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MONTE CARLO NET PRESENT VALUE FOR TECHNO-ECONOMIC ANALYSIS OF OIL AND GAS PRODUCTION SHARING CONTRACT

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ABSTRACT

This paper presents a techno-economic analysis for oil and gas production sharing contract (PSC) which is subjected to uncertainty from fluctuation of natural gas prices and production reservoir capacity. Net present value (NPV) is calculated based on a 10-year contract duration considering capital-operational expenditure, production sharing contract bidding value, and salvage value. The Monte Carlo method is embedded in the NPV analysis to quantify the probability of the production sharing contract's profit and loss. The result of this probability is utilized as input for determining the decision to acquire the PSC. This paper confirms that investment in the oil and gas industry is high risk. This type of investment is only suitable for companies with strong equity or financial power.

Keywords: Monte Carlo method; Net present value; Production sharing contract

1. INTRODUCTION

Techno-economic analysis is a decision process to determine the value of a long-term investment in a project. The decision making process should be based on maximum equity return from an investment. Oil and gas is a risky industry. This kind of business is subjected to major uncertainty, sophisticated technology, and high capital investment. Cheng et al. (2018) states that "oil and gas play a pivotal role in the modern industry, and oil and gas demand is closely related to economic development." The demand for oil and gas production is in correlation with the growth of the transportation, residential, and industrial sectors (Silitonga et al., 2012). Atabani et al. (2012) states that "energy consumption has grown rapidly in the recent years". Therefore, techno-economic analysis for an oil and gas project becomes crucial to determine whether it shall be undertaken or not.

Several studies have been conducted to analysis the technique for optimizing project investment portfolios (Arifin et al., 2015). Net present value is one of the most powerful tools used in techno-economic analysis (Shaffie & Jaaman, 2015). Net present value calculates the present value of future cash flows and, when compared with initial outflows, an investment project is seen as acceptable whenever a positive NPV is the outcome. The internal rate of return (IRR) is a percentage rate that equates the present value of future cash inflows with the present value (Bennouna et al., 2010). Both NPV and IRR are widely used to determine capital investment decisions. However, the usage of this technique has limitations in calculating high risks capital investment projects, such as those in the oil and gas industry. The NPV technique only focuses on current predictable cash flows and ignores the future risk of uncertainty, therefore, may

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undervalue the production sharing contract and mislead the decision makers (Ho & Liao, 2011). The improvement of conventional NPV techniques should be performed in order to quantify the capital investment risk (Arnold & Yildiz, 2015; Rout et al., 2018). A risk-quantified methodology is required to reduce probability of failure in both operational and financial aspects of the project (Hidayanto et al., 2015).

The Monte Carlo method was first used in 1960, and it was extended to simulate uncertainty in financial applications (Shaffie & Jaaman, 2015). The Monte Carlo method has been implemented in several techno-economic analyses for quantifying financial risks. Arnold and Yildiz (2015) present an analysis to determine the financial risk for investors of renewable bio-energy projects. Monte Carlo methods are also implemented for economic evaluation of a Photovoltaic/Thermal concentrator in Sweden (Gu et al., 2018) and an uncertainty analysis for hydrogen production from high pressure polymer electrolyte membrane water electrolysis in Korea (Lee et al., 2017). The Monte Carlo method is able to quantify risk analysis by adopting random numbers in the probability distribution to generate the possibility of uncertainty in net present value (Verbeteen, 2006; Huang, 2008; Nawrocki, 2001; Shaffie & Jaaman, 2015). The novelty of this paper is in its ability to quantify risk as an exact number. The obtained probability then results as a risk percentage of loss, which is embedded into the decision tree analysis. The comprehensive integration of Monte-Carlo NPV and decision tree analysis gives both scientific and practical guidance for the decision making process.

2. METHODS

This study was performed in the Indonesian production sharing contract (PSC) called Constellation-x. This PSC is an oil and gas field operated by a private-joint venture called Petroleum Company. Constellation-x mainly produces natural gas and hydrocarbon condensate from the facilities located on the western side of Indonesia. As of 2016, Constellation-x has been producing for over 30 years and the contract ended in early 2017. This PSC can be extended for up to 10-years after it has ended. In this paper, the Monte Carlo method is embedded in the NPV analysis to quantify the probability of the production sharing contract's profit and loss. The result of this probability is utilized as input for determining the decision to acquire the production sharing contract.

