A Decision-Making Modellingin Probabilistic ConditionUsingMonte-carloand Decision Tree AnalysisonUpstream Petroleum Business Development

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Abstract: The upstream oil and gas industry has high risks, uncertainties and capital costs. An investment decision-making model that considers risk and uncertainty analysis is needed to review the potential advantages and disadvantages of each development scenario. In this study, a risk and sensitivity analysis was carried out to gain an understanding of the decision problem, then the Monte-carlo simulation and decision tree were applied to obtain the best scenario for the development upstream oil and gas business. From sensitivity analysis it is found that oil prices and production have the most dominant influence on NPV. In this research, monte-carlo simulation and decision tree can be combined to improve the quality of analysis and it is hoped that decision makers will have a complete picture with the proposed approach.

Keywords: Business development,Decision-Making,Decision tree,Risk, Uncertainty analysis, Petroleum company

1. Introduction

Oil and gas are the largest source of energy in supporting human life and activities. The oil and gas industry plays an important role for a country's economy (Babajide 2015). The oil and gas industry has experienced very volatile conditions in the past few years (Mashari 2019). In recent years oil prices are very fluctuated in the range of $20/bbl to $140/bbl. Decision makers must be more careful in taking the best steps regarding oil price volatility. The company's management must be prepared to face the volatility and the effect to business portfolio.

Exploration and production process in oil and gas industry are capital intensive businesses and very high risks that require economic analysis to evaluate the feasibility of the project. The risks include the amount of investment required, duration of project, subsurface uncertainty (geology, reservoir, and production) and economics (Capex, oil prices, and Opex). Risk and uncertainty analysis is one of the main concerns in the decision-making process to determine a good and long-term investment and also minimize potential business vulnerability (Asrol *et al.* 2021). This analysis is necessary to define the potential advantages and disadvantages of each oil and gas project scenario, as decision makers will rely on information from the analysis(Mudford, 2000). Therefore, a proper analysis of risk and uncertainty is necessary to get a complete picture of the decision problem (Mbanugo, 2011).

Decision-making models in the oil and gas industry are subject research to be developed. The model that is often applied in decision making is a combination of decision tree analysis (DTA) and expected monetary value (EMV) with weighting against the NPV value. DTA is modeled to make decisions based on maximum EMV. If the EMV is positive then a plan can be said to be feasible. However, it does not mean that the decision taken is definitely the right one. Understanding the probability of success and the number of cases that have been faced greatly affect the quality of decisions (Alkinani, 2019). DTA has a weakness when dealing with many uncertain variables and requiring several other supporting techniques.(Mudford, 2000). Engineers and practitioners in industry generally prefer deterministic evaluations that produce a value by ignoring the uncertainty factor. As a result, the overall information of a plan is not well illustrated and many risks cannot be mitigated (Supriadi, 2013). Experience has shown that deterministic estimates tend to be overly optimistic and have large deviations. This emphasizes the importance of establishing estimation methods that better assess uncertainty and risk.

Probabilistic methods consider a large number of possible scenarios rather than a few. The probabilistic approach allows the implementation of uncertainty and risk, leading to estimates that cover a range of outcomes that may be different significantly from initial estimates (Akins, 2005). Using the confidence interval range from unexpected events to the estimation model, probabilistic methods have advantage over deterministic analysis because can provide more information from various possibilities. In particular, probabilistic methods are commonly used for mass analysis of probable reservoir parameter and reserve but are rarely used in economic analysis.

This study will examine the main factors that influence on an oil and gas business portfolio and design a decision-making model using Monte-carlo simulation and decision tree. The importance of this research is to enlighten decision makers to identify uncertainties and risks in the decision-making process. The results of this analysis will be very influential in determining which scenario should be taken by the company.

2.Review of Related Studies

Neff (2021) conducted research related to estimation hydrocarbon saturation using monte-carlosimulation and machine learning. The research has been done successfully determined hydrocarbon saturation on 15 well using decision model based on Monte-carlo. Chiutoroi (2019) conducted study on risk analysis on water injection and application Decision Treen Analysis (DTA) and Monte-carlo. In this study they showed that DTA and monte-carlo can applied to determination best scenario on injection parameter. Schulze (2012) conducted study on applicationmonte-carlo and decision tree on subsurface and commercial aspect. In this study they find out that combination of monte-carlo and decision tree workflow can be implemented on subsurface and comercial. Research that has been done (Jincong , 2021; Ibarra., 2017; Orlov, 2017 and Grose, 2016) proved that DTA and monte-carlo techniques capable to help in many fields. Therefore, this study uses a combination of DTA and Monte-carlo techniques which will be applied to oil and gas development scenarios.

