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Dynamic programming for shortest path problem in a multimodal transportation network comprising intermediate sinks

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INTERNATIONAL SEMINAR ON INDUSTRIAL ENGINEERING AND MANAGEMENT

[Production and Service System in The New Normal Era]

Bandung, West Java, Indonesia

July 28, 2021

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# PREFACE

*Bismillahirrahmanirrahim,*
*Assalamu'alaikum Warrahmatullah Wabarrakatuh,*

First of all, we apologize for the inconvience in the 13th ISIEM 2021 event, due to current condition and situation of COVID 19. The situation made us has to make some critical modification in the event, including: online presentation of keynote speaker, online presentation for all candidates that cannot attend the seminar. but we hope we all remain excited to continue to contribute to research publications. Nonetheless, we are trying to prepare this seminar as best we can.

This issue is published in line with the Thirteen International Seminar on Industrial Engineering and Management (13th ISIEM) 2021. The articles cover a broad spectrum of topics in Industrial Engineering and Management, which are Quality Engineering Management, Decision Support System and Artificial Intelligent, Ergonomics, Supply Chain Management, Production System, Operation Research, and Industrial Management. These articles provide an overview of critical research issues reflecting on past achievements and future challenges. Those papers were selected from 137 abstracts, and we send these papers to AIP to be published there as an Open Access Proceeding Scopus. This statistic shows the high competition to get published on this proceeding. This issue and seminar become special as more delegates come and join from various country as well as universities. We host 90 delegates both from abroad and local.

The 13th ISIEM is hosted by eight universities, which are Universitas Pasundan, Universitas Esa Unggul, Universitas Trisakti, Universitas Tarumanagara, Universitas Al-Azhar Indonesia, Atma Jaya Catholic University of Indonesia, Universitas Pancasila and Universitas Mercubuana. This is the thirteenth years of the collaboration of those universities, and the first time we had MOU with AIP in America to publishing the papers that is indexed by Scopus. This is also the second years of our international partnership join committee with Chung Yuan Christian University – Taiwan, Yuan Ze University – Taiwan, Kasetsart University – Thailand and Bright Star University – Libya.

In this occasion, let us give special thanks to Prof.Yung-Tsan Jou, PhD (Professor and Chair Department of Industrial and Systems Engineering, Chung Yuan Christian University – Taiwan), Prof. Yun-Chia Liang, PhD (Professor and Chair, Department of Industrial Engineering and Management, Yuan Ze University – Taiwan), Elisa Lumbantoruan (President Director & CEO at ISS Indonesia, Independent Commissioner at PT Indosat Tbk, and Independent Commissioner at Garuda Indonesia) and Naraphorn Paoprasert, Ph.D (Researcher, Department of Industrial Engineering, Faculty of Engineering, Kasetsart University – Thailand), for their contribution as keynote speakers, to Prof. Abdelnaser Omran from Brightstar University, and supported by Indonesian Association of Industrial Engineering Higher Education (BKSTI) and the Institution of Engineer Indonesia – Industrial Engineering Chapter (BKTI-PII). We are also grateful to all reviewers and editors, for their commitment, effort and dedication in undertaking the task of reviewing all of the abstracts and full papers. Without their help and dedication, it would not be possible to produce this proceeding in such a short time frame. I highly appreciate all members of committees (advisory, steering, and organizing committees) for mutual efforts and invaluable contribution for the success of seminar.

*Wassalamu'alaikum Warrahmatullah Wabarrakatuh.*

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# Decision-making for conducting seismic-surveying activities on oil and gas exploration using decision tree and utility functions

*by* Anonim Anonim

RESEARCH ARTICLE | AUGUST 08 2023

# Decision-making for conducting seismic-surveying activities on oil and gas exploration using decision tree and utility functions FREE

Heni Hindayanti ✉; Winnie Septiani



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# Decision-Making for Conducting Seismic-Surveying Activities on Oil and Gas Exploration Using Decision Tree and Utility Functions

Heni Hindayanti [a] and Winnie Septiani [b]

