Risk Cost Analysis Between Pilot Hole with Geosteering Using Decision Tree Analysis

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Abstract. In implementing horizontal drilling, one of the challenges is the risk of uncertainty formation that causes difficulties in performing well placement. Thus, in planning and budgeting horizontal well drilling activities, a deterministic approach is needed. The determination can be done using a decision picker tool that depends on the decision tree analysis's initial capital value (DTA). The aim is to create a predicted model with the value of a target variable by knowing every decision options.

In developing the X-10 horizontal well, the DW field, Malaysia selected two mitigation options using a pilot hole or geosteering to conduct well placement. The option is according to the uncertainty depth condition from the offset well data. There is no denying that there is still a risk of drilling trajectory exit from the target zone when entering the lateral section (called miss landing) in implementing one of these mitigations. This incident occurred at the X-07 well section 12-1/4", where drilling was out too far from the formation target. So, to continue, drilling must be done sidetrack and requiring additional time and cost. Therefore, it takes analysis that calculates risk-based, efficiency ratio, and expected monetary value (EMV). To be able to recommend which decisions are the best and have the most negligible risk costs.

Previously, drilling operational timing and costs have been calculated in each mitigation. Hence, to continue the proper planning of the well, this paper will be made a decision selection based on calculating existing risk costs by using DTA. By calculating each possibility's expected value (EV), the total price of risk costs is obtained in each mitigation. The geosteering has a lower total assessment cost of 5.666.139,55 USD, against using a pilot hole of 7,650,501.42 USD. The use of geosteering can reduce the potential risk by 1,984,361.87 USD with an efficiency of 25.94% for 12-1/4" section in X-10 well.

Keywords: *Decision Tree, Cost Efficiency, Geosteering, Pilot Hole*

INTRODUCTION

In previous studies, it has been determined the estimated price for the required operational time in each mitigation using a pilot hole or geosteering for the X-10 well, DW Field. As a result, the use of the pilot hole takes 58.8 days with the following cost details; total cost of 53,903,120.07 USD, the spread cost of 916,719.73 USD, and cost per depth of 13,594.73 USD/m. As for geosteering, drilling takes 53.5 days with the following cost details; total cost of 50,516,214.72 USD, the spread cost of 944,228.31 USD, and cost per depth 12,740.53 USD. Based on the estimated timing and fee of comparing the two mitigations, geosteering is the best option against pilot holes.

Comparisons that have been done are based solely on time and cost planning without considering the aspect of the possible loss ratio. Because it is undeniable, drilling activities are a risky business. Hence, it needs a deterministic approach that involves the value of the probability of a risk to manage existing risks with decision tree analysis (DTA). A decision tree is a diagram representing the flow of a decision-making process as a sequence of incidents with several outcomes.

In the use of this tool, each event is represented by nodes. Eventually, each node's outcomes are a sign of branches. Nodes are either decision nodes (where the decision-maker chooses which branch to take) or uncertainty nodes (where the result is determined by chance). In drilling planning activities, the decision will be chosen that has a smaller risk cost. As for the profit will be selected a decision that has the result of choice with the highest cost.

In this case, the two mitigations applied to the horizontal well X-10 have the same goal: to ensure the drilling of the X-10 well is not like the X-07 well in 12-1/4" section. Therefore, the risk to both mitigations is a failure when landing in the lateral section. However, the impact of the cost risk required is certainly different because of the difference between equipment and mechanisms carried out. Therefore, this paper will compare total risk costs in both mitigations using decision tree analysis.

GENERAL OVERVIEW

Research Location: The DW field is a deepwater field located in the waters of the western sea, Malaysia. This field has a water depth of 1350 m (4429 ft) above sea level and is 13 km southwest of its production facility. In 2019, a local company carried out a technical engagement to construct new wells in the same formation target. The X-10 well planning was carried out based on the X-07 well offset data to face the uncertainty. Based on this, two mitigation options were chosen, i.e., pilot holes and geosteering.

