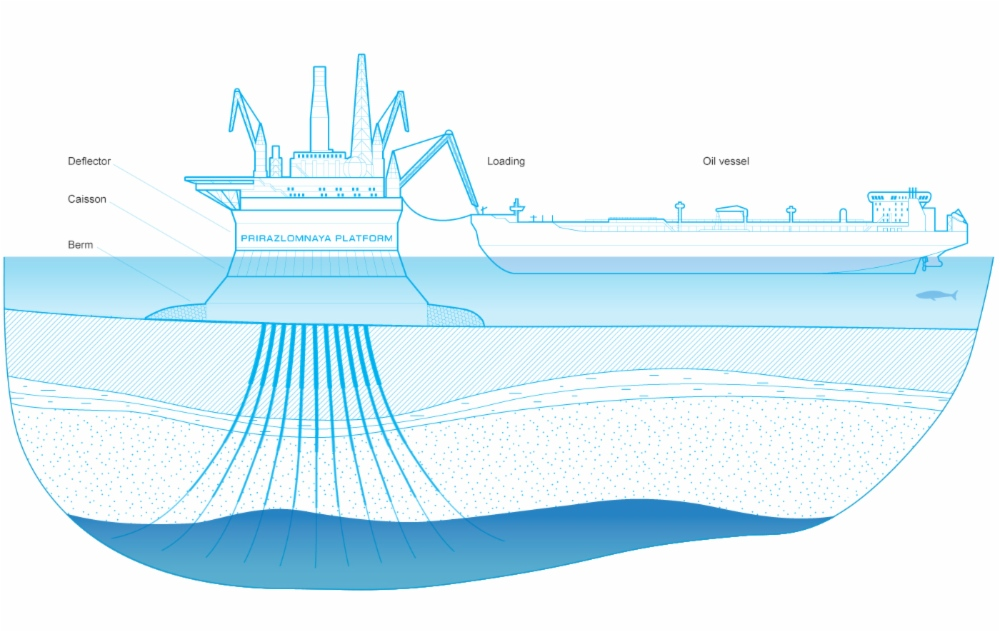


Figure 6. Offshore Ice-Resistant Fixed Platform. Source: http://www.gazprom.ru

## Time series forecast

In order to determine the cash flows of the project it is necessary to project the future state of the economy. Main drivers of the project inflows and outflows are world oil prices and Russian ruble to US dollar exchange rate. Both of them were considered in the forecast.

Applied time series analysis follows the algorithm below:

1. Stationarity tests of time series
2. Box Jenkins model fitting approach for ARIMA (p, d, q) model
   1. Identification
   2. Fitting
   3. Check
3. Choice of best model using information criteria

Model fitting was conducted in Palisade @RISK software, which automatically follows the process described above in order to choose the best model for the data. Forecasted time series – logarithms of monthly URALS price, which in the first differences equal to the logarithmic return on the asset.

The forecast of oil prices was conducted based on the monthly URALS spot prices from 01.01.1985 till 01.01.2017. ARIMA (0, 1, 1) for logarithms demonstrated best performance and was chosen according to BIC criteria. This process is equal to MA (1) process on the first differences for logarithms of the URALS price.

Figure 7. Results of forecasting of main external variables, USD. Source: Author´s figure.

Figure 7 describes the results of time series forecast and contains average forecasted values. URALS price is expected to have a roughly 2% annual growth rate throughout the period. Average price is above $50 per barrel, while Russian ruble exchange rate is below 60 rubles per US dollar.

World oil prices directly affect the revenue, generated by the project while the volume of production is predetermined. However, it is important to note that the actual level of production may significantly differ from the projections due to imperfections of estimation methods and is thus simulated later in this section.

Actual level of extractable reserves, and linked to it production volume, is a major risk for any oil field project is that directly affects annual capacity and thus revenues. The estimation was modeled using triangular distribution based on expert estimates later in this chapter.