*Faculty of Industrial Technology, Campus A, Universitas Trisakti, Jakarta 11440, Indonesia.*

[a]Corresponding author: hinda1016@gmail.co.id
[b]winnie.septiani@trisakti.ac.id

**Abstract.** A seismic-surveying activity is one of the important activities in oil and gas exploration to determine the hydrocarbon content beneath the Earth's surface. Furthermore, the government will pay the cost of exploration activities through cost recovery on the condition that the company is able to find commercial oil and gas reserves. The purpose of this study is to assist companies in deciding for conducting seismic-surveying activities to reduce losses in oil and gas exploration. The methods employed to evaluate this decision were the decision tree and utility functions. After carrying out brainstorming with experts in the field of oil and gas exploration, three alternative decisions were proposed: conducting drilling without carrying out seismic surveys, with 3D seismic surveys, and with seismic surveys through the Exploration Joint Venture Agreement (EJVA). The desired criterion is maximum company profit. Meanwhile, the uncertainties that may occur are the success in finding the reservoir or failing (finding dry hole). Moreover, the results of the interpretation of the seismic structure predictions indicated high and low structures with reservoir categories at high, best, and low levels. The alternative evaluation was determined using the calculation of the Expected Monetary Value and Utility Function which provides options regarding the preferences for decision-makers. The results of the calculation indicated that the EJVA-seismic survey provides the highest value, namely 40,980,915.81 USD. Meanwhile, the VP exploration preference for the EJVA-seismic surveys was 0.403. Therefore, the recommended alternative for the company is to carry out an EJVA-seismic survey to minimize the risk of company losses in oil and gas exploration.
**Keywords:** exploration, seismic, decision tree, expected monetary value, utility function.



## INTRODUCTION

Oil and gas companies require large funds, qualified technology, highly qualified experts, and the ability to face high risks to carry out oil and gas exploration in the layers of the Earth's structure either on land or offshore [1]. In order to find oil and gas reserves, an increase in oil and gas exploration activities is expected to have a positive impact on the prospects for the development of the upstream oil and gas sector in the future. Besides, it is to maintain the availability of energy sources for future generations [2]. Companies that have entered into cooperation contracts with the government can start searching for oil and gas reserves with geological and geophysical (G&G) surveys, seismic surveys, or gravity surveys to find out whether a site contains oil and gas or not [3]. The government highly supports these exploration activities because the oil and gas sectors contribute quite a lot to state revenue. By approving the return of cost recovery for new oil and gas areas by the government, it is hoped that it will be able to attract investors to invest in these exploration activities. Cost recovery or refunds from the government for exploration activities in Indonesia in seeking reserves, developing, producing, and delivering oil and gas products can be carried out on the condition that the oil and gas company has succeeded in obtaining commercial oil and gas products. Costs that will be paid back to the oil and gas company through this cost recovery schema include operational costs, exploration costs, and development costs. Seismic survey costs are included in exploration costs, involving the entire operating cost incurred during routine activities, starting from searching for reserves to producing hydrocarbons [4].

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Information related to oil and gas reserves and other energy can be found out by investigations of the Earth's layer using technological equipment and supported with application tools to interpret data/information as complete as possible, known as oil and gas exploration activities [5]. The oil and gas exploration funds that must be spent and have the high risks make the company consider whether to conduct seismic-surveying activities or to directly conduct drilling [6]. Seismic-surveying activities can be carried out by the use of a technology called 3D seismic imaging utilizing sound waves to produce three-dimensional images of the geological formation of the Earth's layers [7]. The results of this seismic interpretation become the standard for understanding the latest subsurface geological picture of a region and finding more accurate oil and gas reserves. It is undeniable that sometimes these results are not necessarily able to provide satisfactory results related to the presence of hydrocarbon reserves and its category at the high, best, or low level. However, the data found can be used by companies as a strong reference in order to avoid failure if conducting drilling directly without seismic surveys [8].

Some of the exploration companies that are experiencing a lack of funds have chosen to cooperate with seismic-surveying partners that can finance seismic-surveying activities from the beginning until finding commercial reserves through an Exploration Joint Venture Agreement (EJVA) [9]. Even though the costs are borne by the partner, the exploration company still has the potential to lose the company's interest during the agreement. With this alternative, the company will still get the risk of losses due to failed seismic prediction results.