3.Objectives Of The Study

- To analyze and identify themost sensitive parameters that effect on oil and gas gas business portfolio.
- To design a decision-making model by considering uncertainty.

4.Data and Methodology

This research began with collecting data related to oil field plan of development. Data collection and validation were carried out at one of the petroleum company in Indonesia. The field plan of development data was analyzed by viewing development scenario, forecast oil production, capital expenditure (Capex) and Operational expenditure (Opex). Deterministic analysis was performed with assumption of flat oil price at 70$ per barrel. A probabilistic analysis is required to identify uncertainties and risks effect to project NPV. A monte-carlo simulation was performed using confidence interval of oil price, production forecast, capex and opex based on expert interview. Monte-carlo simulation result P-10, P-50, and P-90 each scenario were selected as input on decision tree case.

4.1 Field Development Scenario

AnE&P Company would like to develop one of its fields (Alfa Field). Based on reservoir study, the field still have potential to developed and has substantial oil and gas resources. Management currently evaluated the result from feasibility study and is faced with several development scenario. Risk and uncertainty analysis needs to be carried out to select the best scenario for Alfa field. Reservoir simulation was performed with 5 development scenario to determined production forecast each scenario,Figure 1. The summary of those options can be seen in Table 1:

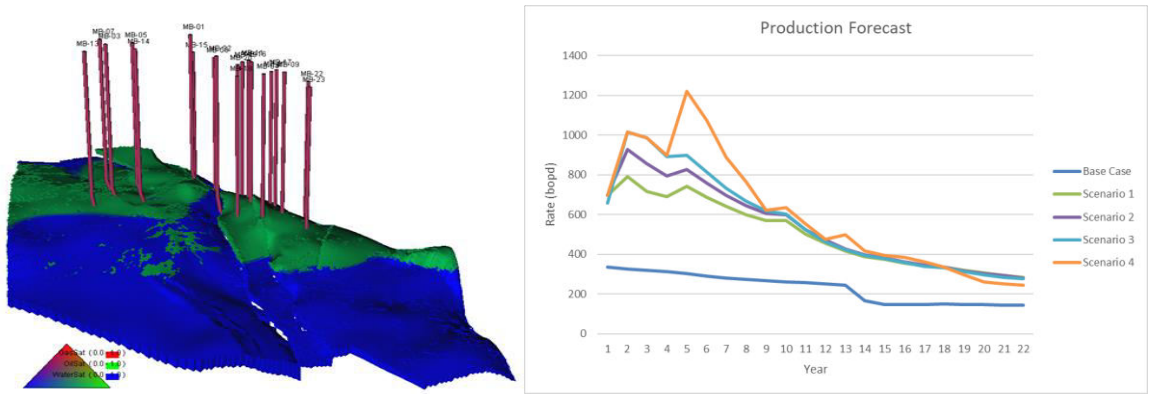

Figure.1 showing the reservoir models and forecast production simulation

Table.1. showing field developmet scenario

	Initial Condition			Forecast		
	Original Oil in Place (OOIP)	Cumulative Production (Np)	Recovery Factor (RF)	Forecast Cumulative Production	Incremental Production	Forecast Recovery Factor
Scenario	MMSTB	MMSTB	%	MMSTB	MMSTB	%
Base Case: do nothing	57.06	12.59	22.06%	14.63	0	0
Scenario 1: Drilling 4 Wells				16.96	2.34	18.59%
Scenario 2: Drilling 5 Wells				17.25	2.62	20.81%
Scenario 3: Drilling 6 Wells				17.40	2.78	22.08%
Scenario 4: Drilling 13 Wells				17.70	3.02	23.99%

4.2 Confidence Interval Uncertainty Factor

Expert interviews are a structured process to assess the range of uncertainty. The assignment of subjective probability distribution is carried out in the early stages of the decision-making process. Experts in the relevant field and experience are called in to implement the expert elicitation method for each uncertainty parameter. In the expert interview, the probability distribution for all uncertain parameters is specified. This method is very useful in the absence of data. At the same time, historical data and information can be used to provide insight experts and analysts. It is not recommended to make judgments without considering historical data and other information. Generally, correlations derived from expert interview methods are more accurate than intuitive correlation, guesses, or estimates. In this case study, uncertain parameters are defined based on expert elicitation. Experts assign specific distributions to the following parameters, Table 2