2.1. Conceptual Framework

The assumptions built in this paper are that uncertainty is coming from the price of U.S. natural-gas prices. The price value is the most important factor for evaluating the exact value of profit. Beside the natural-gas prices, another major uncertainty is the reservoir production capacity. In the oil and gas business, production capacity is often described as a random number. This is because Petroleum Company deals with something that cannot be 100% accurate in a sub-surface reservoir. Based on that assumption, this paper utilizes variables of natural gas prices uncertainty and production capacity as inputs in the Monte Carlo simulation. The investment risk analysis in this paper involves two variables of uncertainties. To formulate the conceptual framework, the identified steps in defining the algorithm method of economic feasibility study are (Platon & Constatinescu, 2014):

1) determining the input variable for random numbers, X_1: U.S natural gas price, X_2: production capacity;
2) creating a parametric conceptual model, $y = f(X_1, X_2, \dots Xn)$; where f(x) is NPV process
3) generating a random input variable, $Xi_1, Xi_2, \dots Xin$;
4) calculating the net present value, and storing the result of the calculation as y_i;
5) performing reiteration of step 2 and 3 for i = 1 ton (n = 1000);
6) quantifying the result of the Monte Carlo - NPV iteration;
7) using this percentage as input parameter for the decision tree analysis;

8) stating the PSC investment analysis value as compared to bank obligations.
The Monte Carlo method generates a random input number for the U.S. natural gas price and production capacity in the triangular random distribution. The application of this conceptual framework is defined in Figure 1.

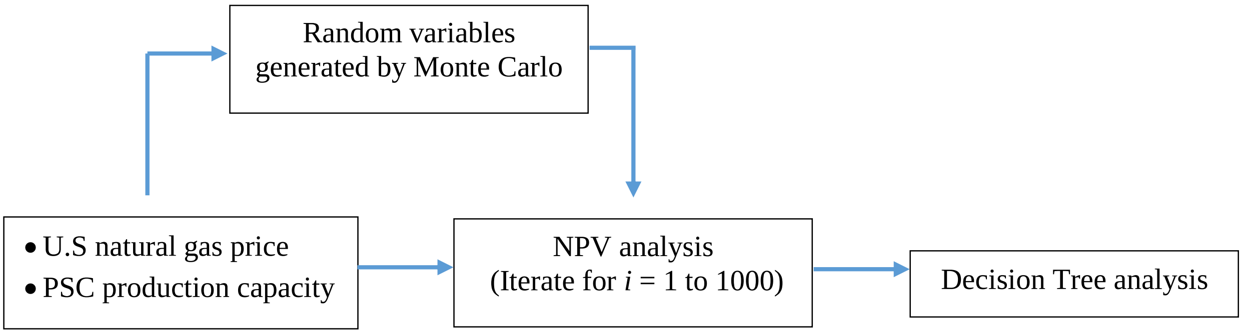

Figure 1 Conceptual framework

2.2. Income Projection

In general, there are two ways to analyze the economic impact, i.e., annualized cost and cash flow (Silitonga et al., 2011). This paper analyzes income projection based on cash flow over the lifetime of the investment.

Constellation-x PSC has proven (2P) to have reserves of 250 billion cubic feet (BCF). In 2016, gas production was stated to be 6.5-million-barrels of oil equivalent. In 2017, the average gas production per day was calculated at 37.9 Million Standard Cubic Feet per Day (MMSCFD) in 2016 it was 37.83 MMSCFD; and in 2015 it was 35.50 MMSCFD. The production increased with 5.2% overall gains per year, and, based on the trends, the production is expected to increase by 7.44% per year for the next 10 years. The linear regression modeling, which is used to calculate PSC production, is showed in Figure 2.