Pilot Hole: Pilot hole drilling is an activity in the early stages of drilling by making a small hole diameter through the pay zone to determine a target reservoir's top and bottom locations. Usually, we drill the pilot hole before determining the actual location of the target well and obtaining lithological information at that depth**.**

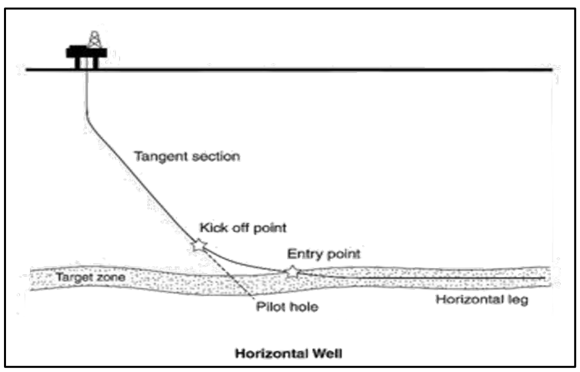

Figure 1 Pilot Hole Application (Shepherd, 2009)

Geosteering: Drilling using Geosteering combines the use of measurement while drilling (MWD) and logging while drilling (LWD) tools which consist of gamma-ray (GR) and resistivity tools that will send data directly to the surface and can be read directly on the Geosteering screen by the operator. The combination with LWD and MWD can measure geological parameters and interpret them in real-time with drilling trajectory control realized by a software system based on formation or structure models.

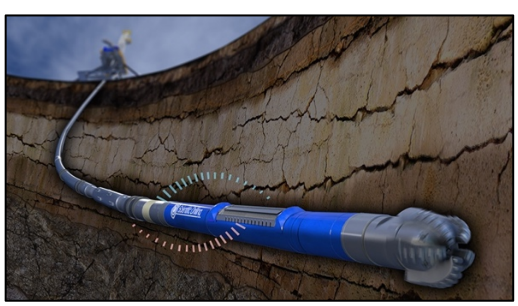

Figure 2 Geosteering (Wellsite Geology)

With the pilot hole, the data interpretation performed has an accuracy of 100% but requires additional time. Meanwhile, in geosteering, the ability to interpret in real-time also has 100% accuracy but requires additional costs for the equipment and personnel used. Therefore we need a comparison based on the cost of risk using a decision tree.

Decision Tree: decision-making tool visualized in graphs, diagrams, or models shaped like tree roots. This tool describes a problem that consists of several series of decisions that lead to a solution. This tool is often used while planning the upcoming drilling to perform risk analysis in deciding on a static approach in conditions of uncertainty.

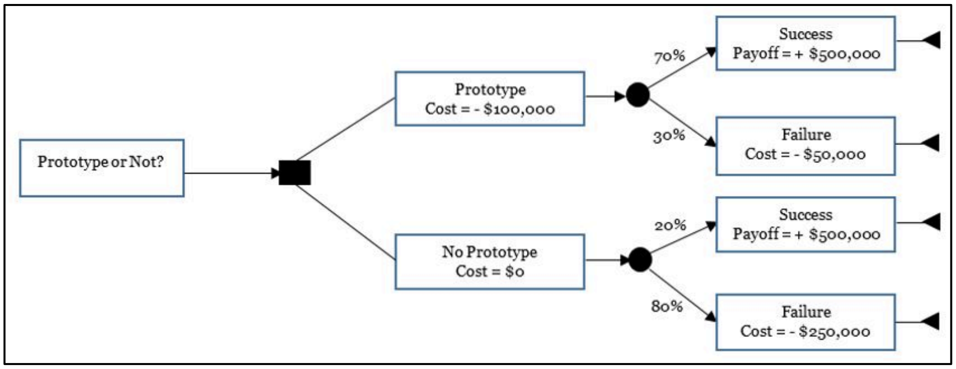

Figure 3 Decision Tree Example

RESEARCH METHOD

With the X-10 well data, the comparison is made by comparing the planning between the pilot hole and geosteering, calculating the total assessment risk cost of each scenario that could happen in the future.

In the next step, by taking a deterministic approach, the probability value is required. In this case, the probability obtained from the efficiency ratio on the use of each mitigation tool. Obtained from SPE-192332-MS paper and Oilfield Review journal, Vol. 5, Issue 2-3, Pages 47 on the efficiency of the pilot hole and geosteering usage ratios. The efficiency ratio is the comparative value between the time the drill bit penetrates the formation and the overall drilling time.