## Base case NPV model

Base case NPV model transforms inputs from previous two steps (i.e. assumptions and projections of time series and underlying uncertainty factors of the project) into an estimation of expected net present value of the project. It accounts for the riskiness in terms of WACC through discounting cash flows, however, it cannot capture the flexibilities. This is the last step of traditional valuation approach.

NPV model for the project follows standard approach of estimation FCF and use forecast data on URALS price and ruble exchange rate as inputs along with all the data and assumptions on the project (Appendix 4).

This section provides in-details description of cash inflows and outflows of the project, states the methodology of their estimation, and represents results of the modeling according to the following structure:

1. Production
2. Revenue
3. Costs
   1. CAPEX
   2. OPEX
4. Taxation
   1. Mineral extraction tax
   2. Export duties
5. Free cash flows and NPV

### Production

Actual production volume depends on actual level of extractable reserves and is a major risk for any oil field project as it directly affects revenues. NPV model use expert estimation (i.e. most probable) value of the extractable reserves for FCF calculation.

Figure 8. Oil production profile of the project, million tons/year. Source: Author´s figure.

Total extractable reserves are 74 million tons. With roughly 6 million tons of maximal annual capacity of the platform it leads to 22 years of operations. Figure 8 describes the production profile of the oil field throughout the planning horizon.

Actual level of production will be determined after the beginning of operations. However, basic NPV approach cannot capture this flexibility and assumes that it is predetermined and cannot neither decrease nor increase. Real options analysis allows to handle this uncertainty through Monte Carlo simulation of cash flows volatility caused by variability of the oil field actual extractable reserves.

### Revenue

Revenue of the project are fully determined by level of production, world oil prices, and Russian ruble exchange rate. Their distribution during the project is mainly linked to the production levels from the previous section.

There is a slight difference between growth of cash inflows in terms of USD and RUR due to the forecasted value of Russian ruble exchange rate, which is expected to strengthen during the period as it depends on URALS price which is expected to increase as well.

Figure 9. Revenues of the project. Source: Author´s figure.

The project starts to generate the highest revenue inflows from the end of seventh year. First three periods generate zero revenue as this is a time of construction process, required to build the infrastructure, move and install the platform and start the production. First inflows start from year 4 and continue till year 25.

Years 4 – 7 form a period of exponential increase of revenue inflows from 10 billion rubles in period 4 to roughly 130 billion rubles in period 7. This increase is limited naturally by the capacity of the oil platform and extractable reserves of the oil field.

Years 7 – 13 form a period of stable inflows of about 130 – 160 billion rubles annually when the production is held at full capacity levels or close to them.

Years 13 – 25 form a period of exponential decline in revenues from roughly 140 billion rubles to zero due to rising level of depletion of the site’s reserves.

### Costs

#### CAPEX

Shelf projects require major investments in exploration, field development, transport infrastructure and onshore facilities before oil extraction can be started on the continental shelf.

Total CAPEX of the project is $5 700. It is distributed equally throughout first 6 years of construction.

The offshore ice-resistant fixed platform is the main cost driver of the project. It is built specifically for the oil field, although it can be moved to another sites if required. The platform is used for all production operations, namely well drilling, oil extraction, storage, treatment and offloading. The platform can be used in extreme weather conditions; it is compliant with the strictest safety requirements and resistant to maximum ice loads.

The wellheads of all wells to be drilled at the field are located within the platform, while its foundation serves as a buffer zone between the well and the open sea. In addition, the equipment installed at the wells is meant to prevent blowouts of oil or gas. The offloading line used for transferring oil to tankers is used to ship oil right from the platform.

#### OPEX

The main types of operating costs on the shelf are those related to the maintenance of platforms and wells and the costs of day-to-day operation of the facilities. These include labor costs for all personnel who are involved in running modifications and maintenance of machinery and other equipment that is essential if costly stoppages are to be avoided. And all other associated costs. It equals to 3% of CAPEX annually for the period of a full capacity production, and varies accordingly within the project lifespan.