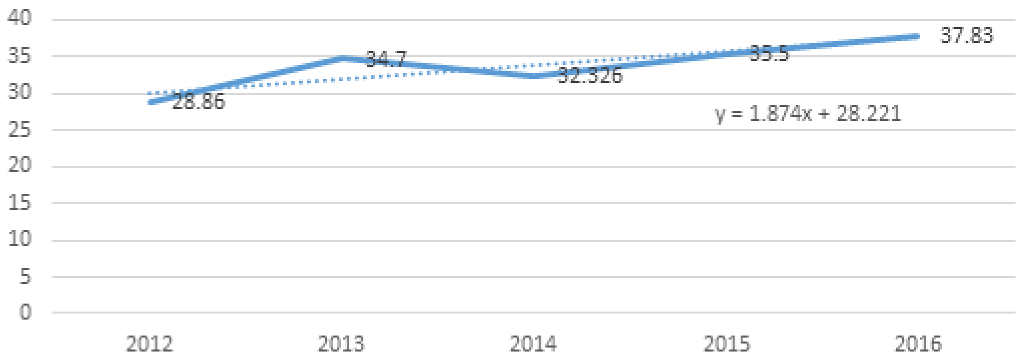

Figure 2 Production figures 2012-2016 in linear regression model

The selling price of Constellation-x gas PSC was stated due to the U.S. natural gas industrial price. During 2017, the U.S. gas industrial prices averaged $4.2 per million standard cubic feet (4,167 dollars / MMSFC). Based on the trend, the expected price during the 10-year contract shall increase by 1.91% per year. In oil and gas industries, the discount rate is accepted to compensate for the rate of inflation and the decrease of natural gas prices. The U.S. dollar inflation rate is, on average, 2.7% per year (inflation.eu, 2018). Based on Equation 1, the obtained result of discount rate is 2.37%.

$$Discount\ rate = (\%\ inflation - \%gas\ prices\ growth) x\ 300\%\ margin \quad (1)$$

Based on PSC agreement terms in the oil and gas industry and company policies, the interest rate expected from this project is 11% (Irham & Julyus, 2018). Expected income per year is calculated based on multiplication of gas price and production, as shown in equation below,

$$I = n \ x \ Q \ x \ P \tag{2}$$

where I is the expected income in a year; n is the number of productive days; Q is the gas quantity per day in MMSCF; and P is the price of natural gas. The projected total income is described in Figure 3. Please note that Figure 3 shows the overall income projection based on growth of gas prices and the growth of production. The figure does not take into account NPV analysis nor the rate of discount. The NPV analysis and IRR will be discussed in Chapter 3 of this paper.

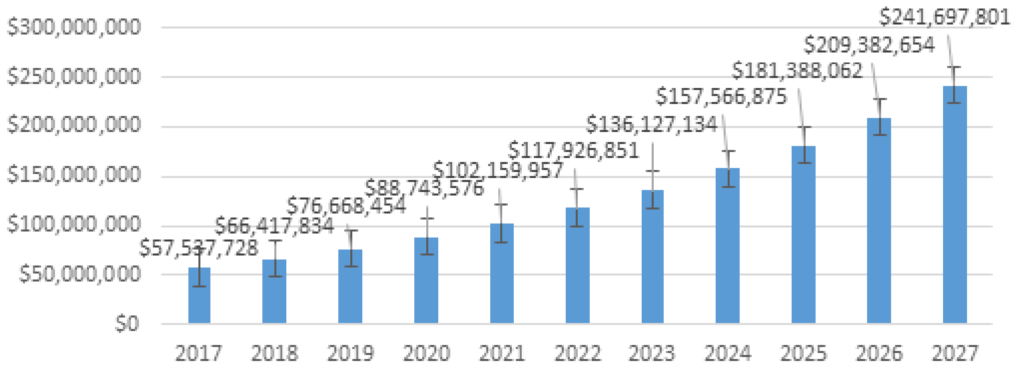

Figure 3 Expected total income of Constellation-x during contract duration. This graphic describes income projection with gains of production capacity, natural gas prices, and the discount rate.

2.3. Salvage Value

The salvage value is described as the remaining potential of production reserve in Constellation-x PSC. The proven reserve of Constellation-x PSC is 250,000,000,000 standard cubic feet (250 BCF). This reserve will be produced in the 10 years of the PSC, with average production described in Table 1. The salvage value is described as the potential value which is not yet produced, and is referred to as the value of potential reserve. In terms of the production sharing contract, the mechanism used is a cost recovery system. This system means that the Indonesian government is participating in funding the operational expenses only for the lifted hydrocarbon values (McQuhae et al., 2017). The entire salvage value will be given back to the Indonesian government. Therefore, the salvage value is considered as zero value for the Petroleum Company. This means that the salvage value only exists for the proven potential reserves inside Constellation-x PSC. The salvage value is described in Table 1.

Table 1 Salvage value at the end of contract duration

Reserves	2025	2026	2027
Proven reserves	729,667,497.61	602,566,697.41	438,015,005.81
Production per year (MMSCF)	24,516.43	26,340.45	28,300.18
Net proven reserves	81,442.97	55,102.52	26,802.34
Salvage value	$602,566,697	$438,015,006	$228,905,521

The final salvage value at the end of the contract period is $228,905,521. Based on this calculation, the profitable period of Constellation-x PSC are around 14 years from 2017.

