

“Real Options Method” vs “Discounted Cash Flow Method” to Analyze Upstream Oil & Gas Projects

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ABSTRACT

Upstream oil and gas project is an example of multiyear investment that has many uncertainties in the whole of project life time (started from exploration, field development and production). Regarding those uncertainties, the executive management is often driven to make a new decision or strategy which may be totally different from previous taken decision.

The Discounted Cash Flow (DCF) method is a most widely used quantitative method to appraise oil and gas field value. Unfortunately DCF method doesn't produce a complete figure of strategy which may address uncertainties appropriately.

In contrary, Real Option method is a method that already captured those uncertainties through probability and volatility metrics. Real Option provides a complete figure of strategy for the whole life time, therefore Real Option method delivers more flexibility to the executive management in decision making process.

Keywords: upstream oil and gas, uncertainties, DCF, flexibility, strategy, decision making process, real option.

1. Introduction

1.1. Exploration & Production (E&P) Business

In commonly business practice, upstream oil and gas should be started by exploration phase. Exploration phase consist of main activities include regional study, play concept, petroleum system, seismic 2D, seismic 3D, hydrocarbon resources estimate and drill exploratory well. The objective of exploration phase is discovery of hydrocarbon.

Discussing about petroleum system, we have to talk about subsurface parameters include source rock, reservoir rock, porosity, hydrocarbon migration, seal, trap. Theses parameters must be exist, as a prerequisite of hydrocarbon discovery. The absence of these parameters may elevate the risk of drilling activity in exploration and it's possible in some circumstances to get dry hole ($P_{\text{dry hole}} = 1 - P_g$). Chance of success an exploration well to discover hydrocarbon is defined as probability of geological success (commonly called as P_g). P_g is product of occurrence five factors as follow:¹

¹ SM IATMI Universitas Diponegoro. Basic Petroleum System. Retrieved from <http://smiatmiundip.wordpress.com/2011/05/01/basic-petroleum-system/>

$$P_g = P_{\text{source}} \times P_{\text{reservoir}} \times P_{\text{structure}} \times P_{\text{seal}} \times P_{\text{migration}} \quad (\text{Equation 1})$$

where:

- P_{source} : the probability of mature source rock
- $P_{\text{reservoir}}$: the probability that reservoir quality rock exists
- $P_{\text{structure}}$: the probability that structure provides a good quality of trap
- P_{seal} : the probability that seal has a good quality (impermeable)
- $P_{\text{migration}}$: the probability that migration occurred in good timing

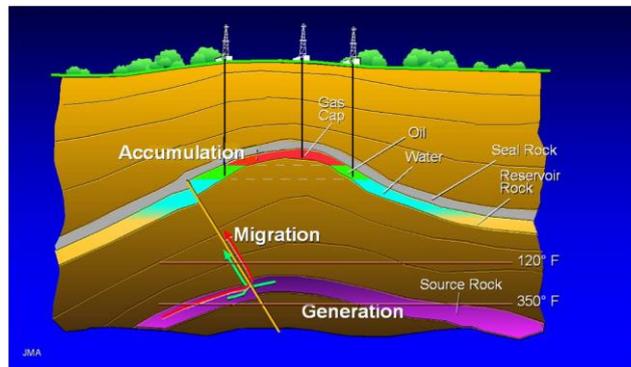


Figure 1. Petroleum System (source: SM IATMI Universitas Diponegoro)²

Once drilling activity in an exploratory well discovers hydrocarbon, it may migrate the hydrocarbon resources class (Figure 2 and 3) from prospective resources to contingent resources. Next, geologist will ask completion test to define hydrocarbon resources against his or her previous estimate. If hydrocarbon resources are economically developed, then a Plan of Development (POD) shall be submitted and approved by authority in the country. If the authority approve POD, then project go to development phase. To do activity in POD, project team must to submit Authorized Financial Expenditure (AFE) and get approval from the authority on proposed AFE.

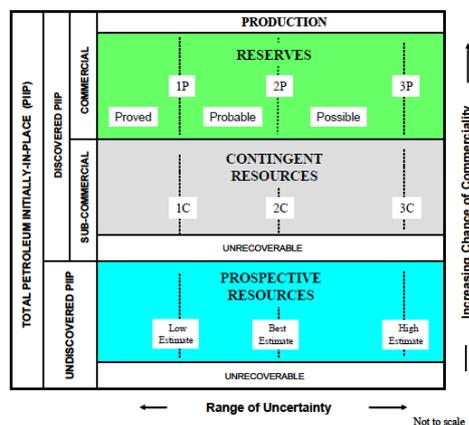


Figure 2. PRMS System – Resources Classification Framework
 (source: Society of Petroleum Engineers)³

² SM IATMI Universitas Diponegoro. Basic Petroleum System. Retrieved from <http://smiatmiundip.wordpress.com/2011/05/01/basic-petroleum-system/>

1P reserves in figure 2 means P1, 2P reserves means P1 (proved reserves) + P2 (probable reserves) and 3P reserves means P1 (proved reserves) + P2 (probable reserves) + P3 (possible reserves). P1 reserves (proved) means quantity of hydrocarbon can be estimated with reasonable certainty to be commercially recoverable which at least 90% probability (P90) that the quantities actually recovered will equal or exceed the estimate.⁴ P2 reserves (probable) are those unproved reserves which analysis of geological and engineering data suggest are more likely than not to be recoverable which at least 50% probability (P50).⁵ P3 (possible) are those unproved reserves which analysis of geological and engineering data suggest are less likely to be recoverable than probable reserves which at least a 10% probability (P10).⁶

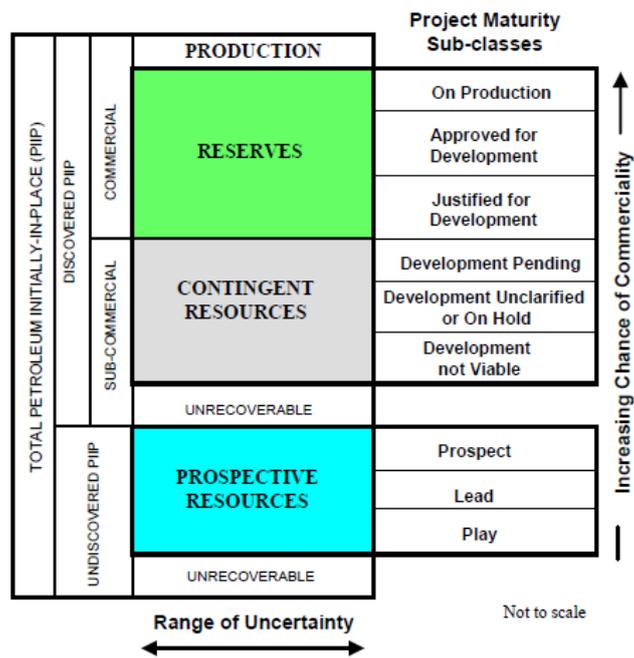


Figure 3. Resources subclasses based on Project Maturity (source : Society of Petroleum Engineers)⁷

Main objectives of development phase is focusing on lifting hydrocarbon from reservoir, treat hydrocarbon in order to fit with buyer specification and build facility to transport hydrocarbon to export point. Activities in development phase may be divided into 2 groups: drilling production well and construction (EPC) of process and facilities. Once POD approved by the authority, the resources class immediately migrate from contingent resources to reserves.

