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Utilization of Multi-Criteria Decision Analysis (MCDA) in Selecting Contract Types for Geothermal Exploration Drilling Project in Indonesia

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ABSTRACT

One of the important factors in achieving a successful drilling campaign is by having proper drilling contracts that fits with the current company's organizational capability. This leads to the question on which type of contract is best for a certain drilling project, especially in the exploration phase in Indonesia. This issue is currently risen in the geothermal industry in Indonesia due to Government of Indonesia's effort to achieve 7,200 MWe geothermal plant installed capacity in 2025. However, there is no absolute answer to that question as the decision-making process to choose the drilling contract type usually involves more than one criterion.

Therefore, it is necessary to use decision-maker's preferences to differentiate between alternatives. Several drilling contract types for geothermal exploration project in Indonesia that are commonly known are the discrete contract, integrated project management contract (IPM), and semi-IPM where usually the selection of contracts is primarily based on the organizational capability that the company has at the time. However, based on literature reviews, there are several other ways for drilling contract types that do not really fit into the three categories mentioned previously and might improve the drilling performance.

This paper discusses the application of Multi-Criteria Decision Analysis (MCDA) in assisting the decision-making process in drilling contract type selection. MCDA is considered to be one of the complex decision-making (DM) tool involving both quantitative and qualitative factors. It has been widely applied in various fields such as; energy and environment, business, economy and production. The study initiated by defining clear objectives of drilling contract. Several drilling contract scenarios or alternatives are then identified to be examined where most of the scenarios are developed based on published literature related to cases in Indonesia. Sensitivity analysis is conducted to test whether conclusions are sensitive to changes in the model.

1. INTRODUCTION

1.1 Research Background

Indonesia, as one of the countries with the greatest potential for geothermal energy in the world, faces various challenges in utilizing this energy source. Since the first geothermal power plant was installed in the Kamojang field in 1930, until the end of 2018, Indonesia has only managed to use less than 7%, namely 1948.5 MW, of its total potential geothermal energy that is estimated at 28.5 GW (EBTKE, 2018). Figure 1 shows the history and target of geothermal energy development in Indonesia.

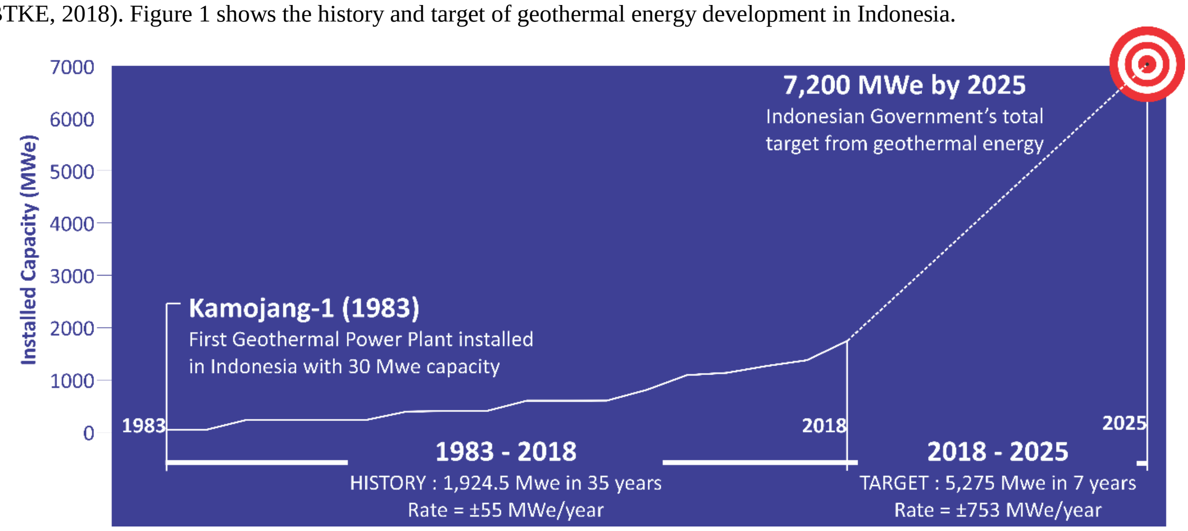


Figure 1: History and target of Indonesia geothermal development (modified from Purba, 2018)

Many studies have discussed various challenges in developing geothermal energy in Indonesia, where the high resource risk in the exploration phase is considered one of the main challenges (IGA, 2014; Darma, et al., 2010; Ngugi, 2014; Purba et al., 2019). The level of risk is high due to the uncertainty of the existence of economic resources in the subsurface combined with the high upfront drilling cost, which makes investors think more carefully before investing.