2.4. Cost of Production Sharing Contract Development

The cost of PSC development is divided into capital costs and operational costs. The capital costs include bidding PSC contract value, cost of production platform development, and cost of drilling. The operational costs include maintenance costs, labor costs, well intervention costs, and cost of goods sold. As described in the table below, the capital cost is defined in U.S. dollars.

Table 2 Capital expenditure

Type of cost	PSC bidding value	Platform development	Drilling cost	Additional production facilities
Value	$ 224,000,000	$ 74,560,000	$ 88,500,000	$ 7,400,000
Total capital cost				$ 394,460,000

The operational cost is defined as variable cost according to the production value. This means the operational cost can be defined in U.S. dollars per MMSFCD of lifted gas. The operational value, which is not a variable of production, is labor cost solely. However, labor costs tend to increase by 7.9% per year. As described below, the expected production increases by 7.44% per year. Consequently, all operational costs (except labor costs) tend to increase by 7.44% per year. In addition, the inflation rate, cost of goods sold, and other operational costs increase by 2.7%. Therefore, the overall increase of operational costs is calculated as 10.14%.

Table 3 Operational expenditure calculation at the near end of contract duration

Operational cost	2025	2026	2027
Labor cost (increase rate 7.9%)	$6,430,424	$6,938,427	$7,486,563
Maintenance (increase rate 10.14%)	$21,825,978	$24,039,132	$26,476,700
Well intervention (increase rate 10.14%)	$28,411,516	$31,292,444	$34,465,498
Cost of good sales (increase rate 10.14%)	$519,290	$571,946	$629,941
Total operational cost	$57,187,208	$62,841,949	$69,058,702

3. RESULTS AND DISCUSSION

3.1. Relation of the Queue Tail Trajectory with Discharging Acceleration

Chapter 2 has revealed the expected income, capital cost, operational cost, and salvage value. The calculation of net present value can be described. In general, NPV is a tool of decision making in project investment.

$$NPV = \frac{C}{(1+r)^0} + \frac{C}{(1+r)^1} + \ldots + \frac{C}{(1+r)^{n-1}} = 0 \tag{3}$$

The expected interest rate (r) is 11%. By implementing Equation 4, the NPV analysis is described in Figure 5.

When the amount of salvage is taken into account, NPV is positive ($180,664,885). Even without counting the salvage value, the NPV is still positive ($100,047,913). Therefore, this investment is profitable.

3.2. Internal Rate of Return

As previously defined, the IRR is formulated so that the overall NPV is set to zero, and the calculation amount of rate, r is based on Equation 4 is described. NPV is described by Equation 5.

$$NPV = -394{,}460{,}000 + \frac{30{,}599{,}028}{(1+r)^0} + \frac{336{,}825{,}949}{(1+r)^1} + \frac{44{,}160{,}546}{(1+r)^2} + \frac{53{,}030{,}643}{(1+r)^3} + \frac{62{,}924{,}220}{(1+r)^4} + \frac{74{,}818{,}878}{(1+r)^5} + \frac{88{,}762{,}676}{(1+r)^6} + \frac{105{,}523{,}382}{(1+r)^7} + \frac{124{,}200{,}854}{(1+r)^8} + \frac{146{,}540{,}705}{(1+r)^9} + \frac{401{,}544{,}620}{(1+r)^{10}} = 0 \tag{5}$$

Based on this calculation, the value of IRR(r) = 15.36% if the salvage value is taken and the IRR (r) = 13.07% if the salvage value is not taken.