### Taxation

Taxation is a tricky part as it comes to oil and gas projects. Russian tax system ensures that government will get maximal tax inflow no matter what external factors turn out to be. Tax rates depend on world oil prices, Russian ruble exchange rate, extractable reserves, location of the oil field, and share of the reserves left to extract. This section is mainly adopted from a report by EY (Ernst & Young Global Limited 2014)

Russian oil and gas producers pay the following taxes:

* *Mineral extraction tax (MET)*
* *Customs payments*
* 20% profits tax
* 18% value added tax
* Payments for the use of mineral resources
* Other taxes applicable to legal entities
* Excise duties

The main tax burden on Russian companies in the upstream segment consists of MET and export duties, which, at the current price for oil, account for more than 90% of tax payments in that segment. Companies in the downstream segment do not pay MET or make payments for the use of mineral resources, but do pay excise duties on petroleum products.

#### Export duties for crude oil and petroleum products

The rates of customs duties are set by the Ministry of Economic Development on a monthly basis, using average prices for Urals crude oil on world crude markets (Mediterranean and Rotterdam) during the monitoring period (from the 15th of each calendar month through the 14th of the following calendar month). The maximum rate of export duty on crude oil is calculated as indicated in the following able, in accordance with the provisions of the Law of the Russian Federation “On the Customs Tariff”:

|  |  |
| --- | --- |
| Actual oil price in world markets per barrel (USD) | Rates of export duty per barrel (USD) |
| Up to $15 | 0% |
| From $15 to $20 | 35% \* (actual price – $15) |
| From $20 to $25 | $1.75 + 30% \* (actual price – $20) |
| Above $25 | $4 + 30% \* (actual price – $25) |

Figure 10. The maximum rate of export duty on crude, in accordance with the provisions of the Law of the Russian Federation “On the Customs Tariff”. Source: (Ernst & Young Global Limited 2014)

Special reduced rates of export duty are introduced for:

* Super viscous oil with a viscosity under formation conditions of not less than 10,000 mPa·s
* Oil with special physical and chemical properties produced in new oilfields in a number of remote and hard-to-reach areas, using methods that take project economy into account
* Oil from fields on the Russian continental shelf

Export duty rates on petroleum products are set by the Ministry of Economic Development of the Russian Federation as a percentage of the rate for crude oil. Current maximum coefficients for certain listed categories are:

* Light petroleum products (with the exception of gasoline) – 65%
* Dark petroleum products – 66%
* Gasoline (including naphta) – 90%

Export duty is not charged on oil or oil products exported to Customs Union countries (Kazakhstan and Belarus).

Federal Law No. 268-FZ of 30 September introduced a special tax regime for export duties on products extracted from continental offshore projects. This regime provides for an exemption from paying export duties during a specified period.

#### Mineral extraction tax

MET is charged on mineral resources, including natural fuel gas, gas condensate and commercial oil.

##### Oil taxation

When the changes go into effect, the following formula will be used to calculate the rate of MET on oil (3.1), (3.2):

|  |  |
| --- | --- |
|  | (3.1) |
|  | (3.2) |

*where:*

*BR* is the base rate of MET. The current rate is 919 Russian rubles per ton from 2017.

*CP* represents the dynamics of world oil prices, calculated by the taxpayer using the following formula *(3.3)*:

|  |  |
| --- | --- |
|  | *(3.3)* |

*where:*

*P* is the average price of Urals oil for the tax period in US$ per barrel.

*R* is the average exchange rate of the US dollar against the Russian ruble in the tax period, as established by the Central Bank of the Russian Federation.

*EМ* represents oil extraction factors depending on the following coefficients:

*CMET* is equal to 559 from 2016.

CD represents the level of depletion (LD) of a given site’s reserves. If the level of reserve depletion of a specific subsurface site is greater or equal to 0.8 and less or equal to 1, inclusive,

CD is calculated according to the following formula (3.4):

|  |  |
| --- | --- |
|  | *(3.4)* |

*where:*

*N* is the amount of accumulated oil extraction at a specific subsurface site (including production losses), according to the state’s balance sheet of reserves of commercial minerals approved in the year preceding the year of the tax period in which CD is calculated.