Exploration activities also have to face uncertainty. Therefore, a company management strategy is highly needed to avoid losses. A strategy mapping needs to be carried out for all uncertain conditions that may occur. One of the methods that can be used is the decision tree [10]. In drawing conclusions using this method, all components are represented in the form of a tree, starting from the roots to stems and leaves [11]. The calculation with the Expected Monetary Value (EMV) can help decision-makers to get the best decisions based on the greatest benefits to be obtained. Meanwhile, the utility function may provide options for decision-makers in addressing the risk of problems.

## METHODS

This study was conducted at an exploration and production company, namely Kontraktor Kontrak Kerja Sama (KKKS). Currently, this company is conducting exploration activities in an exploration field and the VP exploration will determine the prospects in the field currently managed.

The stages in this study to obtain alternative priority decisions for conducting seismic-surveying activities were as follows.

- Identifying the problem.
  The identified problem was that the company required consideration in carrying out seismic or non-seismic exploration for oil and gas oriented to gaining profit.
- Identifying the required data.
  This study required data and information related to oil and gas exploration activities, 3D seismic images, alternatives, uncertainty, and quantitative data for the NPV. To get the NPV, the applied equation was as follows.

$$NPV = -C + \frac{S_1}{(1+i)^1} + \frac{S_2}{(1+i)^2} + \ldots + \frac{S_n}{(1+i)^n} \tag{1}$$

Where: $C$ : initial investment

$S_1, S_2, S_n$ : net cash flow for 1-year, 2-year, and so on, until n-year

$n$ : the number of years (the age of activity)

$i$ : discount rate (bank interest)

- Collecting the data.
  Data were collected through studying relevant literature on several scientific journals and e-books that supported this study. In addition, researchers reviewed previous studies related to the topic of this study and the decision tree. In this study, researchers also held a forum group discussion (FGD) with seismic consultants, risk management experts, and strategic management experts. Furthermore, direct interviews were also carried out with geoscience experts to get a detailed description of seismic-surveying activities.

- Identifying alternatives, criteria, and uncertainties.
  In this stage, researchers identified the criteria expected by the company, alternative decisions that become the focus in supporting the company's goal of obtaining maximum profit, and the uncertainty that is faced by each alternative decision.
- Modeling decision making for conducting seismic-surveying activity using the decision tree.
  The results from the identification of alternatives, criteria, and uncertainties were used to model the decision tree from the analyzed cases for deciding on conducting the seismic-surveying activity. The meaning of the notations or symbols used in the decision tree is as follows.
  □ a square is a symbol of decisions
  ○ a circle is a symbol of uncertainty
  ― a connector (fork)

- Assessing and evaluating the alternatives using the EMV and utility functions.
  At this stage, researchers conducted an evaluation of alternative decision for conducting seismic-surveying activities using the EMV calculation method and the utility function. Decision-making in the uncertainty condition was solved by seeking the largest Expected Monetary Value (EMV), in which the applied formula was as follows.

$$EMV = payoff\ value \times probability\ of\ an\ occurrence \tag{2}$$

  Decision-makers who have a neutral attitude in dealing with risk are perceived as having the fixed equivalent value that is equivalent to its utility value. Therefore, the risk premium is zero. Furthermore, to get the best decision, the thing that must be done is to find the highest expected utility (EU) value, in which the employed formula was as follows.

$$u(x) = \frac{x - x^0}{x^1 - x^0} \tag{3}$$

  where $x^0$ is the lowest preference value and $x^1$ is the highest preference value.
- Determining the priority decisions. The priority decision was determined based on the results of calculations using the EMV. By correlating the results with the utility function, a decision was obtained based on the preferences of the decision-makers.