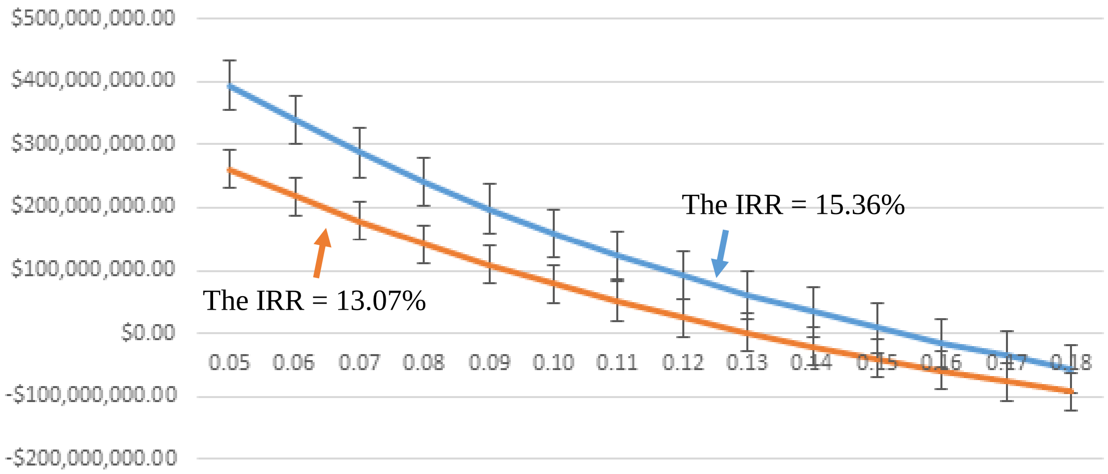

Figure 4 Internal Rate of return graphical explanation. The blue line describes IRR with salvage value, and the orange line without the salvage value. In this graphic, the project will have a negative NPV when *r* reaches approximately 16% (blue line) and 13% (orange line)

3.3. Investment Risk Analysis

The random number is derived from the U.S. Natural Gas Prices. To generate a Monte Carlo random number, a random formula on an Excel spreadsheet is utilized. The value of natural gas is based on the past ten-year trends and listed between $3,167 and $5,167. The current price of U.S. Natural gas price is $4,167. A random number was also chosen for the production capacity. In general, based on previous trends, the production capacity is increasing by around 7.44%. However, this is not exactly accurate. Therefore, Monte Carlo simulation is applied for production capacity in the increase of 7.44%.

The cash flow is then determined by putting the capital cost into triangular distribution. The capital cost is $394,460,000. The variable and probability of the capital cost is then calculated by entering the formula in Excel. The overall cash flow during the contract’s 10-year duration is the product of net gain and random number production capacity.

Then, the Monte Carlo net present value analysis for the cash flow is performed. As demonstrated in Figure 6, the Monte Carlo NPV simulation generates positive and negative random values. This means that the analysis concludes that there is a possible risk of loss of investment. Several iterations are performed to know the value of risk of loss in this investment. After 1,000 iterations, the probability of the loss is determined. The overall probability of profit is calculated to be+-17.85%. Based on the risk analysis of Constellation-x PSC investment, it is found that the risk is higher than the opportunity of profit. It means that this type of investment is a high risk investment.