Then, we determined what scenarios may occur for each mitigation. As decision-makers, we can set how complicated or straightforward the scenario will be. Due to data limitations, the author will assume only three scenarios for each node in each mitigation. From the determination of the scenario, it can initiate the risk cost that should be incurred in the scenario that occurred. These costs include the price of the equipment used, the price of rental per day, and the price of treatment that may be done. These costs can be obtained from the data authority for expenditure (AFE). The next step, from the cost data, can be calculated for the estimated risk cost in each of the existing scenarios. Later, the risk costs will be summed up per mitigation so that there will be mitigation options with the lowest total assessed risk

RESULT AND ANALYSIS

A comparison of the total assessment risk cost results from both mitigations is supervising in this study. The comparison uses a decision tree that shows the total cost required for each existing mitigation in 12-1/4" section.

Based on the reference paper mentioned earlier, the efficiency ratio value for pilot holes is 50%, and geosteering is 73%. This ratio serves as standard drilling scenarios, i.e., without any problems or drilling runs as planned up to the casing point. The total efficiency ratio value from each scenario is 100% so that the efficiency ratio of the other scenario remains reduced from the existing efficiency ratio.

In pilot hole mitigation, the time required to drill is 11.3 days. There are three possible scenarios for this drilling, which is:

(1) When drilling until it enters the casing point, it runs smoothly and can be continued to the next section. This scenario has a probability/efficiency ratio of 50%.

(2) While drilling in the middle of the process (assumed to be half of the total day), drilling indicates miss the landing, so the need to install steering tools redirects drilling back to the target path. This scenario has a probability

value of 50%. Where the ratio is a subtraction from the total value of 100% with the previous scenario, in this scenario, two possibilities occur as follows:

a. With steering tools, it can route the well-path back to the target and continue the drilling to the casing point. The probability value of these nodes is 50%; this probability value is the division with the following ratio.
b. Although the steering tool has been used, the possibility of drilling paths out of the target too far remains. So to continue, drilling sidetrack must continue; this is a similar event in the wells X-07 and X-07ST. The scenario is the worst where it has a 50% chance.

After determining the scenario for the pilot hole on each node, it can be calculated for each scenario's cost. It is known that in drilling the pilot hole, the winding equipment used in section 12-1/4" is mud motor/PDM. The following is a table for pricing details obtained from AFE data:

Table I Determination Price of Decision Tree with Pilot Hole

Mud motor		**Drilling Cost ($/day)**	***Miss landing ($)***	***Sidetrack***
days	**Cost**			***Mud motor***
11,3	393.749,73	380.818,61	250.000	4.100.000,00

On the use of mud motor/PDM has a rental of 34,845.11 USD / day. For sections 12-1/4" takes 11.3 days, so the total cost required is 393,749.73 USD. Then for the necessary expenses in drilling obtained from the operational drilling cost data in the data authority for expenditure (AFE), 380,828.61 USD / day, the cost includes rig contracts, drilling mud, drill bits, directional drilling, and survey, etc.

In the scenario of miss landing, the installation of steering tools (equipped with azimuthal resistivity) has an additional rental value of 250,000 USD. The function of this equipment is to continue drilling directly to the casing point; however, if the drilling-path has strayed too far, then the need for sidetracking activities on the well. Following the costs stated in the AFE submission, there is an additional cost to drill sidetrack of 4,100,000 USD / 5.3 days. These costs are used, including drilling operations such as equipment costs, personnel, well closures, and others. So in this scenario, it is considered the worst event.

Based on these three scenarios on each node, it can be calculated the total cost of risk or, in decision tree terms, is Expected Value (EV). The following are the results of EV calculations in all three scenarios:

Table II Total Risk Cost of Pilot Hole Drilling

Scenario	**Total Risk Cost ($)**
Drilling 12-1/4" Section to Casing Point	4,696,999.99
Drilling 12-1/4" Hole-halfway – Miss Landing – Continue to Casing Point	4,908,918.13
Drilling 12-1/4" Hole-halfway – Miss Landing – Sidetrack	6,876,333.93

Based on the table above, it is known that the more treatment or activities needed in drilling, the greater the risk cost. Then the calculation for the total associated risk value, by multiplying the value of efficiency ratio with the scenario cost when drilling for sections 12-1/4". The following are the calculations in all three scenarios:

Table III Total Associated Cost with Pilot Hole

Scenario	**Total Associated Cost ($)**
Drilling 12-1/4" Section to Casing Point	$2,151,625.13
Drilling 12-1/4" Hole-halfway – Miss Landing – Continue to Casing Point	$2,257,584.20
Drilling 12-1/4" Hole-halfway – Miss Landing – Sidetrack	$3,241,292.10
Total	**7,650,501.42**

Based on table III, it is known that the total associated risk value in drilling mitigation with the pilot hole is 7,650,501.42 USD. Furthermore, for drilling using geosteering, the time required is six days. Similar to mitigation with a pilot hole, three scenarios were created in this mitigation.