*V* represents initial recoverable oil reserves.

CD is 0.3 if the level of reserve depletion (LD) of a specific subsurface site exceeds 1. The coefficient CD is 1 if the level of reserve depletion (LD) is less than 0.8.

CR represents the quantity of a given site’s reserves; it involves a reduction in MET for new minor sites. If a specific subsurface site has initial recoverable oil reserves of less than 5 million tons, and reserve depletion on the site is less than or equal to 0.05, CR is calculated using the following formula (3.5):

|  |  |
| --- | --- |
|  | (3.5) |

*where:*

*VR* represents initial recoverable oil reserves.

Otherwise, CR is equal to 1.

CDE represents the difficulty involved in extracting oil (type of pay zone, permeability, maximum net oil pay). CDE may be 0.2, 0.4, 0.8 or 1, depending on a combination of factors. CDE is applicable only if the following conditions are met concurrently:

* The quantity of oil produced is recorded for each well operating on a hydrocarbon deposit.
* The quantity of well fluid extracted is measured, and its physical and chemical attributes are determined for each operating well on a hydrocarbon deposit at least four times a month.

If these criteria are met, a reduced coefficient (less than 1) may be applied for within 15 years, beginning on 1st January of the year in which the depletion of a hydrocarbon deposit’s reserves first exceeded 1%. In this case, the level of reserve depletion is determined not for a site, but for a hydrocarbon deposit. A hydrocarbon deposit is recognized as an item of accounting in the state’s balance sheet of mineral reserves on a particular site, which was not found to comprise any other items of accounting for reserves. The level of depletion of a particular hydrocarbon deposit’s reserves is calculated by the taxpayer based on the cumulative amount of oil produced on a particular hydrocarbon deposit (including production losses) and initial recoverable oil reserves according to the approved state balance sheet of mineral reserves.

CRD applies to hard-to-recover oil and is calculated for a deposit, depending on the level of its depletion. CRD may be in a range from 0.3 to 1.0.

CCAN represents oil extraction region and properties. It will equal zero for oil produced on sites that are located wholly or partially within the borders of the Republic of Sakha (Yakutia), the Irkutsk Region, the Krasnoyarsk Territory, the north of the Arctic Circle, in the Sea of Azov, the Sea of Okhotsk, the Black Sea or the Caspian Sea, in the Nenets Autonomous District or on the Yamal Peninsula in the Yamalo-Nenets Autonomous District.

CCAN is applicable if at least one of the following conditions is met:

* If the established cumulative level of oil production is not exceeded
* If the date of issue of the license, the level of reserve depletion and the development term are within certain limits
* If the site’s reserves are developed within the established period

CCAN will also equal zero for superviscous oil that is extracted from sites containing oil of a viscosity exceeding 200 mPa\* s and less than 10,000 mPa\* s. Otherwise, CCAN is equal to 1.

A zero tax rate applies to the actual amount of hydrocarbons extracted, which include:

* Superviscous oil extracted from sites containing oil of a viscosity of 10,000 mPa·s or more
* Oil extracted from a specific hydrocarbon deposit that is part of the Bazhenov, Abalak, Khadum or Domanik formations, subject to compliance with legislative requirements.

Appendix 4 provide information on calculation of the export duties and mineral extraction tax of the project in accordance with the rules stated above.

### Free cash flows and NPV

Free cash flows and discounted free cash flows of the project are distributed in the following manner:

Figure 11. Distribution of free cash flows and discounted free cash flows, million Russian rubles. Source: Author´s figure.

It can be noted that the distribution of the cash flows throughout projects lifespan is connected mainly with the production level. It easily explained with the underlying assumptions of NPV modeling: passive management and predetermined state of external environment, specifically oil price. Outlier cash flow of the last year include abandonment costs and is therefore negative.

NPV of the project without value of built in flexibility is 2 018 million rubles. However, it can be significantly improved that shall be demonstrated below.