## RESULT AND DISCUSSION

### Identification of Alternatives, Criteria, and Uncertainties

This section discusses the results of the analyzed case study in determining the best alternative decision for oil and gas exploration activities. The VP exploration of the company is a person who is neutral in addressing risks and will investigate the expected value of exploration if it is carried out without a seismic survey. The FGD discussed about 3 alternatives, namely exploration without seismic surveys, with 3D seismic surveys, and with the EJVA-seismic surveys. The company in this study has 17 years of active status under a contract with the government for the field currently being managed.

If the company does not do seismic-surveying activities, they can use the initial G&G data which may not reflect the current conditions in the field. Meanwhile, if they are successful in finding oil and gas reserves, they can save on seismic-surveying costs. However, the probability of success is small. If they fail to find oil and gas reserves, they will lose the exploration costs. Furthermore, the bad possibilities could also happen, such as natural disasters, because some layers of the Earth contain ancient mud and large cavities. It is uncommon to find companies that do not carry out seismic-surveying activities because of such a large risk. In addition, all exploration procedures must comply with applicable government regulations. From the initial G&G data in the field, the seismic consultant stated that if exploration is not supported by a seismic survey, the success rate of finding a reservoir is only 0.2, in which the reservoir can be at the high, best, or low level with a probability value of 0.4, 0.5, and 0.1 respectively. Based on information related to the economic value analysis of reserves categories obtained from strategic management experts, the evaluation of cash flow, and the equation (1), the NPV is gained and presented in "**TABLE 1.**". By considering the exploration costs that cover all stages of activities, VP exploration assumes that it will cost 130,000,000 USD.

**TABLE 1.** Cash flow for each category of reserves

| Year to | (High Level/HL) | | (Best Level/BL) | | (Low Level/LL) | |
|---|---|---|---|---|---|---|
| | **Cash Flow ($)** | **NPV ($)** | **Cash Flow ($)** | **NPV ($)** | **Cash Flow ($)** | **NPV ($)** |
| 0 | -458.384.161,88 | -458.384.160,88 | -210.482.522,85 | -210.482.522,85 | -127.848.643,51 | -127.848.643,51 |
| 1 | 147.771.665,70 | 137.457.203,43 | 67.854.336,29 | 63.118.103,62 | 41.215.226,49 | 38.338.403,68 |
| 2 | 131.449.136,38 | 113.742.937,71 | 60.359.297,32 | 52.228.899,97 | 36.662.684,30 | 31.724.220,72 |
| 3 | 116.926.546,30 | 94.125.869,77 | 53.690.761,06 | 43.221.062,65 | 32.612.165,98 | 26.252.793,61 |
| 4 | 103.980.844,79 | 77.860.856,58 | 47.746.306,28 | 35.752.434,14 | 29.001.460,11 | 21.716.293,33 |
| 5 | 92.416.563,79 | 64.377.378,33 | 42.436.177,25 | 29.561.041,07 | 25.776.048,40 | 17.955.595,32 |
| 6 | 82.062.332,66 | 53.176.391,57 | 37.681.683,37 | 24.417.730,82 | 22.888.133,60 | 14.831.510,57 |
| 7 | 72.768.388,83 | 43.864.784,78 | 33.414.056,09 | 20.141.993,01 | 20.295.945,18 | 12.234.395,76 |
| 8 | 64.403.092,55 | 36.110.813,99 | 29.572.848,62 | 16.581.496,22 | 17.962.767,31 | 10.071.723,63 |
| 9 | 56.851.433,34 | 29.653.707,63 | 26.105.250,00 | 13.616.498,40 | 15.856.522,22 | 8.270.761,99 |
| 10 | 50.012.540,50 | 24.266.084,65 | 22.964.942,07 | 11.142.589,89 | 13.949.075,92 | 6.768.091,64 |
| 11 | 43.798.089,97 | 19.766.078,00 | 20.111.367,84 | 9.076.260,31 | 12.215.793,80 | 5.512.987,74 |
| 12 | 38.130.611,45 | 16.011.043,75 | 17.508.954,24 | 7.352.009,88 | 10.635.068,50 | 4.465.665,26 |
| 13 | 32.942.293,56 | 12.867.259,87 | 15.126.563,37 | 5.908.435,65 | 9.187.986,64 | 3.588.827,58 |
| 14 | 28.173.888,48 | 10.235.573,69 | 12.936.989,61 | 4.700.008,32 | 7.858.023,32 | 2.854.819,87 |
| 15 | 23.773.218,27 | 8.035.347,78 | 10.916.273,70 | 3.689.700,51 | 6.630.625,50 | 2.241.151,42 |
| 16 | 19.694.677,04 | 6.192.006,46 | 9.043.474,15 | 2.843.268,27 | 5.493.073,19 | 1.727.022,21 |
| 17 | 15.898.334,74 | 4.650.262,91 | 7.300.255,75 | 2.135.324,81 | 4.434.229,42 | 1.297.012,10 |
| | Total | 294.009.440,02 | | 135.004.334,70 | | 82.002.632,93 |