Moreover, managing a high-cost geothermal drilling project might become more complex in the exploration phase due to shortage of personnel. It is realistic to view that a geothermal company most likely still has not yet fully establish a team to run a drilling campaign in that early stage of project. In order to address this issue, the geothermal company need to choose the most suitable drilling contract type since it precedes the performance of work and governs the operator-contractor relationship (Williams, Schaffner, & Co, 1989). By choosing the right type of contract that is suitable for the situation, a geothermal company may expect to successfully manage the drilling risk and complete the exploration phase in a timely manner that eventually could accelerate the development of geothermal energy in Indonesia.

Consequently, the decision maker will need a reliable decision-making tool to assist in choosing the type of drilling contract that is appropriate in accordance with the project characteristics and capabilities of the team that is going to manage the project. It is very natural if the decision maker wants the type of contract that can produce wells with the smallest possible risk, cost and effort. But then again, decision makers will find that compromise is necessary in several criteria to achieve an ideal condition - which is often unrealistic, to produce the most optimum decision in achieving the objectives related to the type of drilling contract to be used.

1.2 Research Objectives and Questions

This study aims to investigate whether Multi-Criteria Decision Analysis (MCDA), a decision-making (DM) tool, is applicable in assisting the decision maker in selecting the type of drilling contract for geothermal exploration project in Indonesia.

To achieve the objective, this study explores several questions as follow:

1. What are the objectives of decision maker in a geothermal drilling contract type selection?
2. What are the limitations in the MCDA application in this case?
3. Is MCDA tool relevant to assist the decision-maker in selecting a drilling contract type for geothermal exploration project?

1.3 Research Method

The main method used in this study is literature review and group discussion. The study initiated by group discussions is to understand the situation and dilemma faced by decision makers in choosing the right type of drilling contract and defining objectives of the drilling contract. Several drilling contract scenarios or alternatives are then identified to be examined where most alternatives are developed based on published literature related to actual cases in Indonesia (Isa et al., 2017; Purwanto et al., 2018; Hartono, 2019). Sensitivity analysis is conducted to test whether conclusions are sensitive to changes in the model.

2. GEOTHERMAL EXPLORATION DRILLING IN INDONESIA

2.1 Geothermal project cycle

The understanding of the drilling project cycle and the geothermal project cycle is very important for any decision maker to enable them to get the most suitable type of contract for the project. Figure 2 illustrates the stages of geothermal energy development projects in Indonesia in accordance with government regulations in Indonesia. In general, geothermal energy development projects in Indonesia are divided into 2 main phases; the exploration phase and the development phase.