## Monte Carlo simulation

In order to estimate the real options built into the project the Monte Carlo simulation was applied. It allows to use actual volatility of the cash flows, which include all the uncertainties stated, in order to estimate value of the option.

### Modeling uncertainties

#### URALS oil price and Russian ruble exchange rate.

In order to simulate the uncertainty in oil prices ARIMA (0,1,1) model on logarithms of the time series was used. We assume a strong correlation between Russian ruble exchange rate and URALS oil prices, which is used in a simulation model.

#### Extractable reserves

Level of real extractable reserves contribute a lot to the volatility of the project cash flows. Triangular distribution based on expert estimations is used in order to model the volatility. With 540 million barrels most likely field reserves, 432 minimum field reserves and 648 maximum field reserves levels.

### Volatility estimation

The logarithmic present value approach was chosen to determine volatility. The logarithmic present value approach collapses all future cash flow estimates into two sets of present values, one for the first time period and another for the present time. This approach was first introduced by Tom Copeland (Copeland and Antikarov 2003). The steps are seen below. The cash flows are discounted all the way to time 0 and again to time 1. Then the values are summed, and the following logarithmic ratio is calculated using (3.6):

|  |  |
| --- | --- |
|  | *(3.6)* |

where *FCFi* is the value of future cash flows at different time periods *i*. (Mun 2002)

Using this *X* value, it is possible to perform a Monte Carlo simulation on the discounted cash flow model and obtain the resulting forecast distribution of X. The standard deviation of the forecast distribution of X is the volatility estimate used in the real options analysis. It is important to note that *only the numerator is simulated* and the denominator is unchanged.

The downside to estimating volatility this way is that Monte Carlo simulation is required, but the calculated volatility measure is a single-digit estimate, as compared to the logarithmic cash flow approach, which yields a distribution of volatilities, which will in turn yield a distribution of calculated real options values. The main objection to using this method is its dependence on the variability of the discount rate used. For instance, we can expand the *X* equation as follows (3.7):

|  |  |
| --- | --- |
|  | (3.7) |

where *r* represents the constant discount rate used.

Here, we see that the cash flow series *CF* for the numerator is offset by one period, and the discount factors are also offset by one period. Therefore, by performing a Monte Carlo simulation on the cash flows alone versus performing a Monte Carlo simulation on both cash flow variables as well as the discount rate will yield very different *X* values.

Modifications to this method include duplicating the cash flows and simulating only the numerator cash flows, thereby providing different numerator values but a static denominator value for each simulated trial, while keeping the discount rate constant. This approach reduces the measurement risks of autocorrelated cash flows and negative cash flows and was used in this thesis for the project volatility estimation.



Figure 12. Results of simulation. Source: Author´s figure.

Resulting standard deviation of returns is 81,2%, which is high. However, it is connected to volatile oil prices, which mostly account for the risk.

## Description of real options

Real options of the project are directly connected to the flexibilities of the management. The design of the project, Russian specifics and usage of offshore ice-resistant fixed platform allow investor to actively manage the project during its lifespan.

### Option to wait

The project does not require the company to invest immediately, as a result management is able to wait and see how the uncertainty about future world oil price is resolved.

This flexibility adds value t the investment and can be captured with a real option to wait. By its design the option can be executed during unlimited timeframe. However, we assume that under conditions of real life 10 years is a maximal period to make decision about participating or leaving the project.

### Option to abandon

The project uses an offshore ice-resistant fixed platform to develop the field. Cost of the platform is one of the main drivers of CAPEX an is roughly 50% of the initial investment (Lunden and Fjaertoft 2014). However, the platform offers significant flexibility as is can be moved to different oil fields or sold to another company.

Another 50% of capital expenditures cannot be reused in different projects or sold to third parties as are project specific and include mainly infrastructural objects onshore, located near the platform. This part thus does not provide any flexibilities for leaving the project and does not affect the price of the option to wait.