(1) With steering tools, it can route the well-path back to the target and continue the drilling to the casing point. The probability value of these nodes is 73%; this probability value is the division with the following ratio.
(2) While drilling is in progress (assumed to be half of the total day), there is an indication of a missed landing due to differences between geo-modeling planned to the actual. Because in this mitigation has been installed steering tool equipment, it takes at least one day to maneuver the drilling direction. This scenario has an efficiency value of 23%. in this scenario, two possibilities occur as follows:
    a. With the addition of geosteering usage time, drilling activities can run smoothly until it reaches the casing point. The probability value of these nodes is 50%; this probability value is the division with the following ratio.
    b. Although with a fairly small percentage, but must still consider. If drilling is done out of the target path too far, it should be done sidetrack drilling activities

After determining the scenario for the geosteering on each node, it can be calculated for each scenario's cost. It is known that in drilling the geosteering the winding equipment used in section 12-1/4" is steering tool that equipped with azimuthal resistivity. The following is a table for pricing details obtained from AFE data:

Table IV Determination Price of Decision Tree with Geosteering

Geosteering		Drilling Cost ($/day)	Miss Landing ($)	Sidetrack
days	Cost			Geosteering
6	398.788,20	380.818,61	250.000	5.350.000,00

On the use of geosteering, there is an additional cost for the equipment and the software. The geosteering rental of 63,001.01/day. For sections 12-1/4" takes 6 days, so the total cost required is 398.788,20 USD. Although the total cost required does not differ much, but when viewed based on the cost of equipment rental per day, geosteering has a cost twice the price of a pilot hole. The necessary cost in drilling obtained from the operational drilling cost data in the data authority for expenditure (AFE), 380,828.61 USD / day, the cost includes rig contracts, drilling mud, drill bits, directional drilling, and survey, etc.

In the scenario of miss landing, However, if drilling is considered too far from the target line of drilling, it should still be done drilling sidetrack. Although this condition has a very slight possibility, given the efficiency ratio on large geosteering, but still has to be taken into account. According to AFE data, the cost of sidetracking is $4,100,000 for 5.3 days, including well closure and re-drilling. Plus, there is an additional charge because this mitigation uses geosteering equipment for 1,250,000.00 USD. So, the total for sidetrack drilling is 5,350,000 USD and is the most considerable risk cost.

Based on these three scenarios on each node, it can be calculated the total cost of risk or, in decision tree terms, is Expected Value (EV).

Table V Total Risk Cost of Geosteering Drilling

Scenario	Total Risk Cost ($)
Drilling 12-1/4" Section to Casing Point	2,683,699.84
Drilling 12-1/4" Hole-halfway – Miss Landing – Continue to Casing Point	2,933,699.84
Drilling 12-1/4" Hole-halfway – Miss Landing – Sidetrack	7,141,244.02

Based on the table above, it is known that the more treatment or activities needed in drilling, the greater the risk cost. Then the calculation for the total associated risk value, by multiplying the value of efficiency ratio with the scenario cost when drilling for sections 12-1/4". The following are the calculations in all three scenarios:

Table VI Total Associated Cost with Pilot Hole

Scenario	Total Associated Cost ($)
Drilling 12-1/4" Section to Casing Point	1,667,985.50
Drilling 12-1/4" Hole-halfway – Miss Landing – Continue to Casing Point	947,190.98
Drilling 12-1/4" Hole-halfway – Miss Landing – Sidetrack	3,050,963.07
Total	**5,666,139.55**

Based on table above, it is known that the total associated risk value in drilling mitigation with the pilot hole is 5,666,139.55 USD. The calculation above can be directly inputted on the decision tree diagram to facilitate the selection of existing decisions, as seen in below.