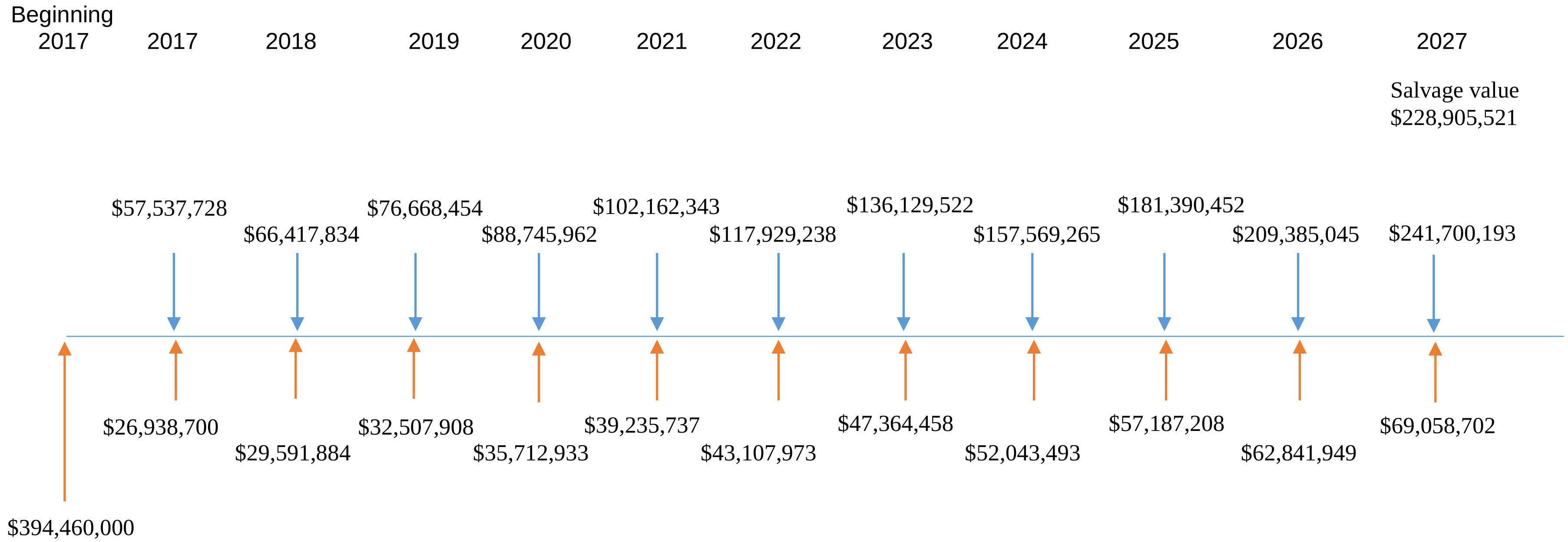

Figure 5 Net present value descriptive graphic year in arrears. The value of investment gains and costs is described with the line diagram. The sum product of the present value reveals a positive value

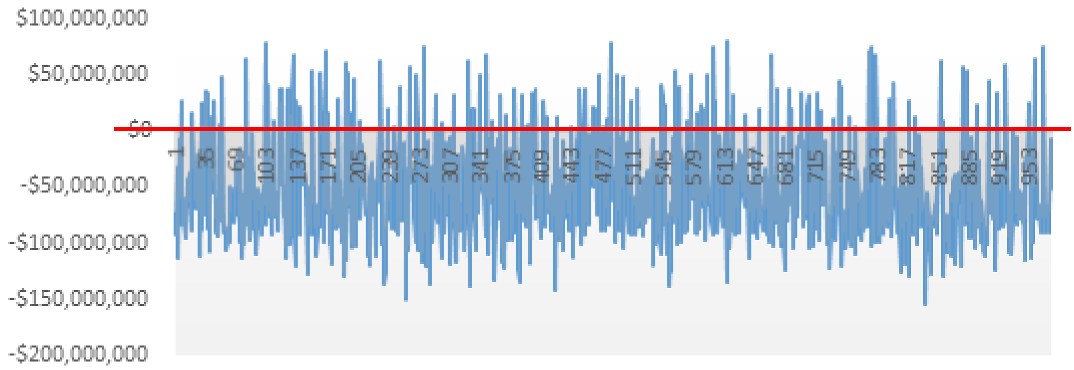

Figure 6 NPV probability risk of loss over1,000 iterations. Based on this graphic, the probability of loss is 82.15%. Positive values are the points above the red line, and the negative values are below the red line

3.4. Decision Tree Analysis

To build the decision tree analysis, related project experts in the Petroleum Company are consulted. They validate the decision tree results by confirming the probability of profit and loss based on the net present value analysis. The decision tree analysis is then made based on those probabilities, called risk percentage. In short, the risks percentage which is obtained in chapter 3.3 will be an input value to the decision tree analysis. The decision tree analysis will reveal the results as a product of risk percentage and amount of money which is gained (profit). The higher value of those multiplications, the more valuable the type of project.

It is known that the initial capital cost is $394,460,000. The decision is made whether Petroleum Company should invest this amount of money into the Constellation-x PSC project, or whether they should simply deposit this money into a bank obligation and receive 4.25% interest. To start the decision tree analysis, the expected gain should be determined if Petroleum Company invests in the Constellation-x PSC (calculated in chapter 2.1–2.3). The bank obligation is paid with the form of an annuity, with annual payments.

The total expected income is then calculated from total cash flow from Constellation-x PSC; the result is: $1,435,616,926. If Petroleum Company suffers losses from the Constellation-x PSC, the amount of loss should be quantified. The calculation using the Monte Carlo method has been performed to determine numbers of negative NPV. The iteration is performed 1,000 times. The number of quantified losses is gained by averaging the value of negative NPV in the Monte Carlo iteration. Average value of negative NPV = -$66,499,936. To calculate the total value of loss, the average negative NPV then is converted into repeating payment (PMT) form, as listed on Table 4.

Table 4 Loss valuation in PMT form

Year	Year *0*	Year *n*	Year *n+1…*	Year *n+10*
Value	($66,499,936)	$6,896,256	$6,896,256	$6,896,256

Therefore, the total expected loss is -$75,858,816. Afterward, the obligation value with an interest rate of 4.25% is converted into simple annuity forms.