Table.2. Probability distribution for each uncertain parameter

Criteria		Value	Unit	Distribution
Oil Price	Min	34	$/BBL	Triangular
	Most likely	52	$/BBL	
	Max	83	$/BBL	
Opex	Min	85	%	Triangular
	Most likely	102	%	
	Max	118	%	
Capex	Min	86	%	Triangular
	Most likely	106	%	
	Max	132	%	
Production	Min	56	%	Triangular
	Most likely	90	%	
	Max	128	%	

4.3Indonesia Fiscal Regime

All scenario cases are evaluated using the Indonesia Cost recovery PSC fiscal regime. Indonesia was the first country using the cost recovery PSC fiscal regime model in 1966. Cost recovery PSC is a fiscal model that allows contractors to recover all operating costs. Investment costs will include the costs of exploration (geology study, seismic, and exploration drilling), development drilling, and production facilities. On the other hand, operating costs will include the cost of daily activities, such as daily maintenance, oil well services, general and management costs, personnel costs, transportation costs, labour costs, fuel costs, maintenance costs, etcTangible costs will be recovered through depreciation and intangible costscan be recovered when all costs occur. The schematic of Indonesian Cost recovery PSC for national oil company showed in Figure 3.

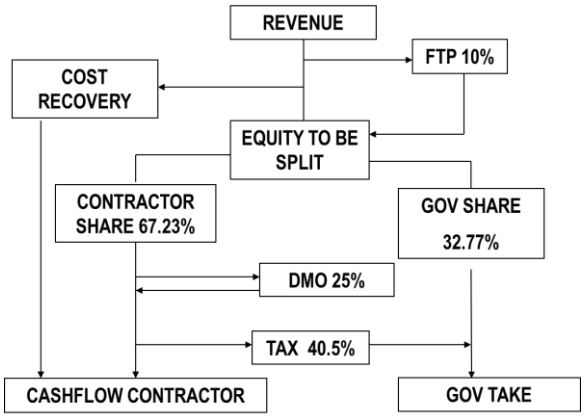

Figure.2 Cost recovery PSC model

5.Data Analysis and Interpretation

Sensitivity analysis is conducted to determine which parameterthat have the greatest impact on the NPV. Figure 3 show the spider diagram on scenario 3 for Cost recovery PSC fiscal model. From the spider diagram, oil price and oil production have the greatest impact on NPV.Anychanges in capex and opex values do not have a significant impact on NPV compared to oil prices and production.This is because NPV is very dependent on the value of revenue which is multiplication on oil price and production.

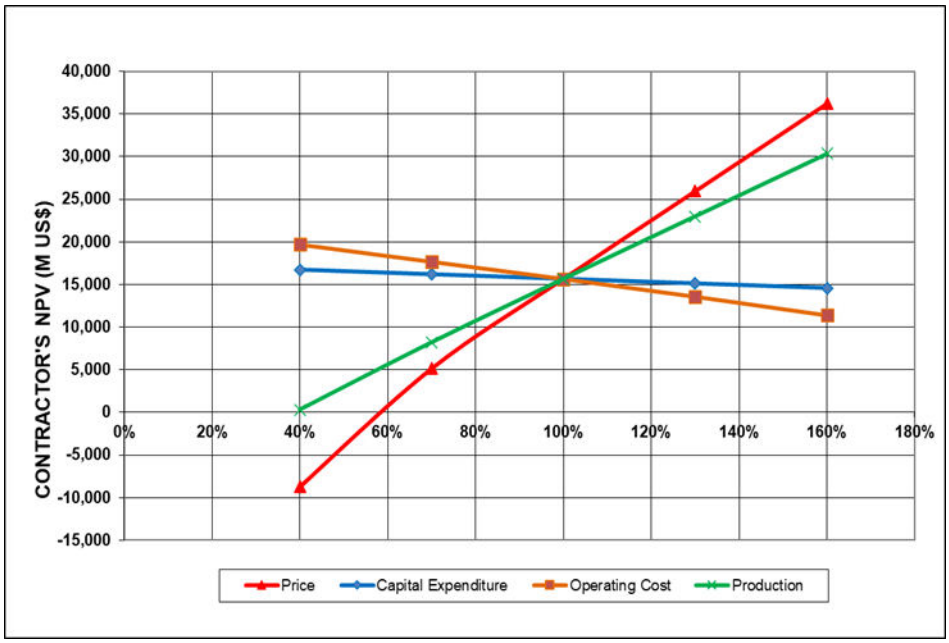

Figure.2 Spider diagram scenario 2 using cost recovery PSC model

Monte-carlo method is used to simulate uncertain parameters in the input parameter to the model.Monte-carlo simulation was performed with 100.000 iteration with a software. Simulation provided for the uncertainty analysis based on the probability distribution from expert interview through the model. The Monte-carlo result are shown in Figure 3.