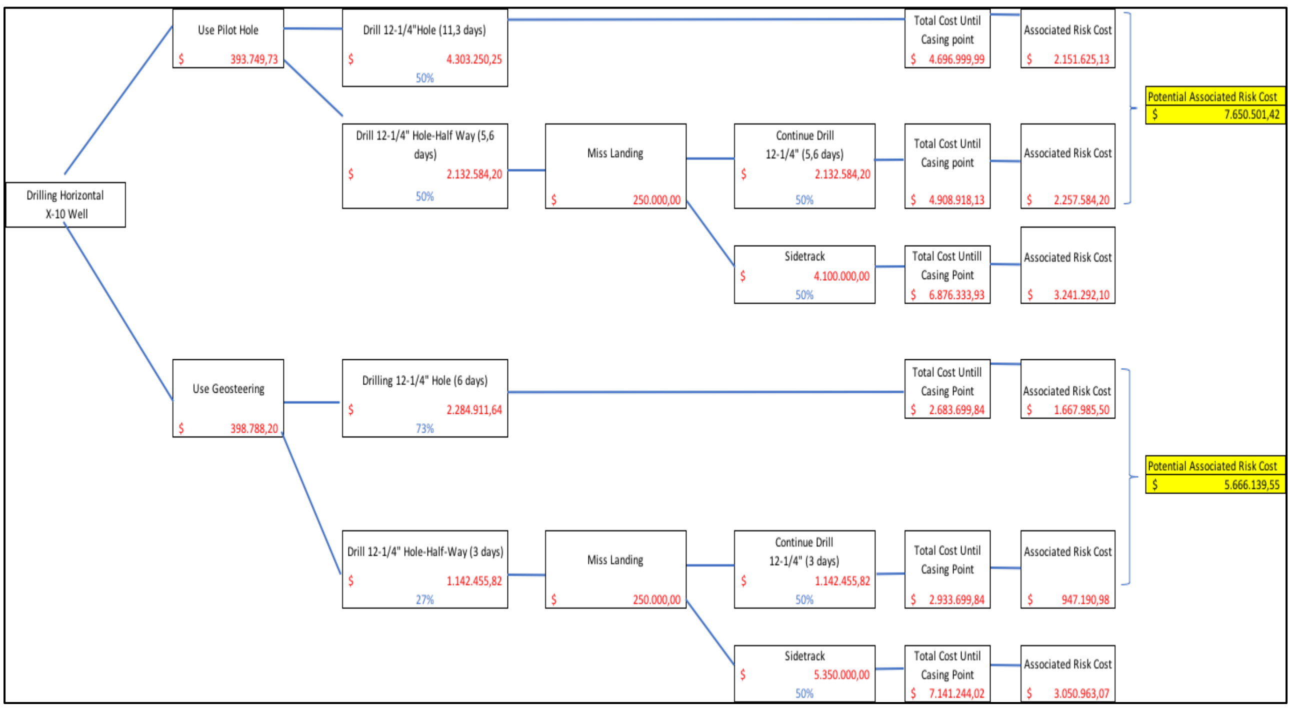

Figure 4 Decision Tree of Well X-10

The final result of the decision tree shows that drilling a pilot hole with PDM has a more significant risk cost of 7,650,501.42 USD, while the use of Geosteering has a potential risk of 5,666,139.55 USD. This selection is based on the principle of decision tree selection, where to choose profit and choose EMV / most negligible risk cost to choose cost planning. To know the efficiency of the risk of geosteering drilling risk to the pilot hole, the calculation of the efficiency of the use of geosteering is as follows:

$$Difference = |\,Total\ Risk\ for\ Mud\ Motor - Total\ Risk\ for\ Geosteering\,|$$

$$Difference\ (\$) = |\ 7.650.501{,}42 - 5.666.139{,}55\ |$$

$$Difference\ (\$) = \ 1.984.361{,}87$$

$$Efficiency = \frac{Difference}{Total\ Associated\ for\ Mud\ Motor} x100\%$$

$$Efficiency = \frac{1.984.361{,}87}{7.650.501{,}42} x100\%$$

$$Efficiency = \ 25{,}94\%$$

The use of geosteering can reduce risk potential by 1,984,361.87 USD with an efficiency of 25.94%. So, based on an economic analysis considering the value of existing risks, the use of decision trees can help select mitigation options for X-10 wells. In this case, the final result selection is chosen the least because it considers the uncertainty of the risk.

CONCLUSION

The use of decision trees can clearly describe the problem, despite the situation's complexity. The decision tree findings revealed what was causing the decision and the path to be followed.

Although geosteering has a larger initial capital of 398,788.20 USD for six days and mud motor of 393,749.73 USD for 11.3 days, the use of geosteering can reduce the risk potential by 1,984,361.87 USD with an efficiency of 25.94%. The calculation is taken only in sections 12-1/4", but it will have a significant impact on the operational plan of drilling DW field.

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