From considering the reserves with a high-level category and utilizing equation (1), in which the initial investment and discount rate set by the company are 458,384,160.88 USD and 7.5% respectively, the obtained NPV is as follows.

$$\begin{aligned} NPV &= \$-458{,}384{,}160.88 + \frac{\$147{,}771{,}665.70}{(1.075)^1} + \frac{\$133{,}449{,}136.38}{(1.075)^2} + \ldots + \frac{\$15{,}898{,}334{,}74}{(1.075)^{17}} \\ &= \$294{,}009{,}440.02 \end{aligned}$$

The obtained economic values for the best level and the low level by utilizing equation (1) are 135,004,334.70 USD and 82,002,632.93 USD respectively.

The second alternative proposed by strategic management experts is to conduct a 3D seismic survey, in which for an area of ± 250 km2, it requires the funding of 12,000,000 USD. The results of the analysis indicate that the probability of success from the 3D seismic survey is greater than exploration without conducting a seismic survey, which is 50%. By conducting 3D seismic surveys, strategic management experts optimistically state that the results of seismic data interpretation can indicate the latest predictions of the seismic structure, whether the category is high or low with probability values of 0.4 and 0.6 respectively. From the predictions of the seismic structure in the high category, an overview regarding oil and gas reserves can be found whether it is at high, best, or low levels. The value of the expected probability of oil and gas reserves is similar to the value of the expected oil and gas reserves in the first alternative. If the results of the 3D seismic interpretation are low, the company will not continue to the drilling activities so that they lose its seismic-surveying costs.

The last alternative proposed by the seismic consultant is that if the company is demanded to be efficient with operational costs, then they can consider doing EJVA-seismic surveys. In this alternative, the company will be freed from the overall seismic-surveying cost. However, the risk that the company will face is the loss of the company's interest during the agreement, in which the percentage of interest released depends on the agreement with the EJVA partner. From the data interpretation results, if the results of the seismic structure prediction are low with a probability of 2%, then the company still has the opportunity to be able to get the value from the next reservoir interpretation carried out by the EJVA-seismic survey partner.

The limitation of this research lies on the desired criteria, in this case, is to get the maximum benefit from the best alternative decision. These advantages are based on conditions of uncertainty, namely the success or failure of the company to carry out seismic-surveying activities, the acquisition of high or low predicted seismic structures, and the NPV of the economic value of oil and gas reserves by considering the costs incurred by the company for seismic-surveying and exploration activities as a whole. This Research can be proceeded by adding other criteria to help make a more comprehensive decision.

## The Design of Decision Making for Conducting Seismic-Surveying Activities Using the Decision Tree

The results of identification of alternative, criteria, and uncertainty based on the analysis from several experts are presented in the decision-making model which can be seen in "**FIGURE 2.**".

## Assessment and Evaluation of Alternatives with the Expected Monetary Value

After conducting the gradual calculation using equation (2) for each occurrence of uncertainty from each alternative, the EMV value is found. The EMV calculation for conducting the EJVA-seismic surveys is presented as follows.