Offshore ice-resistant fixed platform provides the investor with an opportunity to exit the project in case real present value of all the cash flows turns out to be lower than salvage value of the platform.

Both platform sale and reutilization can be treated as an exit for salvage value. In case of sale, the price of the realization to a third party composes the salvage value for the investment project. In case of reutilization salvage value equals to savings on capital expenditures (specifically on construction or purchase of a new platform) of new investment project.

For the analysis of the project salvage value is calculated as book price of the platform net of cumulated amortization and depreciation.

## Valuation of real options and adjustment of the base case NPV

### Option to wait

To solve the timing option, we follow (Mun 2002) and start by assuming that the value of an underlying asset’s *X = (Xt)* follows a Geometric Brownian Motion*.* Then the value of a call option is described by (3.8):

|  |  |
| --- | --- |
|  | (3.8) |

*where:*

*I* is the initial capital investment outlay,

*XT* is the time value of the underlying asset at the terminal time *T,*

*r* is the discount rate.

The optimal investment strategy is to maximize the value of the option with respect to time *T* given the underlying stochastic investment process *X*. The following formula provides the solution of this problem (3.9):

|  |  |
| --- | --- |
|  | (3.9) |

where *α* is growth rate (drift) of underlying asset.

Option to wait captures managerial ability to postpone investment decision in order to resolve the uncertainties, mainly URALS price. Its value depends on expiration date. It is maximal in **7 years 11 months**.



Figure 13. Valuation of option to wait. Source: Author´s figure.

### Option to abandon

Option to abandon captures managerial ability to exit the project and use the platform for other fields development. It significantly increases the NPV of the project as it allows the management to handle all the extreme realizations of uncertainty through leaving the project for salvage value.

First step of valuation is construction of binomial lattice of underlying asset value based on the geometric Brownian motion and no arbitrage assumptions. This tree is formulated assuming risk neutral investors and that the price either increases or decreases in each period, as expressed by (1.14)

The probabilities of occurrence of a price increase *(p)* and decrease *(1 – p)* are set to guarantee a zero expected gain from trading the product.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PV of inflows | *0* | *1* | *2* | *3* | *4* |
| *0* | **233 244** | 523 748 | 1 176 077 | 2 640 882 | 5 930 100 |
| *1* |  | 103 872 | 233 244 | 523 748 | 1 176 077 |
| *2* |  |  | 46 258 | 103 872 | 233 244 |
| *3* |  |  |  | 20 600 | 46 258 |
| *4* |  |  |  |  | 9 174 |

Figure 14. Binomial lattice for present value of cash inflows (first 5 periods). Source: Author´s figure.

Second step is adjustment of binomial lattice to managerial flexibility. At each period management can compare expected present value of the project and salvage value of investments. In case salvage value exceeds expected present value, the project shoul be abandoned, otherwise it should be continued.

Both platform sale and platform reutilization can be treated as an exit for salvage value. For the analysis of the project salvage value is calculated as book price of the platform net of cumulated amortization and depreciation.

Figure 15 captures this flexibility for first 5 periods.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Option to abandon | *0* | *1* | *2* | *3* | *4* |
| *0* | **270 620** | 550 115 | 1 190 852 | 2 647 973 | 5 933 074 |
| *1* |  | 152 955 | 270 026 | 545 028 | 1 186 534 |
| *2* |  |  | 109 501 | 154 806 | 263 756 |
| *3* |  |  |  | 100 093 | 116 201 |
| *4* |  |  |  |  | 105 754 |

Figure 15. Binomial lattice for present value of cash inflows with option to abandon (first 5 periods). Source: Author´s figure.

Creating the option valuation lattice proceeds in two steps, the valuation of the terminal nodes and the valuation of the intermediate nodes using a process called backward induction. If you recall from the first lattice, the values are created in a forward multiplication of up and down factors, from left to right. For this second lattice, the calculation proceeds in a backward manner, starting from the terminal nodes. That is, the nodes at the end of the lattice are valued first, going from right to left.

Figure 16 describes inputs for the estimation and main outputs of the model.