³ Society of Petroleum Engineers. American Association of Petroleum Geologists. World Petroleum Council. Society of Petroleum Evaluation Engineers. Society of Exploration Geophysicists. Guidelines for Application of the Petroleum Resources Management System. Retrieved from http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, Chapter 2 page 7

⁴ Schuyler, John. (2010). Decision Analysis Collection, Decision Precision, Chapter 100 page 110-4

⁵ Schuyler, John. (2010). Decision Analysis Collection, Decision Precision, Chapter 100 page 110-6

⁶ Schuyler, John. (2010). Decision Analysis Collection, Decision Precision, Chapter 100 page 110-7

⁷ Society of Petroleum Engineers. American Association of Petroleum Geologists. World Petroleum Council. Society of Petroleum Evaluation Engineers. Society of Exploration Geophysicists. Guidelines for Application of the Petroleum Resources Management System. Retrieved from http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, Chapter 2 page 18

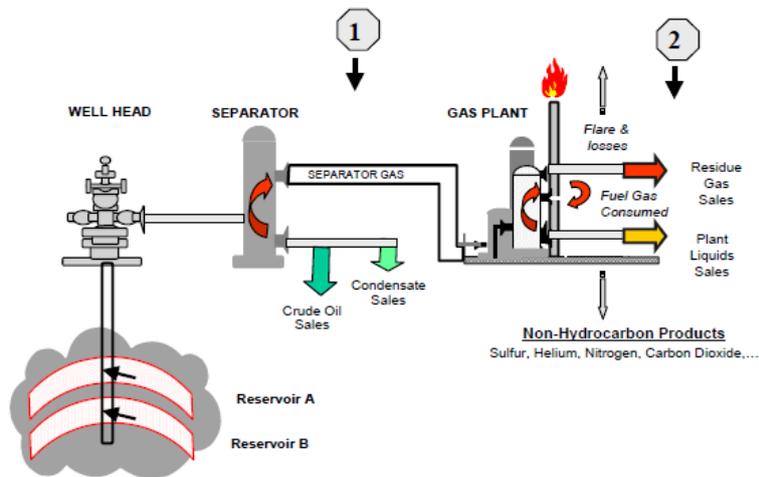


Figure 4. A Typical Oil & Gas Operations (source: Society of Petroleum Engineers)⁸

Generally development of a gas field more complex rather than an oil field, because gas requires more complex treatment process & facilities to recover some impurities (H₂S, CO₂, etc) in order to fit to buyer’s gas composition. In straight forward way, development of a gas field may consume more Capex (Capital Expenditure) than development of an oil field. Commonly gas field POD may be approved by authorities, if gas seller has Head of Agreement (HoA) with gas buyer. Development of gas field can be more challenging in remote area where lack or no existence of gas infrastructure and buyer. In general, development of a gas field more risky than development an oil field.

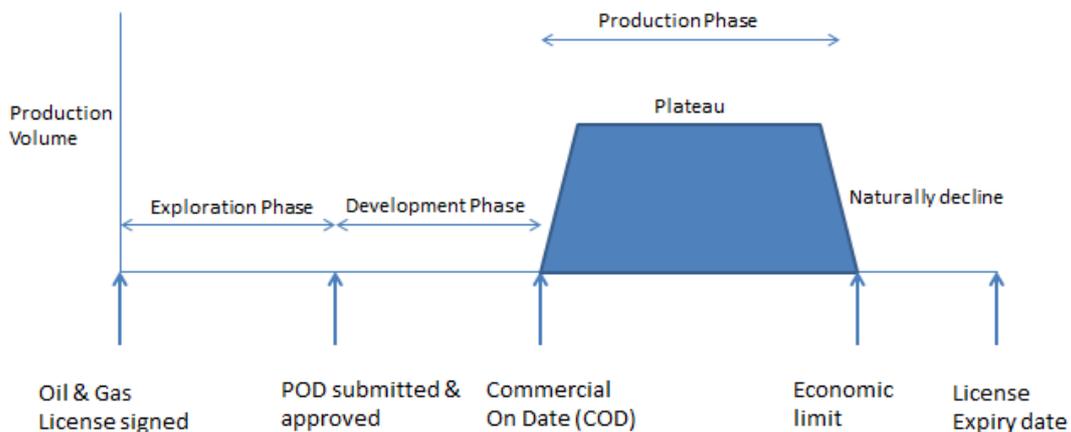


Figure 5. Typical Upstream Business Life Cycle (source : author)⁹

⁸ Society of Petroleum Engineers. American Association of Petroleum Geologists. World Petroleum Council. Society of Petroleum Evaluation Engineers. Society of Exploration Geophysicists. Guidelines for Application of the Petroleum Resources Management System. Retrieved from http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, Chapter 9 page162

⁹ author

Not all of reserves quantities can be lifted up to surface and be produced. Recoverable hydrocarbon is a fraction of reserves quantities, which this fraction factor commonly called as Recovery Factor (RF).¹⁰ Get known recoverable hydrocarbon, then Petroleum Engineer may forecast production profile until economic limit. Achieving peak production profile and plateau duration are challenging and complex matters specifically if deal with poor quality of formation and/or poor or very limited data available. In some circumstances, this formation issues in some degree may be resolved by application of a certain kind of technology, but this approach of technology may elevate the Capex number which finally may deteriorate financial performance. This condition may describe that there’s uncertainty about actually recoverable hydrocarbon quantities.

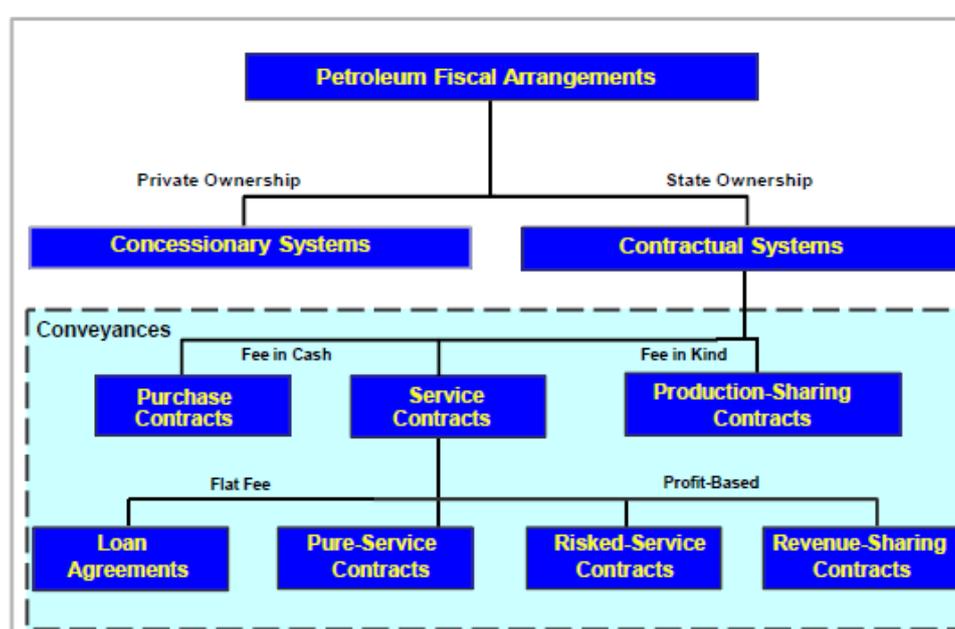


Figure 6. Classification of Petroleum Fiscal System
 (source : Society of Petroleum Engineers)¹¹

Generally, upstream oil and gas block license are covered in a contractual arrangement between license seller and license buyer. In concessionary system, Private owner act as license seller. In contractual system, State act as license seller. License buyer can be a single oil & gas company or joint venture (JV). JV is most preferable because this is a strategy to share risk among parties in JV.