Table 5 Bank obligation with 4.25% simple annuity form

Year	Year *0*	Year *n*	Year *n+1 …*	Year *n+10*
Value	($394,460,000)	$49,240,490	$49,240,490	$49,240,490

The total expected income from total annuity is $541,645,388. Although the probability of loss in obligation is very small, the rate of lower medium grade (BBB) obligation risk is around 2%. The decision value analyzed is based on this calculation:

$$Prob.Node\ 1\ (Constellation\ PSC) = EV = \$1{,}435{,}616{,}926\ (17.85\%) - \$75{,}858{,}816\ (82.15\%) = \$183{,}890{,}285 \quad (6)$$

$$Prob.Node\ 2\ (Obligation) = EV = \$541{,}645{,}388 (98\%) + 0\ (2\%) = \$530{,}812{,}480 \quad (7)$$

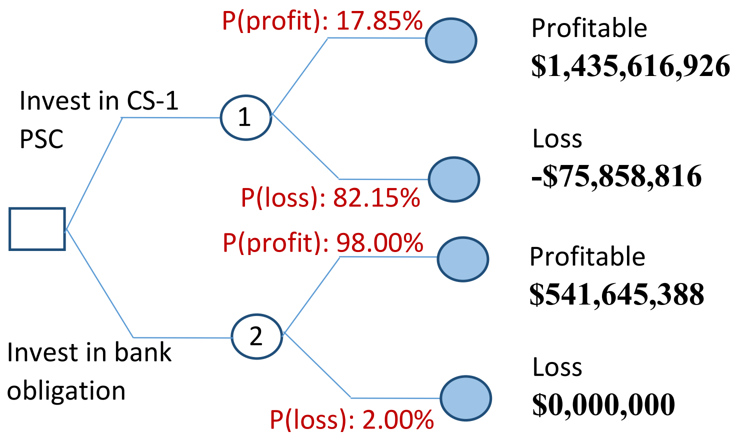

Figure 7 Graphical explanation of decision tree. This decision tree represents the calculation of Equations 6–7

Based the decision tree analysis, it is better to have the obligation than the Constellation-x PSC. However, Petroleum Company still has to maximize the potential gain or profit of the Constellation-x PSC. This is possible if the 3D seismic technique is utilized. The 3D seismic is a geologist's method to extract a picture of a sub-surface reservoir. This methodology will increase the accuracy of hydrocarbon reserves. Based on past experience, if there is oil, then the probability of unfavorable seismic soundings is *P(USS|Oil)* = 0.2, so *P(FSS|Oil)* = 1-0.4 = 0.8. Similarly, if there is no oil (i.e., the true state of nature is dry), then the probability of unfavorable seismic soundings is estimated to be *P(USS|Dry)* = 0.6, so *P(FSS|Dry)* = 1-0.8 = 0.4. Where the prior probabilities *P(Profit)* = 17.85% and *P(Loss)* = 82.15%. The posterior probabilities are calculated as follow,

$$P(oil/FSS) = \frac{P(FSS/oil).P(profit)}{P(FSS/oil).P(profit) + (FSS/dry)P(loss)} = 0.302 \quad (8)$$

$$P(oil/USS) = \frac{P(USS/oil).P(profit)}{P(USS/oil).P(profit) + (USS/dry)P(loss)} = 0.098 \quad (9)$$

$$P(dry/FSS) = \frac{P(FSS/dry).P(loss)}{P(FSS/dry).P(loss) + (FSS/oil)P(profit)} = 0.698 \quad (10)$$

$$P(dry/USS) = \frac{P(USS/oil).P(loss)}{P(USS/dry).P(loss) + (USS/oil)P(profit)} = 0.902 \quad (11)$$

Then, the calculated probability of favorable seismic soundings = 0.4728 and unfavorable seismic soundings = 0.5307. The posterior graphic of the decision trees are described in Figure 8. The posterior calculation of the decision tree after 3D seismic simulation is described with Equations 12–14.

$$Probe\ nodeA = (0.302)x(1{,}435{,}616{,}926) - (0.698)x(75{,}858{,}816) = \$\ 380{,}606{,}858 \quad (12)$$

$$Probe\ nodeB\ = (0.098)x(1{,}435{,}616{,}926) - (0.902)x(75{,}858{,}816) = \$\,72{,}265{,}806 \quad (13)$$
$$Probe\ nodeC\ = (0.4728)x(380{,}606{,}858) + (0.5307)x(72{,}265{,}806) = \$218{,}302{,}385 \quad (14)$$