1. The calculation for the value of uncertainty occurrences on the high structure prediction:

$$0.4(\$294{,}000{,}000)+0.5(\$135{,}004{,}334.70)+0.1(\$82{,}002{,}632.93)=\$193{,}306{,}206.65$$
$$0.5(\$193{,}306{,}206.65)+0.5(\$0)=\$96{,}653{,}103.33$$

2. The calculation for the value of uncertainty occurrences on the high structure prediction:

$$0.4(\$294{,}000{,}000)+0.5(\$135{,}004{,}334.70)+0.1(\$82{,}002{,}632.93)=\$193{,}306{,}206.65$$
$$0.02(\$193{,}306{,}206.65)+0.98(\$0)=\$3{,}866{,}124.13$$

3. The calculation for the EMV:

$$0.4(\$96{,}653{,}103.33)+0.6(\$3{,}866{,}124.13)=\$40{,}980{,}915.81$$

The obtained EMVs for the alternative without conducting a seismic survey and with a 3D seismic survey using equation (2) are -96,267,751.73 USD and 29,061,241.33 USD respectively.

## Assessment and Evaluation Using the Utility Function

By using equation (3), the expected utility value and its fixed equivalent value for each alternative decision is obtained. The gained expected utility values and the fixed equivalent values for the EJVA-seismic survey alternative are presented as follows.

1. The calculation for the value of uncertainty occurrences (HL, BL, and LL) on the high structure prediction:

$$U(\$294{,}009{,}440.02) = \frac{(\$294{,}009{,}440.02 - (\$130{,}000{,}000))}{(\$294{,}009{,}440.02 - (\$130{,}000{,}000))} = 1$$

$$U(\$135{,}004{,}334.70) = \frac{(\$135{,}004{,}334.70 - (\$130{,}000{,}000))}{(\$294{,}009{,}440.02 - (\$130{,}000{,}000))} = 0.625$$

$$U(\$82{,}002{,}632.93) = \frac{(\$82{,}002{,}632.93 - (\$130{,}000{,}000))}{(\$294{,}009{,}440.02 - (\$130{,}000{,}000))} = 0.5$$

$$0.4(1) + 0.5(0.625) + 0.1(0.5) = 0.762$$

2. The calculation for the value of uncertainty occurrences (HL, BL, and LL) on the low structure prediction:

$$0.02(0.762) + 0.98(0.307) = 0.316$$

3. The calculation for the value of the 3D seismic survey alternative

$$0.4(0.535) + 0.6(0.316) = 0.403$$

By using equation (3), the results from the calculation for the alternatives without seismic-surveying activity and with 3D seismic-surveying activity are 0.152 and 0.375 respectively. From these results, it indicates that the largest EU value is found on the alternative of conducting the EJVA-seismic survey, namely 0.403, which is higher than the other alternatives. Furthermore, its fixed equivalent value is 118,558,688.95 USD. The utility graph is obtained based on the highest EU value which can be seen in "**FIGURE 1.**".

## Determining the Priority Decision in Conducting Seismic-Surveying Activity

Based on the calculation using the EMV approach, the obtained decision priority is the alternative of conducting an EJVA-seismic survey because it provides the highest EMV as the company's maximum profit. Furthermore, by employing the utility function approach, the gained priority preference is also the alternative of conducting an EJVA-seismic survey. These both approaches end in the same decision priority: EJVA-seismic survey. According to risk management experts and management strategy experts, the priority decision is to conduct the 3D seismic survey with the consideration that the company's interest can still be maintained. Furthermore, they also suggest that if the company is unable to bear operational costs, the company can close the uneconomical field.

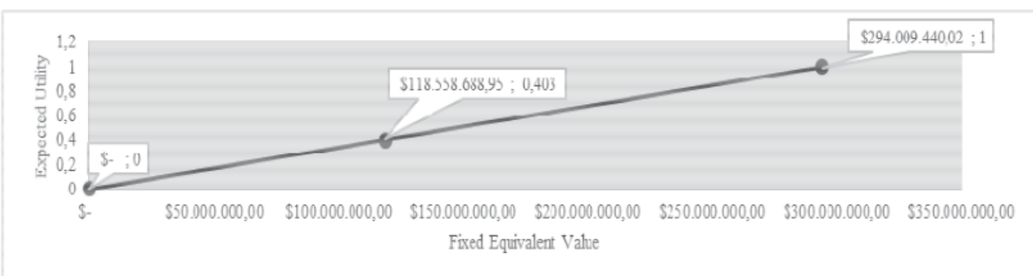


**FIGURE 1.** The Graph of Expected Utility and Fixed Equivalent Value.

The illustration of the overall model of this study using the decision tree can be seen in "**FIGURE 2.**", including the results of calculations using EMV and the utility function.