¹⁰ Mireault, Ray. Dean, Lisa. Fekete Associates Inc. Reservoir Engineering for Geologist. Retrieved from <http://discoverygeo.com/Papers/Reservoir%20Eng%20for%20Geos%20c.pdf>, page 2

¹¹ Society of Petroleum Engineers. American Association of Petroleum Geologists. World Petroleum Council. Society of Petroleum Evaluation Engineers. Society of Exploration Geophysicists. Guidelines for Application of the Petroleum Resources Management System. Retrieved from http://www.spe.org/industry/docs/PRMS_Guidelines_Nov2011.pdf, Chapter 10 page 177

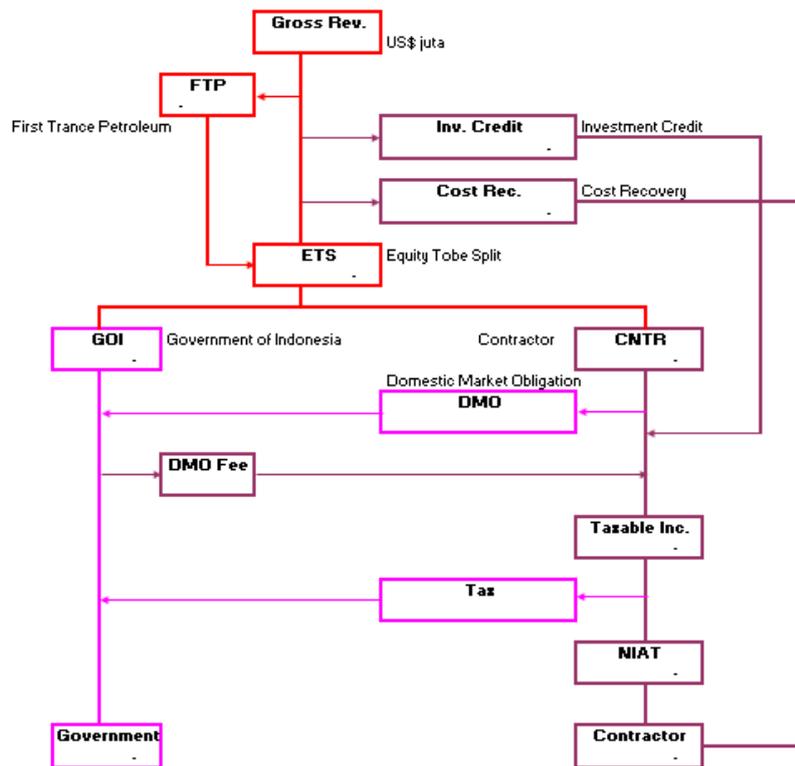


Figure 7. A Typical PSC Flow of Revenue (source : author)¹²

In this paper, I'd like to discuss comparison between Production Sharing Contract (PSC) and Risked Service Contract. In PSC, hydrocarbon quantities are shared between Government and contractor (contractor means license buyer) in a fix percentage (but some PSC apply sliding scale percentage) after deducted by FTP, Investment Credit (optional and determined by Government) and cost recovery. Contractors have the right to recover Operating cost out of production of Petroleum. Calculation the economic should adopt flow of revenue in Figure 7 into economic model. Based on my experience, upstream economic is very sensitive to oil price fluctuation. Some of countries which apply PSC are Algeria, Malaysia, Indonesia and Vietnam. In risk service contract, contractors are paid by remuneration fee plus cost recovery. Example of country that apply risk service contract is Iraq.

1.2. Discounted Cash Flow (DCF) Model

DCF Model (in Engineering Economy by Sullivan called as PW Method) is a quantitative tool to get the value of an asset at present by discounting all future cash flow at $i\%$. Sullivan described PW formula as follow:¹³

$$PW(i\%) = \sum_{k=0}^N F_k (1 + i)^{-k} \quad \text{(Equation 2)}$$

¹² author

¹³ Sullivan, William G., Wick, Elin M., Koelling, C. Patric. (2012). Engineering Economy, Fifteenth Edition, Prentice Hall, Chapter 5 page 203

Sullivan defined decision rule to evaluate project economy as follow¹⁴:

PW Decision Rule: if $PW (i = MARR) \geq 0$, the project is economically justified (Equation 3)

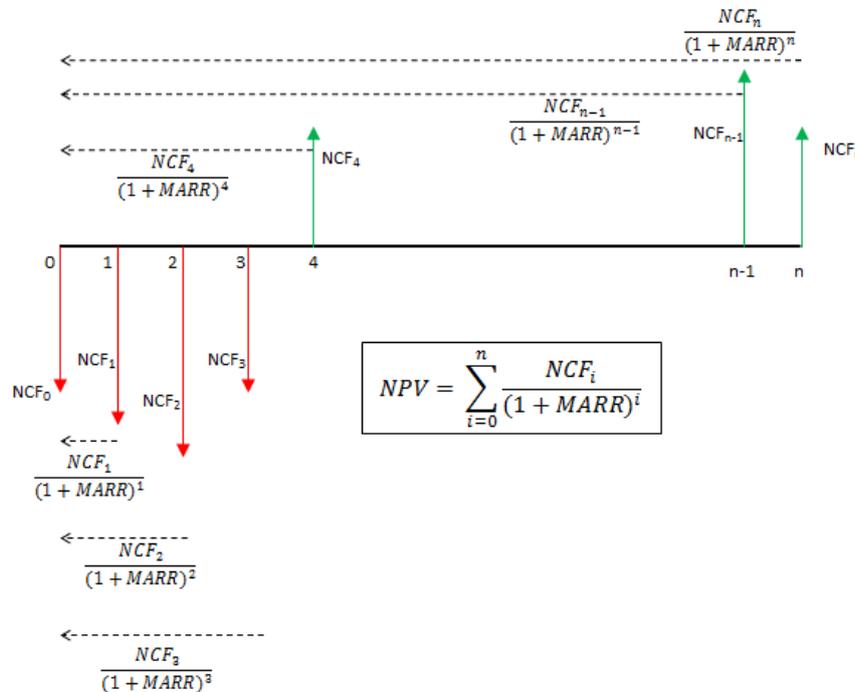


Figure 8. DCF Model (source : author)¹⁵

Mun identified DCF advantages as follow:¹⁶

- Clear, consistent decision criteria for all projects.
- Same results regardless of risk preferences of investors.
- Quantitative, decent level of precision, and economically rational.
- Relatively simple, widely taught and widely accepted.

The main drawback of DCF model that DCF model assumes the outset that all future outcomes are fixed. In a real world, any projects face many uncertainties because off the limited available information when it started and changes of business environment. With regard to this DCF model main assumption, DCF model may fail to incorporate the existence of those uncertainties into model which may finally affect management lack of flexibility in making decision (in another word, DCF model unable to provide room for management to alter the decision have made previously). Any projects value from DCF model may provide a value that understates the true market value of the projects.

¹⁴ Sullivan, William G., Wick, Elin M., Koelling, C. Patric. (2012). Engineering Economy, Fifteenth Edition, Prentice Hall, Chapter 5 page 204

¹⁵ author

¹⁶ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc, Chapter 2 page 66

<i>DCF Assumptions</i>	<i>Realities</i>
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 lifecycle, including checkpoints, decision options, budget constraints, etc.
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.