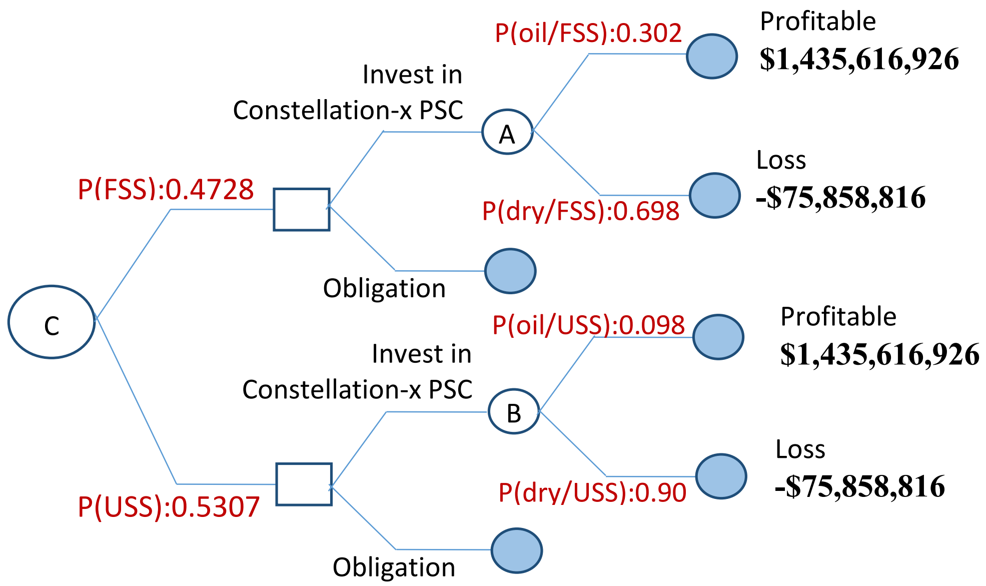

Figure 8 Graphical explanation of decision tree after 3D seismic simulation is performed. The probability numbers are based on posterior calculations in Equations 8–11

Therefore, after utilizing the 3D seismic method, the investment value ranges from $183,890,285 to $218,302,385. This means that the 3D seismic method provides an additional value of $34,412,101. Based on this analysis, the cost to perform the 3D seismic method must not be higher than $34,412,101.

Based on the analysis above, it seems that depositing the money in the bank with a 4.25% interest rate involves less risk than investing in Constellation-x PSC. The overall risk investment value for the Constellation-x PSC is described in Table 6.

Table 6 Decision analysis matrix

Investment Option	Risk Investment Value	Decision
Obligation 4.25% rate	$530,812,480	Low risk investment
Invest in PSC Constellation-x	$218,302,385	High risk investment

The decision tree analysis shows depositing the money into the obligation shall be taken in accordance to its risk value. Based on the risk investment value in Table 6, this paper implies that depositing money in the obligation is better than investing in PSC Constellation-x. This means that, considering the multiplication value of risk percentage and amount of profit, the bank obligation brings more valuable results. This circumstance is true when the probability of loss is high and the potential profit is small. In other words, the higher risk involved the less valuable the projects will become.

4. CONCLUSION

Based on the analysis that has been performed, it is confirmed that oil and gas industries are high-risk investments. As a basic economic principle, high risk investments yield high potential returns. Based on the NPV analysis, with 11% rate of return, the Constellation-x PSC shows a positive value. The internal rate of return calculated is at 15.6%, taking into account the salvage value, and 13.07% without considering the salvage value. This number is categorized as a high return investment. As a comparison, most bank obligations only promise to have returns of 3.35%–5.05%. This paper has also calculated the value of positive NPV over1,000 iterations using the Monte Carlo methodology. At this point, the probability of loss is quite high (82.15%). In conclusion, this type of investment is only suitable for a company with strong equity or financial power. This analysis also proves that the oil and gas industry provides high risk – high returns investments.

The analysis presented in this paper reveals that quantified risks and uncertainties come from two parameters: reservoir production and the US natural gas price. The analytical results are expected to lead to correct decision making. However, this paper has limitations in determining intangible factors, such as the natural gas commercial market, operational process efficiency, and government tax rates. This paper demonstrates those factors as negligible aspects. Further deep analysis on risk quantification may be performed by using more realistic statistics distribution. As this paper uses triangular distribution for the Monte Carlo simulation, normal distribution or binomial distribution may be more relevant to simulate the Monte Carlo simulation for the uncertainties parameters.

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