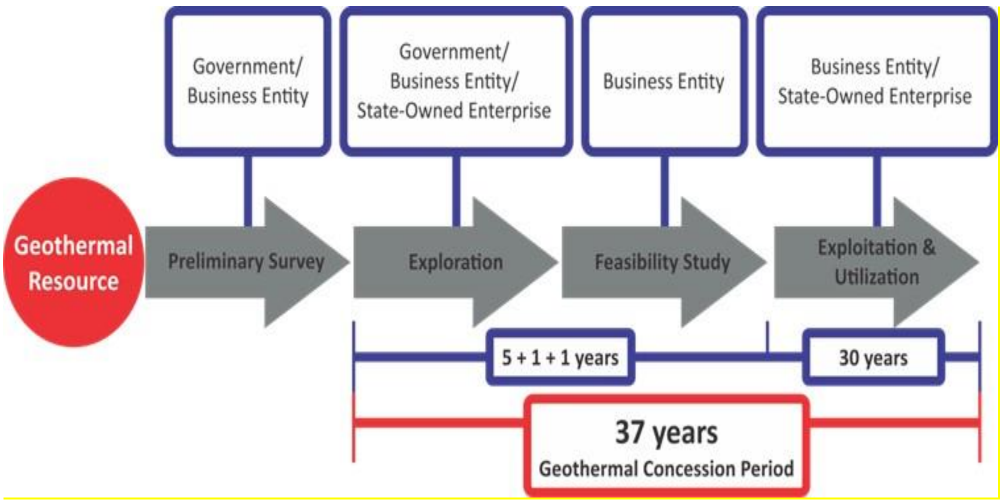


Figure 2: Geothermal energy development phases in Indonesia based on regulation (EBTKE, 2018; Purba, 2018)

In the exploration phase the purpose of drilling is to prove the existence of economic geothermal reserves in the sub-surface, that have been initially mapped through geology, geochemistry and geophysical (3-G) surveys. Due to the high level of uncertainty during this phase, generally geothermal companies (developer) will only commit to drill 3-5 wells, depending on the area of interest size. After conducting exploration drilling or test drilling, the developer will conduct well testing and assess the size of the economic reserves that can be developed. Once an agreement regarding the development plan is reached between the developer and the government, the project will continue into the development phase where the number of wells will increase as according to the electricity target.

Regarding the geothermal exploration drilling project in Indonesia, some discussion notes obtained from authors' experiences were:

1. The drilling risk in exploration phase is still high due to limited or minimum sub-surface data. This creates a more challenging situation for drilling team in the planning stage.

2. The number of drilling personnel and drilling contractors, in Indonesia, who have experience in geothermal drilling is far less than oil and gas. Geothermal developers must compete in recruiting experienced geothermal drilling personnel during the project phase of where the level of uncertainty is very high. Umam et al. (2018) mentions how the difference in nature between geothermal and oil and gas drilling requires competency adjustments, when personnel from one of the industries migrates to the other.

3. In Indonesia recently, developing companies that are undergoing an exploration phase on geothermal fields are often new companies in the geothermal industry. Consequently, they have not yet gained any trust from the drilling contractors.

4. Like any other project, the key activities in a geothermal drilling project are planning and execution (Figure 3). The success rate of a drilling project is determined by the ability of the team to execute the approved drilling plan. Having proper contract documents is the main factor in bridging the planning and execution phases.

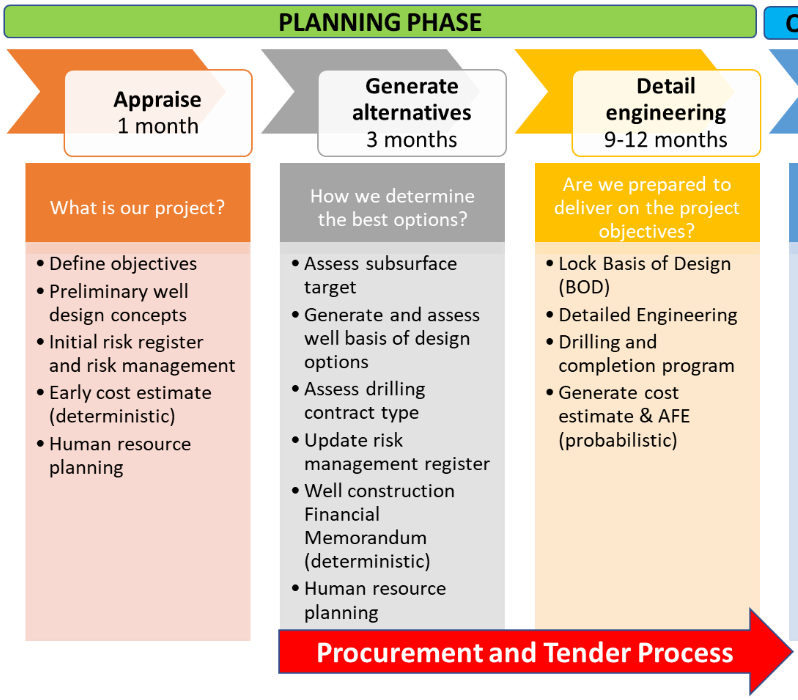


Figure 3: Simplified geothermal drilling project cycle assuming drill 3 (three) exploration wells