Table 1. Disadvantages of DCF: Assumption versus Realities (source: Mun)¹⁷

1.3. Financial Option Theory

Options are derivative instrument other than forward and future contracts that gives holder of option the right to do something. Options are traded both on exchange and in the over the counter market. There are 2 types of (plain vanilla) options: call options and put options. A call option gives the holder the right to buy the underlying asset by a certain date for a certain price. A put option gives the holder the right to sell the underlying asset by a certain date for a certain price. The price in the option contract is known as the exercise price or strike price. The date in the option contract is known as the expiration date. European options can be exercised only on the expiration date itself. American options can be exercised at any time up to the expiration date. There are two sides to every option contract. On one side is investor who has taken the long position (bought the option). On the other side is the investor who has taken a short position (sold or written the option).¹⁸

¹⁷ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc. Chapter 2 page 67

¹⁸ Hull, John C. (2009). Options, Futures and Other Derivatives, Seventh Edition, Pearson Prentice Hall, Chapter 1 page 6

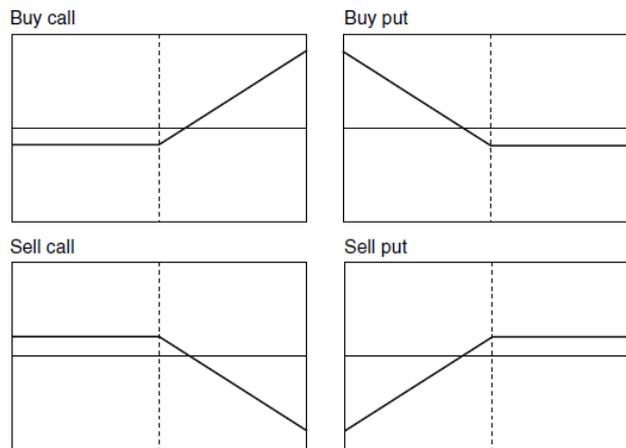


Figure 9. Profit Payoffs on Long (buy) and Short (sell) Calls and Puts (source : Jorion)¹⁹

Long position in European call option will expect price of underlying asset (S_T) > strike price (K) at the expiration date, then holder will exercise the option to buy underlying asset at strike price (K) and immediately may sell the underlying asset at S_T . Thus holder of call option may make profit from those transactions. Payoff from a long position in a European call option:²⁰

$$\text{Max}(S_T - K.e^{-rt}, 0) \tag{Equation 4}$$

Long position in European call option will expect price of underlying asset (S_T) < strike price (K) at the expiration date, thus holder of call option may make profit from the transaction. Payoff from a long position in a European call option:²¹

$$\text{Max}(K.e^{-rt} - S_T, 0) \tag{Equation 5}$$

An American call option on a non-dividend-paying stock (or asset with no income) should never be exercised early because American option more valuable if the option is exercised at the expiry date of the option . If the asset pays income, early exercise may occur, with a probability that increase with the size of the income payment. An American put option on a non-dividend-paying stock (or asset with no income) may be exercised early. If the asset pays income, the possibility of early exercise decreases with the size of the income payments.²²

Hull described the Black-Scholes formulas to calculate a European call option on a non-paying-dividend stock and a European put option on a non-paying-dividend stock as follow²³:

¹⁹ Jorion, Philippe. (2009). Financial Risk Manager Handbook, Fifth Edition, John Wiley & Sons, Inc, Chapter 6 page 129

²⁰ Hull, John C. (2009). Options, Futures and Other Derivatives, Seventh Edition, Pearson Prentice Hall, Chapter 9 page 207

²¹ Hull, John C. (2009). Options, Futures and Other Derivatives, Seventh Edition, Pearson Prentice Hall, Chapter 9 page 208

²² Jorion, Philippe. (2009). Financial Risk Manager Handbook, Fifth Edition, John Wiley & Sons, Inc., Chapter 6 page 140

²³ Hull, John C. (2009). Options, Futures and Other Derivatives, Seventh Edition, Pearson Prentice Hall, Chapter 13 page 291

$$c = S_0 N(d_1) - Ke^{-rT} N(d_2) \quad \text{(Equation 6)}$$

$$p = Ke^{-rT} N(-d_2) - S_0 N(-d_1) \quad \text{(Equation 7)}$$

where:

$$d_1 = \frac{\ln(S_0/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \quad \text{(Equation 8)}$$

$$d_2 = \frac{\ln(S_0/K) + (r - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \quad \text{(Equation 9)}$$

$N(x)$: the cumulative probability distribution function for a standardized normal distribution.

S_0 : stock price at time zero

K : strike price (sometimes strike price is typed as X)

r : risk free rate

For a paying dividend stock, European call option and put option formula above slightly modified by taking into account as follow²⁴:

$$c = S_0 e^{-qT} N(d_1) - Ke^{-rT} N(d_2) \quad \text{(Equation 10)}$$

$$p = Ke^{-rT} N(-d_2) - S_0 e^{-qT} N(-d_1) \quad \text{(Equation 11)}$$

$$d_1 = \frac{\ln(S_0/K) + (r - q + \sigma^2/2)T}{\sigma\sqrt{T}} \quad \text{(Equation 12)}$$

$$d_2 = \frac{\ln(S_0/K) + (r - q - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \quad \text{(Equation 13)}$$

Where:

q : dividend payout

1.4. Problem Statement.

This paper takes an upstream oil block as case study. The research questions in this paper are:

1. What method should be applied to appraise value of asset which has uncertainty and management need more flexibility in making decision?
2. What Real Option model should be chosen to figure out case study?
3. How much the upstream block value based on chosen real option model?
4. How much flexibility value which provided by Real Option model?

²⁴ Hull, John C. (2009). Options, Futures and Other Derivatives, Seventh Edition, Pearson Prentice Hall, Chapter 15 page 323

2. Real Option

Real Option emerged to resolve the drawback of DCF model and incorporate the uncertainty and appropriate strategy in each stage, thus Real Option may provide more flexibility to management in making decision. Real Option is a quantitative approach which adopted financial option theory to evaluate physical or real assets. Not in all cases that real option can be applied, there're some requirements which should be fulfilled before running real option²⁵:

- A financial model must exist
- Uncertainties must exist
- Uncertainties must affect decisions when a company is actively managing the project and these uncertainties must affect the results of the financial model
- Management must have strategic flexibility or options to make midcourse corrections when actively managing the projects.
- Management must be smart enough and credible enough to execute the options when it becomes optimal to do so.

FINANCIAL OPTIONS	REAL OPTIONS
<ul style="list-style-type: none"> • Short maturity, usually in months. • Underlying variable driving its value is equity price or price of a financial asset. • Cannot control option value by manipulating stock prices. • Values are usually small. • Competitive or market effects are irrelevant to its value and pricing. • Have been around and traded for more than three decades. • Usually solved using closed-form partial differential equations and simulation/variance reduction techniques for exotic options. • Marketable and traded security with comparables and pricing info. • Management assumptions and actions have no bearing on valuation. 	<ul style="list-style-type: none"> • Longer maturity, usually in years. • Underlying variables are free cash flow, which in turn are driven by competition, demand, management. • Can increase strategic option value by management decisions and flexibility. • Major million and billion dollar decisions. • Competition and market drive the value of a strategic option. • A recent development in corporate finance within the last decades. • Usually solved using closed-form equations and binomial lattices with simulation of the underlying variables, not on the option analysis. • Not traded and proprietary in nature, with no market comparables. • Management assumptions and actions drive the value of a real option.