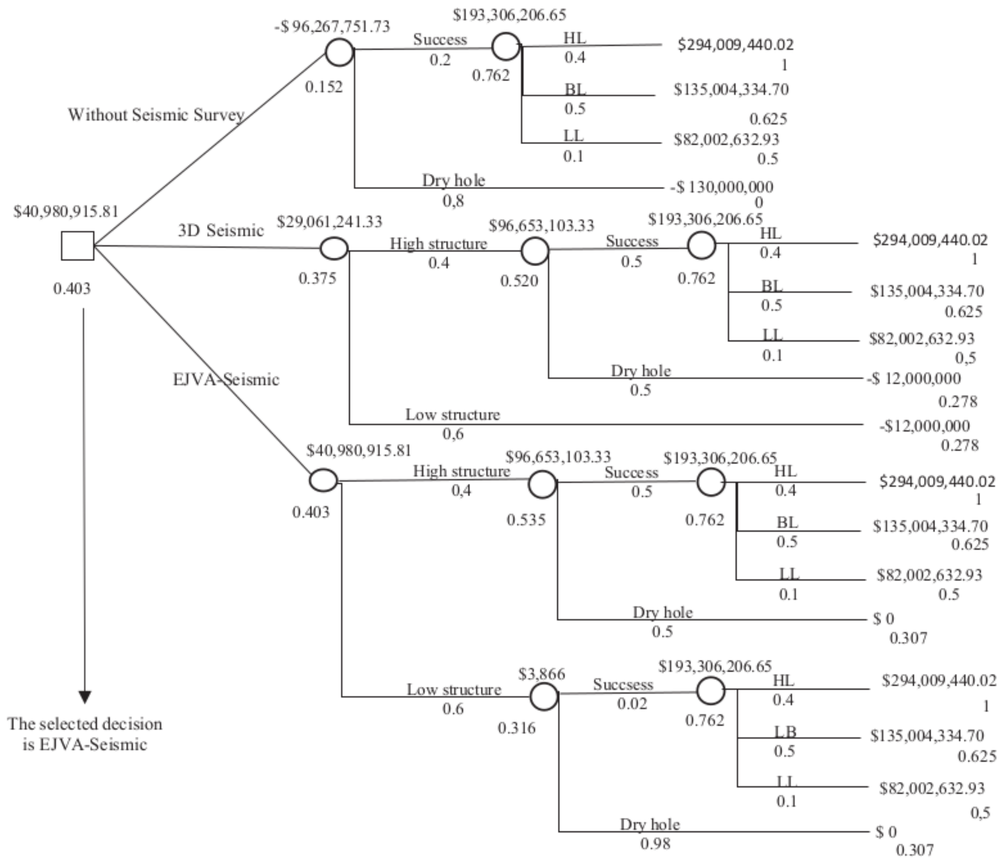


**FIGURE 2.** Illustration using a decision tree on decision making for conducting seismic-surveying activity.

## CONCLUSION

The decision for conducting seismic-surveying activity on oil and gas exploration using the decision tree and utility functions is determined based on the company's profit criteria, in which the alternative decisions are to run exploration without conducting the seismic survey, with the 3D seismic survey, and with the EJVA-seismic survey. The probability of uncertainty is determined based on the judgment of the seismic consultant and strategic management experts. The type of decision-maker is neutral because this decision needs to be carried out as objectively as possible to avoid the risk of loss. The results of the assessment and evaluation of the alternative decisions using the decision tree and utility functions show that the proposed priority is to conduct the EJVA-seismic survey. This alternative decision provides the greatest profit value for the company and is based on the preferences of the decision-maker.

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