2.2 Drilling Contract Type in Indonesia

By definition, Williams, Schaffner, & Co (1989) stated that a contract is a deliberate engagement between competent parties with a lawful consideration or cause to do or not to do a particular thing; and the obligation of a contract is found in the terms in which the contract is expressed. They also mentioned that the key words of any contract are the same, which are: promise, agreement, obligation, performance, and consideration.

Several reasons why a company needs to have the correct type of drilling contract are follows (de Wardt & van Gils, 1994; Isa et al., 2017):

1. To produce and maintain cost-effective quality wells
2. To achieve highest safety standard in the process of well construction
3. To comply with local government regulation and with company's policy

In both the petroleum and geothermal Indonesian drilling industry, standards for drilling contract type or name does not yet exist. However, International Association Drilling Contractor (IADC) has been providing forms or template of several types of drilling contract through their website (IADC, 2018).

Figure 4 shows the various contracts that a geothermal company might establish with drilling contractors. Should every part of the service be defined into a single and separate contract, then there will be approximately 26 contract documents in total, not including drilling infrastructure (wellpad, access road and basecamp) construction.

In general, drilling rig service is usually become top cost contributor, especially when other smaller services are integrated into the rig contract such as top drive, mud logging unit, VSAT, H_2S, heavy equipment, and fuel supply. The next major cost components come from cementing, directional drilling, drilling fluids and tangibles items such as casing, wellhead, and master valve. It is also common in Indonesia for a company to apply handling fee on the services provided by other company under the same contract (sub-contracting). Therefore, the geothermal company need to take into consideration when choosing which drilling services to be the leader of the contract bundle.

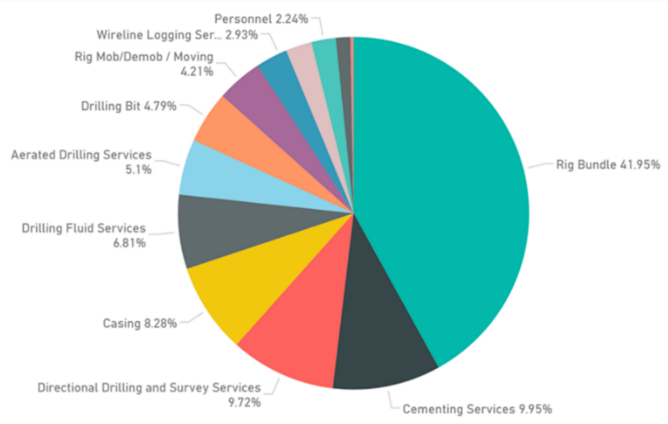


Illustration of drilling cost allocation taken from an actual field data

List of services commonly utilized in a geothermal drilling project in Indonesia	
Rig services	Drill Bit
Top Drive	Conventional coring
H_2S service	Fuel supply
Heavy equipment	Fishing tool
Mud logging unit	Aerated drilling
Directional drilling and MWD (personnel and equipment)	Wireline logging (truck and tool)
Cementing and casing accessories (personnel, equipment and material)	Drilling fluids (personnel and material)
Liner/casing tieback	Drilling water supply
Rig inspection	Tubular inspection
Project implementation team	Casing drilling level 1 (personnel and material)
Casing and Liner (OCTG, long lead)	Wellhead and Master valve (long lead)
Drilling waste management	Casing running services
VSAT (internet and telecommunication)	General services

Figure 4: Illustration of drilling cost component (left) and list of drilling services in a geothermal drilling project (right)

In this study, several types of drilling contract that has been found through literature study and authors experiences are summarized based on document contract type and payment scheme.