Table 2. Comparison between Financial Option and Real Option (source : Mun)²⁶

Before talking furthermore about real option process and model, it's important to talk about binomial lattice. Binomial lattice is a tool to model uncertainty which take this uncertainty into

²⁵ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 1 page 38

²⁶ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 5 page 110

calculation. In binomial lattice, the expected outcomes or events are limited for 2 outcomes or events only i.e. “fail-success”, and “happened-not happened”.

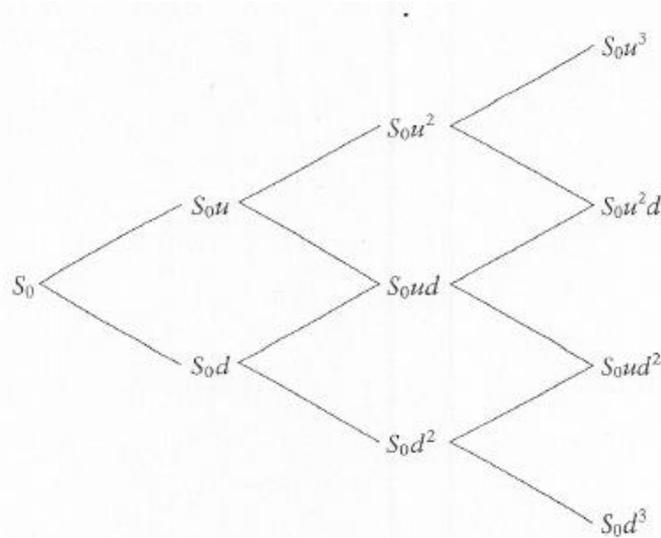


Figure 10. Binomial Lattice – 3 steps (source : Mun)²⁷

Binomial lattice is adopted by real option to figure out the uncertainty and to calculate the value from underlying asset. To get the option value, risk neutral probability is incorporated into binomial lattice. Underlying asset value is solved by forward induction. Underlying asset value in at time = 1 is a result from simply multiplication underlying asset value at time = 0 (S_0) to up factor (u) or down factor (d). Up factor and down factor are calculated by formula as follow²⁸:

$$u = e^{\sigma \sqrt{T}} \tag{Equation 14}$$

$$d = e^{-\sigma \sqrt{T}} = \frac{1}{u} \tag{Equation 15}$$

Where:

e : exponential function

σ : the natural logarithm of the underlying free cash flow returns

T : time

Approach to solve option value is different to the approach (forward induction) which applied to solve underlying asset value. Option value in binomial lattice will be solved in backward induction, started from end node in binomial lattice. Option value at the end node in binomial lattice is solved by applying maximization between executing the option and let the option expire. The option value 1 stage before end node is continuous discounted (e^{-rT}) of probability

²⁷ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 6 page 130

²⁸ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 6 page 128

weighted value between upside option value and downside option value. Risk neutral probability is calculated as follow²⁹:

$$p = \frac{e^{r_f \cdot T} - d}{u - d} \quad \text{(Equation 16)}$$

$$p = \frac{e^{(r_f - q) \cdot T} - d}{u - d} \quad \text{(Equation 17)}$$

Equation 16 is applied for a non-paying dividend stock and equation 17 applied for paying dividend stock.

Real Option has some types which relied on the decisions should be made³⁰:

- **Option to expand (or Expansion Option):**

This type of real option basically adopts financial call option (in long position). In this type, the option owner has the right to expand the business or asset. The available decisions or strategy in this type are expansion and continuing (means continue the operation with the existing business). At the terminal node of binomial lattice, option value is calculated through maximization between Expansion and Continuing. At the intermediate node, option value is calculated through maximization between Expansion and Keeping Option Open where Keeping Option Open is result from continuous discounted of probability weighted value.

- **Option to contract (Contraction Option):**

This type adopts financial put option (in long position). In this type, the owner has objective to transfer risk to other party through contract (party here could be mean contractor, or partner in Joint Venture/JV). The available decisions in this type are contract and continue (means continue with existing business). American option is more valuable than European because in American option the right can be exercised at any time up to the expiration date. At the terminal node of the binomial lattice, option value is calculated through maximization between Contraction and Continuing with the existing business. At the intermediate node, option value is calculated through maximization between Contraction and Keeping Option Open.

- **Option to abandon (or Abandonment Option):**

Similar to Option to contract, this type adopted financial (European either American) put option (in long position). In this type, the owner has right to abandon the operation or asset. The available decisions in this type are Abandonment and Continuing with existing business. At the terminal node, option value is calculated through maximization between Salvage value of Abandonment and Continuing. At the intermediate node,

²⁹ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 6 page 128

³⁰ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 7 page 163 - 186

option value is calculated through maximization between Salvage value of Abandonment and Keeping Option Open.

- **Option to choose (or Chooser Option):**

In this type, the option owner has the right to choose one of the alternatives, which the alternatives are expansion option, contraction option or abandonment option. At the terminal node, option value is calculated through maximization among Salvage Value of Abandonment, Expansion, Contraction and Continuing. At the intermediate node, option value is calculated through maximization among Salvage value of Abandonment, Expansion, Contraction and Keeping Option Open. Value of chooser option significantly differ with the sum of individual those options (Abandonment, Expansion, Contraction) because value of choose option is taken account for the interaction of those options. The sum of individual options does not equal to the interaction of the same options is due to the mutually exclusive and independent nature of those specific options.³¹

- **Compound options:**

In compound option, value of an option depends on value of another option. There are 2 types of compound option which include simultaneous compound option and sequential compound option. In simultaneous compound options, an option depends on another option and both option occurring together. Simultaneous compound option yields the same value as a simple call option where the implementation cost or strike price (X) is the sum of all different individual option costs.³²

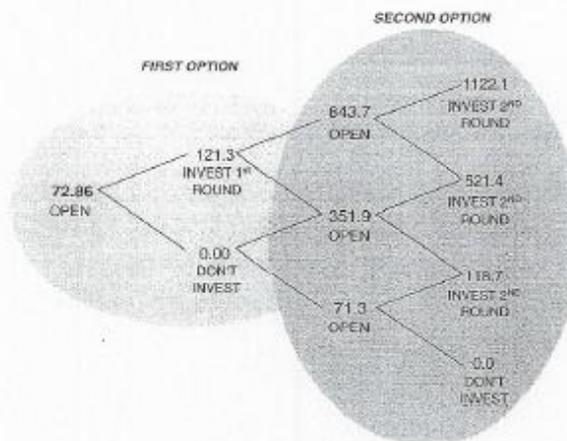


Figure 11. Sequential Compound Options (source : Mun)³³

Sequential compound options are applicable for a project has multiple phases and later phases depend on the success of previous phases. Calculation of option value is started

³¹ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 7 page 174 - 177

³² Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 7 page 177 - 186

³³ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 7 page 186

from later option. Underlying asset in calculation of previous option is the value of later option.

3. Data Gathering

An oil & gas company just acquired an exploration (on shore) oil project in X island in Indonesia. Project cash flow is generated by filling forecasted oil production profile (which delivered by reservoir engineer), all expenditures profiles (include capex and opex) into project economic model. Project economic model is developed in respecting fiscal term which already described in Production Sharing Contract (PSC). The project has NCF as shown in figure 12. The MARR in this paper is referred to Lita Liana paper³⁴, MARR = 16.92%. By applying DCF approach, the project value is – USD 126.70 million.