Figure 16. Valuation of option to abandon. Source: Author´s figure.

By having a platform that can be moved to another oil field or sold, and therefore provides a way out for management given dire circumstances, the project is worth more than its static net present value of 6 billion rubles. The 6 billion rubles is the static NPV without flexibility, the 37 billion rubles is the real options value, and the combined value of 44 billion is the expanded net present value of the project (eNPV) according to (1.6).

## Formulating risk management recommendations

### Option to wait

Option to wait has maximum value if it expires in 7 years and 11 months. It means that within this period acquiring information on realizations of uncertainty (specifically, Russian ruble exchange rate and world oil prices) adds value to the project.

Notice that the period 7 years 11 months provides the maximum NPV. Hence, this maximum NPV of 19 billion RUB determines the option value of waiting to be 13 billion RUB, as compared to 6 billion RUB NPV if the project is executed immediately.

Management should not postpone investment beyond this timeframe, however they can start earlier.

**Option to abandon**

Option to abandon defines future situations when active management will increase value of the project. In nodes (5;4), (5;5), (6;4) and so forth the option has to be executed and investor should leave the project for salvage value as expected future cash inflows are *lower* than inflow from platform sale or reutilization.

This approach allows to account for extreme conditions of external environment and factors of the uncertainty and thus significantly increase the value of the project and reduce level of risk i.e. the volatility of the returns.

Figure 17 describes the managerial recommendation for the first 7 periods, and Appendix 1 provides overview of the full lattice.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Option to abandon | *0* | *1* | *2* | *3* | *4* | *5* | *6* |
| *0* | Develop | Develop | Develop | Develop | Develop | Develop | Develop |
| *1* |  | Develop | Develop | Develop | Develop | Develop | Develop |
| *2* |  |  | Develop | Develop | Develop | Develop | Develop |
| *3* |  |  |  | Develop | Develop | Develop | Develop |
| *4* |  |  |  |  | Develop | ***Abandon*** | ***Abandon*** |
| *5* |  |  |  |  |  | ***Abandon*** | ***Abandon*** |
| *6* |  |  |  |  |  |  | ***Abandon*** |

Figure 17. Risk management recommendations for option to abandon execution. Source: Author´s figure.

## Chapter summary

Illustrative case – shelf oilfield development project – is a long term capital intensive investment project with 20 years planning horizon. It includes large investment into offshore and onshore infrastructure and subject to numerous risks.

Main contributor to overall fluctuation of expected cash inflows – price of URALS oil and connected ruble exchange rate. Uncertainty in extractable reserve is next most significant reason of volatility. Price of URALS was forecasted with ARIMA model based on historical data. Extractable reserves were modeled with triangular distribution based on expert estimations.

NPV of the project without value of built in flexibility is 6 155 million rubles. However, it increases significantly when built-in real options are accounted for.

Project has two main flexibilities – ability to defer the investment and option to abandon the project for salvage value, which is granted by the platform that can be moved to another oilfield or sold to third party.

Valuation of option to wait demonstrated that investor can increase value of the project by roughly 13 billion rubles through waiting no longer than 7 years 11 months until uncertainty is resolved. Within this timeframe passive waiting will contribute to overall present value of the project and can thereby be critical for investor.

Option to abandon significantly improves financial outcomes of the project. It allows exiting the project if uncertainty will resolve into unfavorable conditions, and first of all if the extractable reserves turn out to be lower than expected.

With a platform that can be moved to another oil field or sold the project is worth more than its static net present value. Value of option to abandon is 37 billion rubles, and the combined value of 44 billion is the expanded net present value of the project (eNPV)

Description and valuation of option to abandon determines conditions when the option should be executed to handle the unfavorable conditions that is when expected present value of cash inflows is lower than salvage value of the platform.

# Conclusion

The main goal of this thesis was to investigate application of real options analysis to Russian oil and gas investment projects and provide an illustrative example of possible application. This goal is based on the hypothesis that existing discounted cash flow method traditionally used for the valuation, planning, and design of the oil and gas investment projects can be improved by addressing the flexibility embedded within the projects and their environment, which can be evaluated with real options analysis.