2.1.1 Discrete Type

Based on contract document, the most common type is called “discrete”. This term has been used by drilling personnel in Indonesia referring to the most conventional type of drilling contract, where the geothermal developer is contracting separately with the rig contractor and every other service company. This kind of approach may create a lot of contract documents, 15-23 in estimate (Hartono, 2019; Hole, 2006; Isa et al., 2017).

2.1.2 Integrated Type

Another contract type, based on contract document category, is called “integrated”. This is a term used by drilling personnel in Indonesia in describing the type of contract that brings together several drilling services into a single contract. This is done with the aim to coordinate various drilling service companies so that developers will only communicate with one project coordinator as the point of contact. Companies that become contract leaders are usually drilling rig companies or other drilling service companies such as directional drilling, cementing, or other services. This approach is expected to result in much less contract documents; 4-5 in estimate.

This type of contract, in Indonesia, is also known by several terms such as "IPM", "Semi-IPM" and "Bundled Services". IPM (Integrated Project Management) in the geothermal industry in Indonesia refers to a single contract that covers all drilling services required, including permitting, wellpad and access road construction, community engagement, water supply and other drilling supporting services. Two cases of geothermal projects in Indonesia recently used this type are Sarulla (Ganefianto et al., 2015) and Tulehu (Richter, 2017).

While semi-IPM and bundled services have similar characteristics, the choice of term usage depends on the company's preference on mentioning the type of contract. Semi-IPM or bundled services, in Indonesia, refers to the type of contract that consists of several services, not all services, which are incorporated into one contract document. An example of a geothermal project in Indonesia that uses this type of contract is Sorik Marapi (Isa et al., 2017).

2.1.3 Day Rate or Unit Rate Type

While based on the payment scheme, contract type can be categorized into three major type, namely “day rate” or “unit rate”, “footage” and “turnkey”.

“Day rate” is the conventional method scheme where the drilling rig and service companies are paid based on working days. The unit may be in a form of day rate or another unit rate. This type places the risk more towards the developer, in which the developer is forced to establish a competent internal drilling team. In Indonesia, companies that accommodate this type are usually companies that have long been in the geothermal industry and have had experience developing geothermal fields (Isa, Hartono, Jayanto, & Putra, 2017).

2.1.4 Footage

This scheme allows the developer to pay the rig company and service companies based on contractor performance, which is footage drilled. This type places the risk more towards the rig contractor and drilling service companies, which forces the contractors to allocate the risk in their proposal price. During the creation of this report, the authors did not find any published documents that mentions the use of this type of contract for geothermal drilling in Indonesia. However, based on personal communication with several drilling engineers, there are 2 (two) drilling projects, in North Sumatera and East Nusa Tenggara, that will use the "footage" payment system.

2.1.5 Turnkey

This is the most uncommon type of drilling contract in Indonesia. The payment scheme is very simple, the contractor will only be paid when the well is delivered as per agreed specification. This is uncommon due to the risk is almost fully absorbed by the contractor, which makes the contractor put a high proposal price to the developer to compensate the drilling risk. At the time this study was conducted, the authors were not able to find any documents reporting the practice of "turnkey" contract in geothermal drilling project in Indonesia.

3. SELECTING CONTRACT TYPE

3.1 Decision-Making Process

Multiple Criteria Decision Analysis (MCDA) is one of the DM tool that has been widely used in many industries, including geothermal industry (Greco, Ehrgott, & Figueira, 2016; Khan, 2019; Cook, Fazeli, & Davidsdottir, 2019). The difference between MCDA and other DM or DA tool such as Financial analysis, Cost-benefit analysis and Cost-effectiveness analysis is it does not require monetized measurements, thus making it more applicable to more complex decision-making situation (Raith, 2018).