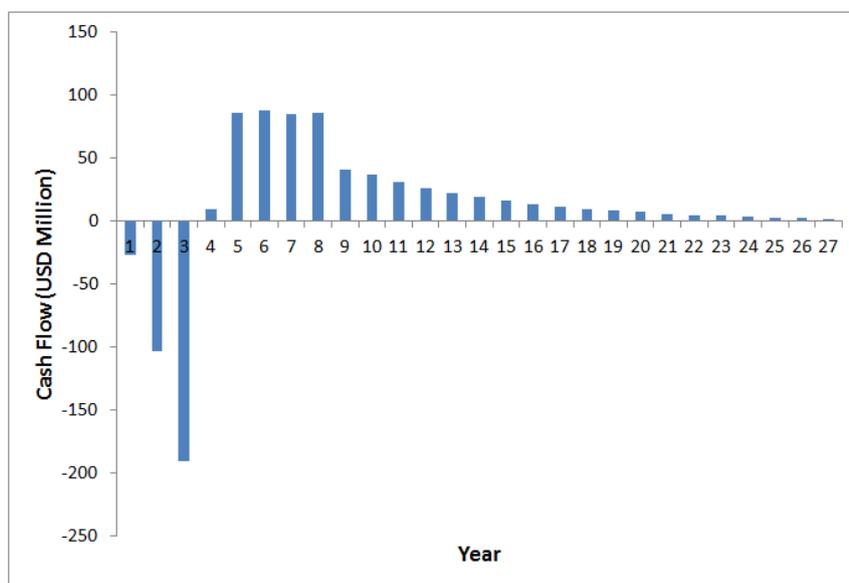


Figure 12. Forecasted Project Net Cash Flow (source : author)³⁵

4. Real Option Framing

Project life cycle is divided into 3 phases include exploration phase, development phase and production phase. Each phase has each own cash flow and the sum of each cash flow may result total project cash flow. Project cash flow can be separated into 2 periods include investment period and cash inflow period, show in figure 13.

³⁴ Liana, Lita, (February 2014). Using Analytical Hierarchy Process to Determine Appropriate Minimum Attractive Rate of Return for Oil and Gas Projects in Indonesia, Vol III, Issue II., page 11

³⁵ author

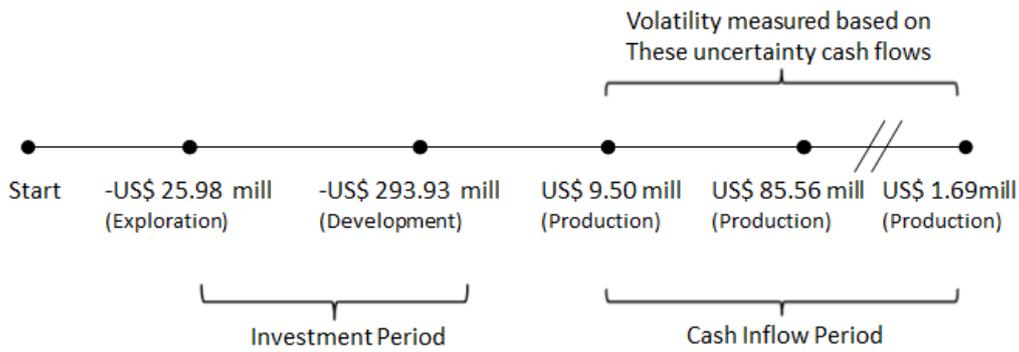


Figure 13. Graphical Presentation of Project Cash Flow (source : author)³⁶

At the end of exploration phase, there are 2 options which available to the executive management in making decision. Those 2 options are not available when company will acquire the oil exploration block because the estimate of oil contingent resources is only available after the engineering team finished the work program in exploration phase (which commonly include GGR study, drill exploration well as well as appraisal well). Those 2 options are continuing project to development phase or abandoning it. If the executive management decides to continue the project into development phase, then the executive management has to allocate budget which cover project capex as well as opex. If management decides to abandon the project, the company may seek buyer who interest to that block and farm out from that block. This approach is more valuable to company other than relinquish the oil block to government. Regard to case study in this paper, abandon means to sell 100% of Participating Interest (PI) or Working Interest (WI) in this block to other oil & gas company.

The reality above will be figured into real option by applying abandonment option (1st option). At the terminal node, option value is calculated through maximization between Salvage value of abandonment and Continuing to Development phase. At the intermediate node, option value is calculated through maximization between Salvage value of abandonment and Keeping Option Open.

³⁶ author

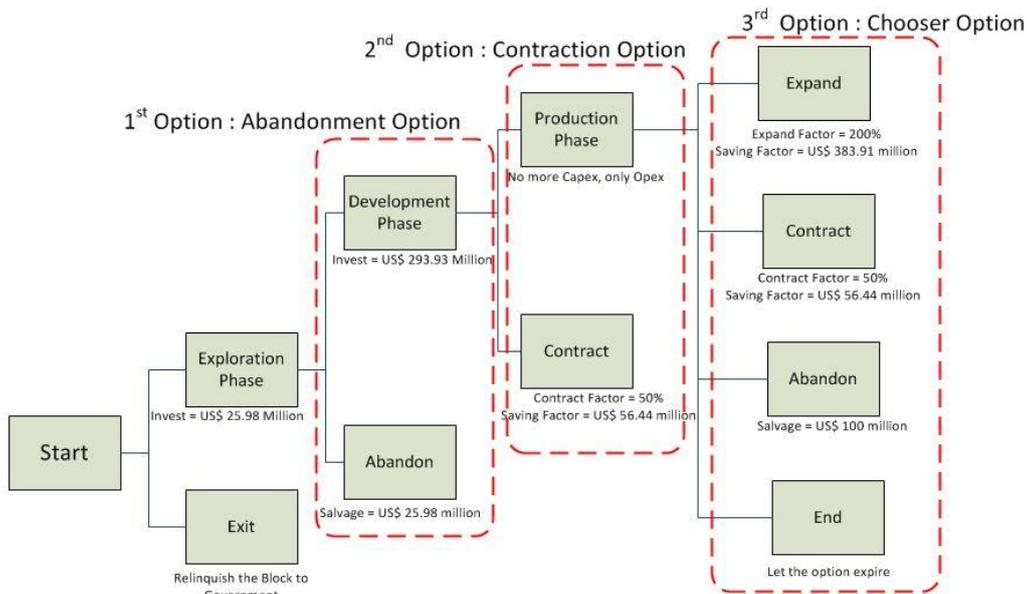


Figure 14 Project Strategy Tree (source : author)³⁷

At the end of development phase, there are 2 options which available to the executive management in making decision. Those 2 options are continuing project to production phase or contract it to other oil & gas company. Respecting case study in this paper, contract means selling 50% of PI in this block to other oil & gas company. If the executive management decides to continue the project into production phase, then company may enjoy profit generated from the oil production. If management decides to contract the project, company may enjoy 50% of the oil profit.

The reality in paragraph above will be figured into real option by applying contraction option (2nd option). At the terminal node, option value is calculated through maximization between Contract and Continuing to Production phase. At the intermediate node, option value is calculated through maximization between Contract and Keeping Option Open.