The results show the probability of a particular NPV value for each scenario. The probability distribution of each option replaces the deterministic evaluation and provides a picture of the uncertainty of each scenario. Based on this result, the proposal to develop 6 wells in option 3 is considered to be the most promising option, with the highest NPV distribution.This is followed by scenario 2 and scenario 1.If the monte-carlo process is used, option 3 will be selected to continue with the project.

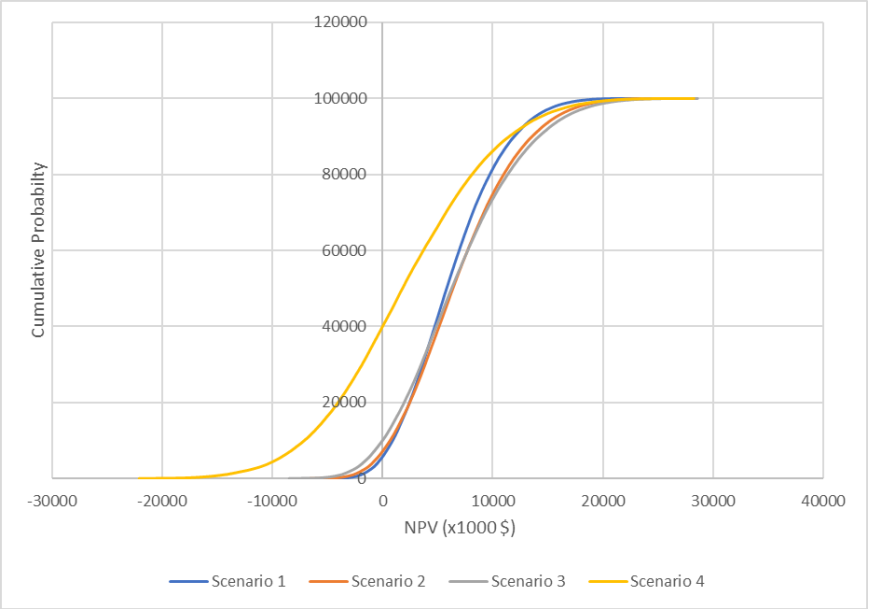

Figure.3 Monte-carlo simulation result on each scenario

Decision trees are designed for each scenario with input from the Monte-carlo simulation. The value of P-10 will be categorized as a high case, P-50 as a medium case and P-90 as a low case that showed in Figure 4. Based on the evaluation results from decision tree analysis, scenario 2 is considered to be the most promising option, with the highest EMV results. This scenario 3 has a greater risk when conditions are not as expected.

From this case studies, it can be seen that the developed framework can be implemented properly. The results of the sensitivity analysis show a significant effect between oil prices and oil production on the NPV value. Risks due to volatility price and production cannot be avoided, but an assessment level of deviation and its consequences can be carried out using sensitivity analysis and Monte-carlosimulation.