In order to make a good decision, a person must weigh the positives and negatives of each option and consider all the alternatives (WebFinance Inc., 2019). Hence the same with what a decision maker must do when trying to make a decision on which type of drilling contract is the best for the project situation that they are managing at the time. Some studies (Yadav & Paudel, 2017) describes MCDA as follows:

1. It does not provide the "right" answer
2. It does not provide an objective analysis
3. It does not relieve decision makers from the responsibility of making difficult judgements
4. It assists the decision makers to confidently decide by:
    a. Gaining a better understanding of the problem that they are facing
    b. Organizing and synthesizing the entire range of information
    c. Integrating objective measurements with value judgements
    d. Making explicit and managing the decision maker's subjectivity
    e. Ensuring that all criteria and decision factors have been taken into proper account

3.2 MCDA Application in Drilling Contract Selection

As discussed in the Introduction, this study aims to exercise the application of MCDA in assisting the decision-maker in the drilling contract type selection process. As to the author's knowledge, so far publications on this kind of MCDA application is still in absence. The steps in implementing the MCDA are illustrated in Figure 5.

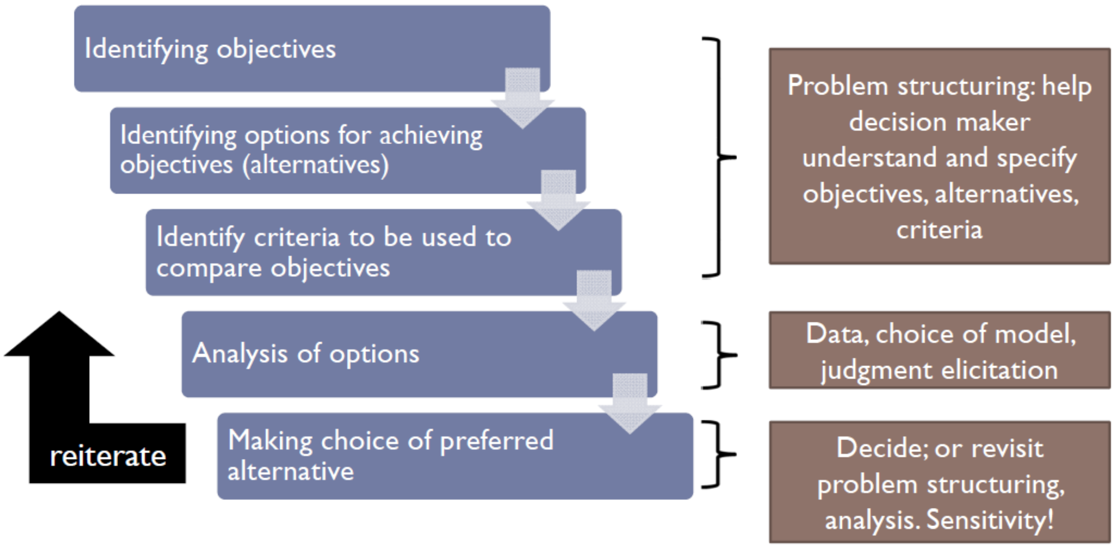


Figure 5: Steps in Implementing MCDA (Raith, 2018)

3.2.1 Define alternatives

The first step in applying this method is to define as many possible unique alternative ways for the decision maker to consider in contracting drilling service providers. In this study, the authors have defined that there 9 (nine) unique alternative ways as itemized in Table 1.