At the end of production phase, there are 4 options which available to the executive management in making decision. Those 4 options are expansion, contraction, abandonment and let the option expire. Expansion option means the ability of developing another geology structure in this block. In the case study, there’s another geology structure (the resources status is lead) which is attractive to be studied further.

The reality in paragraph above will be figured into real option by applying chooser option (3rd option). At the terminal node, option value is calculated through maximization among Expansion, Abandonment and let the option expire. At the intermediate node, option value is calculated through maximization among Expansion, Contract, Abandonment and Keeping Option Open.

³⁷ author

To solve the case study, it's required to combine those 3 options (1st: Abandonment Option, 2nd: Contraction Option, 3rd: Chooser Option) into one single option. This single option is called Complex Multiphase Sequential Compound Options.³⁸

Option Valuation Lattices

ProductionPhase

Cost	\$383.91
Riskfree	3.17%

Dividend	0.00%
Steps	27

Terminal Equation
Intermediate Equation
Intermediate Equation (Blackout)

Max(Underlying, Underlying*Expansion-Cost, Salvage, 0)
Max(Underlying, Underlying*Expansion-Cost, Underlying*Contract+Saving, Salvage, OptionOpen)

DevelopmentPhase

Cost	\$319.91
Riskfree	3.17%

Dividend	0.00%
Steps	3

Terminal Equation
Intermediate Equation
Intermediate Equation (Blackout)

Max(ProductionPhase-Cost, ProductionPhase*Contract+Saving)
Max(ProductionPhase-Cost, OptionOpen)

ExplorationPhase

Cost	\$25.98
Riskfree	3.17%

Dividend	0.00%
Steps	1

Terminal Equation
Intermediate Equation
Intermediate Equation (Blackout)

Max(DevelopmentPhase-Cost, Salvage, 0)
Max(DevelopmentPhase-Cost, OptionOpen)

Custom Variables

Name	Contract	Expansion	Salvage	Salvage	Saving				
Value	0.50	2.00	25.98	100.00	56.44				
Starting Step	0	0	1	3	0				

Table 3. SLS Input (source : author)³⁹

Volatility of underlying asset (underlying asset refer to cash inflow period, look at Fig. 13) was generated by running Monte Carlo Simulation. Underlying asset in this case study is US\$ 169.13 million. Prior to explain further about Monte Carlo Simulation, it is important to define variables and distributions which will be as inputs in Monte Carlo Simulation. Respecting to project cash inflow, it's chosen oil price and production volume as the variables that will change project cash inflow. Volatility of underlying asset is standard deviation of Natural Logarithmic Present Value Return Approach. The target output in Monte Carlo Simulation is Natural Logarithmic Present Value Return where the input for Monte Carlo Simulation shown in Table 4. Monte Carlo Simulation is performed by using Risk Simulator as an aid tool (from Real Option Valuation Inc.). Volatility of underlying asset is 3.04% (look at table 5).

Variables	Distribution Type	Minimum	Base Case	Maximum
Oil Price (US\$)	Triangle	90	100	110
Production Volume (thousands bbls)	Triangle	23,349.33	32,610.37	35,871.41

Table 4. Input for Monte Carlo Simulation (source : author)⁴⁰

³⁸ Mun, Johnathan. (2006). Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions, Second Edition, John Wiley & Sons, Inc., Chapter 10 page 427

³⁹ author

⁴⁰ author

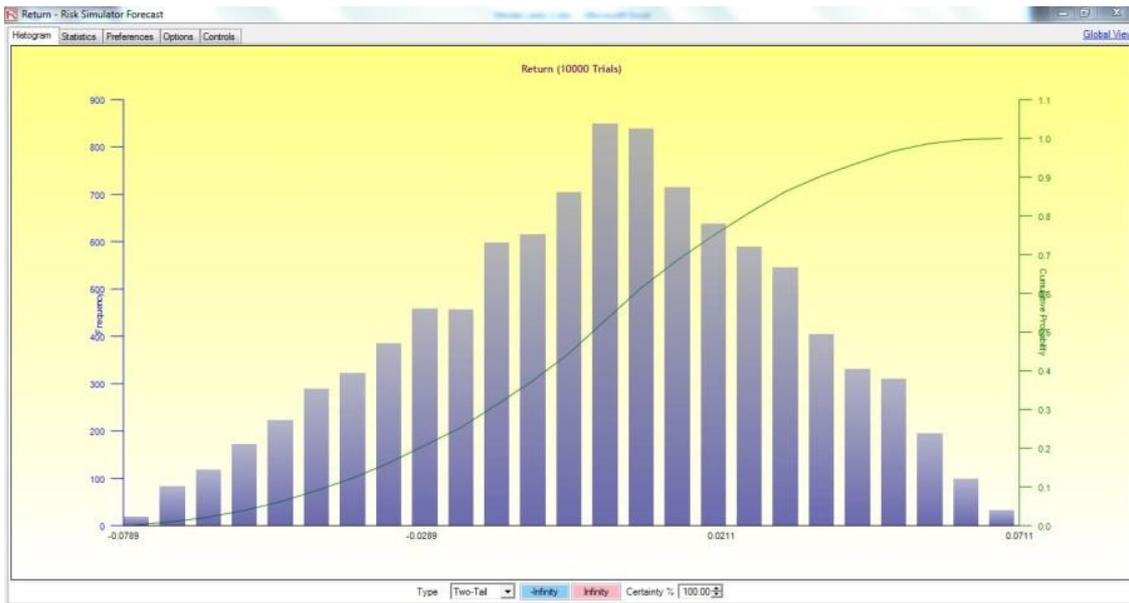


Figure 15. Result of Monte Carlo Simulation (source : author)⁴¹

Return - Risk Simulator Forecast	
Statistics	
Statistics	Result
Number of Trials	10000
Mean	-0.0021
Median	-0.0004
Standard Deviation	0.0304
Variance	0.0009
Coefficient of Variation	-14.2192
Maximum	0.0681
Minimum	-0.0829
Range	0.1510
Skewness	-0.1923
Kurtosis	-0.5254
25% Percentile	-0.0228
75% Percentile	0.0200
Percentage Error Precision at 95% Confidence	27.8692%

Table 5. Statistic of Monte Carlo Simulation (source : author)⁴²

5. Analysis

After filling the inputs in Table 3 into Multiple Super Lattice Solver (Multiple Super Lattice Solver is a menu in SLS to model customized and complex options), SLS generated lattice for underlying asset (figure 16 – 17) and complex multiphase sequential compound options (figure 18 – 19). Lattice for underlying asset and multiphase sequential compound options has 28 steps or nodes (start from step 0 to step 27 which represent year 0 up to year 27).

⁴¹ author

⁴² author

Value on each node in underlying asset lattice was generated by multiplication of underlying asset at year 0 (US\$ 169.13 million) with upside factor (u) and downside factor (d). Figure 16 and 17 show the evolution of underlying asset value from year 0 until year 27 which primarily driven by uncertainty (σ).