The research was driven primarily by following factors:

1. The importance of oil and gas industry for Russian economy;
2. Specifics of oil and gas projects (i.e. long life span and high uncertainty);
3. Specifics of Russian market that increase uncertainty of oil and gas projects;
4. The drawback of traditional DCF techniques of undervaluing flexible projects under uncertainty;
5. The potential of real option analysis to address these drawbacks.

Projects in oil and gas in general are very capital intensive and differ from many others with their extremely long lifespan. Due to complexity and broad planning horizon projects in oil and gas industry are subject to wide range of uncertainties.

The research shows that majority of projects, including those in oil and gas industry, are assessed with traditional techniques, based on idea of discounted cash flows, which allow a logical, well accepted, and reasonable assessment. However, DCF techniques are not capable to account for the flexibility in a project that allows management to adjust the project in response to external environment. Consequently, traditional techniques tend to undervalue flexible projects under uncertainty. This factors can be correctly evaluated by enhancing traditional NPV with real options analysis.

*“Real option”* is defined as the right, without obligations, to adjust a project in response to the evolution of uncertainty. Real options analysis is known for properly addressing the flexibility embedded within projects, which is modelled as options to adjust the projects in response to the evolution of uncertainty. The benefits of real option analysis are not limited to enhancing the value of flexible projects. Real option analysis theory also provides insights about the projects’ risk management, and helps to identify potential design changes that can increase the profitability of projects through increase in managerial flexibility.

Oil and gas industry in Russia was investigated applying to real options analysis, including main uncertainties and flexibilities. Oil and gas industry remains a core part of Russian economy. Allocation of oil and gas resources allow Russian market participants to enjoy extremely low upstream costs. However, location of oil and gas fields require complex and expansive infrastructural investments and profound technologies, that often require participation of foreign investors.

Projects in oil and gas in are depend on numerous factors of uncertainty which can be divided into three groups: economic, technical and political. All types of uncertainties are stronger in Russian market if compared to developed countries. Real options analysis can offer recommendations for managing economic and partially technical risk, however, political risks are not within the scope of the method.

Real option analysis can be performed in 7 stages, which include steps of traditional analysis (project description, forecasting, base case NPV) and specific for real options approach (simulation, description of real options, valuation of real options, formulating risk management recommendations).

Algorithm was applied to a specific case, shelf oilfield development project. It is a capital intensive investment project with 25 years’ lifespan. It includes large investment into offshore and onshore infrastructure and is subject to numerous uncertainties. Project has two main flexibilities – ability to defer the investment and option to abandon the project for salvage value, which is granted by the platform that can be moved to another oilfield or sold to third party. Base case NPV of the project is roughly 6 billion rubles.

Valuation of option to wait demonstrated that investor can increase value of the project by roughly 13 billion rubles through waiting no longer than 7 years 11 months until uncertainty is resolved. Within this timeframe passive waiting will contribute to overall present value of the project and can thereby be critical for investor.

Option to abandon determines conditions when the flexibility should be used to handle the unfavorable conditions that is when expected present value of cash inflows is lower than salvage value of the platform (described by Appendix 1). Option to abandon significantly improves financial outcomes of the project. This flexibility adds 37 billion rubles to the projects value.

Application of real options analysis allowed to estimate the built-in flexibilities that turn out to have a significant influence on project value. It also contributed to formulation of risk management recommendations that increase the expected value of the project and decrease its risk.

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# Appendices

## Appendix 1. Full lattice for Option to abandon



## Appendix 2. Option to wait



## Appendix 3. DCF Model





## Appendix 4. Inputs

## 

1. Refer to equation (1.1) in section “Traditional Valuation Techniques” for explanation of net present value concept. [↑](#footnote-ref-1)
2. *Vt* is the value of the project's expected operating cash flows at time t. [↑](#footnote-ref-2)