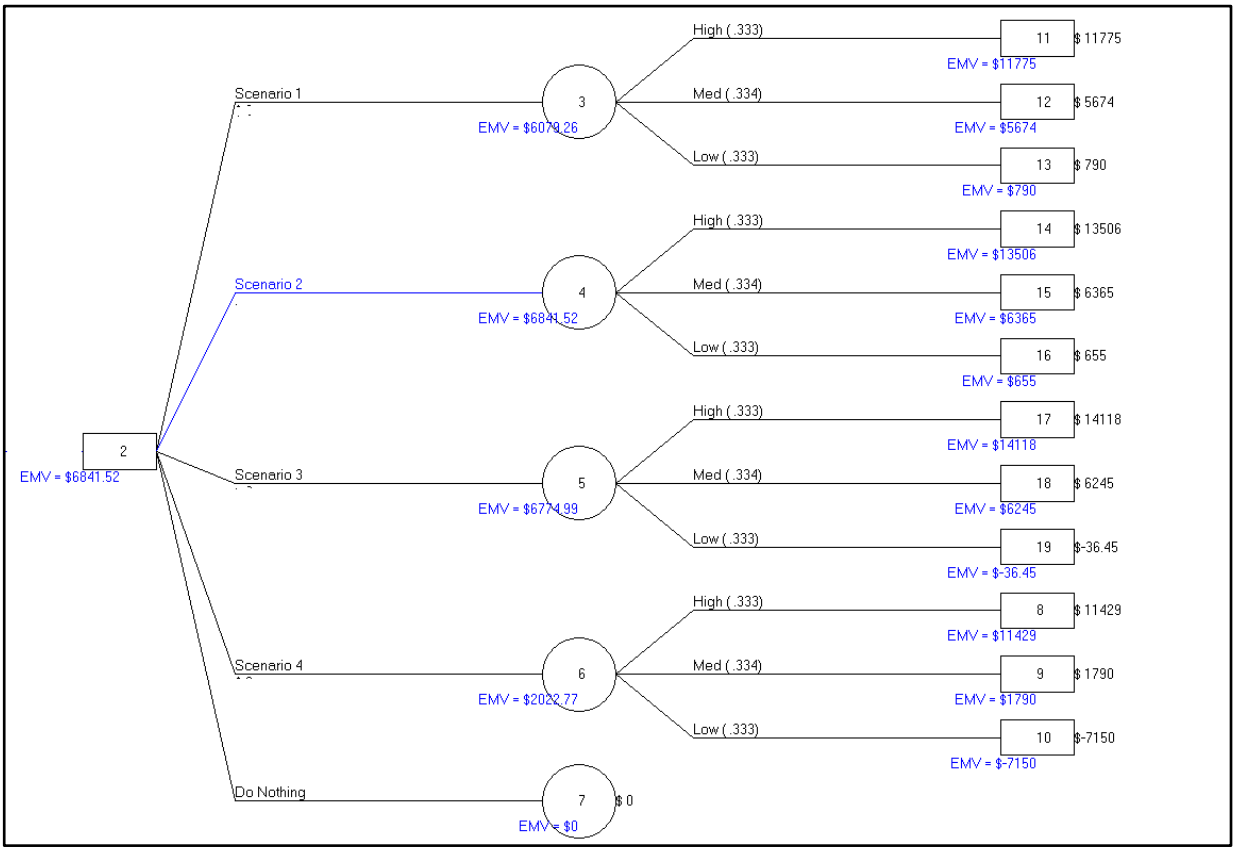

Figure.4 Decision tree analysis on each scenario

The method proposed in this study is based on a more representative analysis of risk and uncertainty. A case study in upstream oil and gas development are used to apply the proposed approach. Identification of uncertain parameters impact such as oil prices, production and costs is carried out by expert and sensitivity analysis. The purpose of this analysis is not to eliminate uncertainty but to gain a good understanding of the impact of each parameter. Probability distribution is used as a measure of uncertainty.Triangular distributions are assigned to measures of uncertainty in oil prices, production, Opex and Capex. NPV calculations presented in this study are proposed to associate the uncertain input parameter with the output parameter using Monte-carlo simulation and decision tree analysis. Monte-carlo simulation and decision trees analysis are provided to decision makers as information.

The weakness of this study lies in the lack of knowledge of the probability of occurrence of each scenario in various conditions as the basis for decision tree analysis. The probability value of the events used in this study is assumed to be the same. The value of this opportunity can be changed if there is statistical data or expert opinion.

6.Recommendations

For further research to develop a better decision-making model, the researcher provides several suggestions that can be used as the development of the next research:

- This research was conducted when the price of oil dropped drastically due to the corona which caused the possibility of expert opinion regarding the oil price range to be pessimistic. The researcher suggests doing a comparison with the fundamental analysis of future oil prices which considers supply, demand and geopolitics.
- In this study, the decision tree model was made using the same probability value. It would be better if there was additional research on the value of the probability of occurrence using either statistical data or expert opinion.
- This research only considers technical and economic aspects in decision making. It would be better if we could study the effects of human factors and other aspects such as political, social and ethical in decision making.

6.Conclusions

1. Based on the results of sensitivity analysis, the amount of production and oil prices are the most dominant factors in influencing the economy of an upstream oil and gas business portfolio.
2. In this study, a decision-making model using Monte-carlo and a decision tree was applied which tried to be applied to real case studies that occurred. As a result, this model can be used to make decisions by considering the uncertainty.

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