169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85
	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59
		159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22
			154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70
				149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97
					145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00
						140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73
							136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13
								132.62	136.71	140.93	145.28	149.77	154.39	159.15
									128.65	132.62	136.71	140.93	145.28	149.77
										124.79	128.65	132.62	136.71	140.93
											121.06	124.79	128.65	132.62
												117.43	121.06	124.79
													113.92	117.43
														110.51

Figure 16. Underlying Asset (Lattice step 0 – 14) (source : author)⁴³

266.84	275.08	283.57	292.33	301.35	310.65	320.24	330.12	340.31	350.82	361.65	372.81	384.32
251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24	330.12	340.31	350.82	361.65
236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24	330.12	340.31
222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24
209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35
196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57
185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84
174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10
164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29
154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35
145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24
136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89
128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28
121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35
113.92	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07
107.20	110.51	113.92	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39
	103.99	107.20	110.51	113.92	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28
		100.87	103.99	107.20	110.51	113.92	117.43	121.06	124.79	128.65	132.62	136.71
			97.85	100.87	103.99	107.20	110.51	113.92	117.43	121.06	124.79	128.65
				94.92	97.85	100.87	103.99	107.20	110.51	113.92	117.43	121.06
					92.08	94.92	97.85	100.87	103.99	107.20	110.51	113.92
						89.32	92.08	94.92	97.85	100.87	103.99	107.20
							86.65	89.32	92.08	94.92	97.85	100.87
								84.05	86.65	89.32	92.08	94.92
									81.54	84.05	86.65	89.32
										79.10	81.54	84.05
											76.73	79.10
												74.43

Figure 17. Underlying Asset (Lattice step 15 – 27) (source : author)⁴⁴

Figure 18 and 19 shows the values of Complex Multiphase Sequential Compound Options which is generated by value from combination of three single options include abandonment option (1st option), contraction option (2nd option) and chooser option (3rd option). Chooser option exists on node number 4 until 27 in figure 18 and 19. Contraction Option exists on node 2 until 3 in figure 18. Abandonment option exists on node 1 in figure 18. Value of chooser option depends on value of underlying asset on respected node in figure 16 and 17. Value of

⁴³ author
⁴⁴ author

contraction option depends on value of chooser option on respected node. Value of abandonment option depends on value of contraction option on respected node.

The decision or strategy that shown on each node in figure 18 and 19 is the best decision (means decision which has the greatest value) corresponding to underlying value on respected node in figure 16 and 17. Value of each decision is shown on one line above the decisions line. Value of Complex Multiphase Sequential Compound Options is US\$ 110.87 Million (node 0 in figure 18).

If the movement of underlying asset’s value as shown in figure 16 and 17, therefore it’s worth full for the company to continue until production phase (not exercise abandonment option neither contraction option at the end of exploration phase and development phase respectively). Starting from node or year 11 until year 27, executive management may apply different decision with regard underlying asset’s value on respected year and those decisions may generate greater value than underlying asset value in figure 16 and 17.

110.87	114.29	144.57	149.03	191.32	197.22	203.30	209.57	216.03	222.69	229.56	236.64	243.94	251.46	259.21
Continue	End	Continue	End	Continue										
	107.55	136.04	140.24	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59
	End	Continue	End	Continue										
		128.02	131.97	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22
		Continue	End	Continue										
			124.18	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70
			End	Continue										
				149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97
				Continue										
					145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00
					Continue									
						140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73
						Continue								
							136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13
							Continue							
								132.62	136.71	140.93	145.28	149.77	154.39	159.15
								Continue						
									128.65	132.62	136.71	140.93	145.28	149.77
									Continue	Continue	Continue	Continue	Continue	Continue
										124.79	128.65	132.62	136.71	140.93
										Continue	Continue	Continue	Continue	Continue
											121.06	124.79	128.65	132.62
											Continue	Continue	Continue	Continue
												117.43	121.06	124.79
												Continue	Continue	Continue
													113.89	117.43
													Continue	Continue
														111.69
														Contract

Figure 18. Complex Multiphase Sequential Compound Options (Lattice step 0 – 14) (source : author)⁴⁵

⁴⁵ author

267.21	275.45	283.94	292.70	301.72	311.03	320.62	330.51	340.70	351.21	362.05	373.21	384.72
Continue	Expand											
251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24	330.12	340.31	350.82	361.65
Continue	End											
236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24	330.12	340.31
Continue	End											
222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35	310.65	320.24
Continue	End											
209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57	292.33	301.35
Continue	End											
196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84	275.08	283.57
Continue	End											
185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10	258.85	266.84
Continue	End											
174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29	243.59	251.10
Continue	End											
164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35	229.22	236.29
Continue	End											
154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24	215.70	222.35
Continue	End											
145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89	202.97	209.24
Continue	End											
136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28	191.00	196.89
Continue	End											
128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35	179.73	185.28
Continue	End											
121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07	169.13	174.35
Continue	End											
113.89	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39	159.15	164.07
Continue	End											
110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77	154.39
Contract	Contract	Continue	End									
108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28	149.77
Contract	Contract	Contract	Continue	End								
106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62	136.71	140.93	145.28
Contract	Contract	Contract	Contract	Continue	End							
105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62	136.71	140.93
Contract	Contract	Contract	Contract	Contract	Continue	End						
103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62	136.71
Contract	Contract	Contract	Contract	Contract	Contract	Continue	Continue	Continue	Continue	Continue	Continue	End
102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65	132.62
Contract	Continue	Continue	Continue	Continue	Continue	End						
101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79	128.65
Contract	Continue	Continue	Continue	Continue	End							
100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06	124.79
Abandon	Contract	Continue	Continue	Continue	End							
100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43	121.06
Abandon	Abandon	Contract	Continue	Continue	End							
100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89	117.43
Abandon	Abandon	Abandon	Contract	Continue	End							
100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69	113.89
Abandon	Abandon	Abandon	Abandon	Contract	Continue							
100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04	111.69
Abandon	Abandon	Abandon	Abandon	Abandon	Contract							
100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43	110.04
Abandon	Abandon	Abandon	Abandon	Abandon	Abandon	Contract						
100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88	108.43
Abandon	Contract	Contract	Contract	Contract	Contract	Contract						
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37	106.88
Abandon	Contract	Contract	Contract	Contract	Contract							
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90	105.37
Abandon	Contract	Contract	Contract	Contract								
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48	103.90
Abandon	Contract	Contract	Contract									
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10	102.48
Abandon	Contract	Contract										
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	101.10
Abandon	Contract											
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Abandon												

Figure 19. Complex Multiphase Sequential Compound Options (Lattice step 15 – 27) (source : author)⁴⁶

Decision not to exit now from this exploration block and continue until production phase in this case study may produce greater value to company and more flexibility to the executive management. This is very easy and clear for executive management to find the best decisions given movement of underlying asset's value in whole oil and gas block's life time. This advantage is what traditional DCF model doesn't have. By applying real option approach, this oil exploration block may produce value of US\$ 110.87 million instead of negative US\$ 126.70 million (from traditional DCF approach). If relying on DCF model which produced value of negative US\$ 126.70 million, the executive management may take to exit from the exploration block as decision (which inappropriate decision) and finally this decision may affect the

⁴⁶ author

company suffer a huge financial loss. Value of Flexibility (or value of having real option) is US\$ 237.57 million (which result of subtraction between US\$ 110.87 million and negative US\$ 126.70 million).

6. Conclusion.

Real option is a strategic decision tool that may provide flexibility for decision making, differencing factor that may differentiate a company among its peer in winning the competition and may leverage company competitive advantage.

Answer Research Question#1

The method applied to appraise value of asset which has uncertainty and management need more flexibility in making decision is Real Option.

Answer Research Question#2

Real Option model chosen to figure out case study is Complex Multiphase Sequential Compound Option.

Answer Research Question#3

The upstream block value based on chosen real option model is US\$ 110.87 million.

Answer Research Question#4

Flexibility value which provided by Real Option Model is USD 235.57 million.

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