Table 1: List of unique alternatives

No	Alternative Name	Contract type	Description
1	**1-DU**	Discrete + Unit Rate	• The conventional contract type where the geothermal company holds a contract with the rig company and all other drilling services. • It is assumed to result in around **20 contract documents**. • The compensation scheme will apply **unit rate or day rate** since it is almost impossible to use the footage scheme with 20 different parties. Due to this, it places more risk towards the geothermal company. • There will be no handling fee or double taxation applied in this alternative.
2	**2-ISU**	Integrated service + Unit Rate	• Recently in the Indonesian geothermal drilling community, this type is often called Bundled service or Semi-IPM contract. • In this alternative, the rig contract is separated from other services contract, where all the drilling services is integrated into a single contract document. • It is assumed to result in **5 contract documents**: Rig contract, integrated drilling services contract, equipment inspection contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **day rate** which places more risk towards the geothermal company. • In this alternative, the service company that leads the bundled services will most likely apply a handling fee of 25%.
3	**3-ISF**	Integrated service + Footage	• Recently in the Indonesian geothermal drilling community, this type is often called Bundled service or Semi-IPM contract. • In this alternative, the rig contract is separated from other services contract, where all the drilling services is integrated into a single contract document. • It is assumed to result in **4 contract documents**: Rig contract, integrated services contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **footage** which places the larger risk towards the rig and service company. • In this alternative, the service company that leads the bundled services will most likely apply a handling fee of 25%. • Rig and service company is assumed to will apply a footage risk compensation of 50%, each.
4	**4-SubU Rig**	Subcontracted + Unit Rate (Rig as leader)	• Recently in the Indonesian geothermal drilling community, this type is often called IPM contract. • In this alternative, the **rig company acts as the leader** and subcontracts other services such as directional drilling, cementing, wireline logging, etc. • It is assumed to result in **4 contract documents**: Rig/IPM contract, equipment inspection contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **day rate** which places more risk toward the geothermal company. • In this alternative, the rig company that leads the bundled services will most likely apply a handling fee of 25%.
5	**5-SubU SC**	Subcontracted + Unit Rate (Service company as leader)	• Recently in the Indonesian geothermal drilling community, this type is often called IPM contract. • In this alternative, the **service company acts as the leader** and subcontracts other services such as directional drilling, cementing, wireline logging, etc. • It is assumed to result in **4 contract documents**: IPM contract, equipment inspection contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **day rate** which places more risk towards the geothermal company. • In this alternative, the service company that leads the bundled services will most likely apply a handling fee of 25%.
6	**6-SubF Rig**	Subcontracted + Footage (Rig as leader)	• Recently in the Indonesian geothermal drilling community, this type is often called IPM contract. • In this alternative, the **rig acts as the leader** and subcontracts other services such as directional drilling, cementing, wireline logging, etc. • It is assumed result in **3 contract documents**: Rig/IPM contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **footage** which places more risk towards the IPM company/drilling. • The rig company acting as the contract leader will most likely apply a handling fee of 25% and a footage risk compensation of 50%.
7	**7-SubF SC**	Subcontracted + Footage (Service company as leader)	• Recently in the Indonesian geothermal drilling community, this type is often called IPM contract. Sometimes it can also be interpreted as a turnkey contract. • In this alternative, the **service company acts as the leader** and subcontracts other services such as directional drilling, cementing, wireline logging, etc. • It is assumed to result in **4 contract documents**: IPM contract, equipment inspection contract, casing purchase contract and wellhead purchase contract. • The compensation scheme will apply **footage** which places more risk toward the IPM company/drilling contractor. • The service company acting as the contract leader will apply a handling fee of 25% and a footage risk compensation of 50%.
8	**8-Turnkey Rig**	Full turnkey (Rig as the leader)	• It is usually used to drill a well for a fixed lump sum price. • This type of contract is currently uncommon in the Indonesian geothermal industry. • The leader can be the **rig or any other service company** that has the capability to run the full IPM project where the risk is fully borne by the IPM contractor. • It is assumed to result in only **1 contract document**: Turnkey contract. • The rig company acting as the contract leader will most likely apply 25% of handling feel and 75% of turnkey risk compensation.
9	**9-Turnkey SC**	Full turnkey (Service company as the leader)	• It is usually used to drill a well for a fixed lump sum price. • This type of contract is currently uncommon in the Indonesian geothermal industry. The leader can be the **rig or any other service company** that has the capability to run the full IPM project where the risk is fully borne by the IPM contractor. • It is assumed to result in only **1 contract document**: Turnkey contract. • The service company acting as the contract leader will most likely apply 25% of handling feel and 75% of turnkey risk compensation.

These unique alternative ways are only cases created based on authors preference to exercise the utilization of MCDA in contract type selection. Any decision-maker is free to create their own alternatives of contract type, based on what is necessary for the project.

3.2.2 Define Objectives and Criteria

The next step is to define the objective of the decision. In this study, the objective of this "Getting Suitable Drilling Contract Type" decision analysis is to determine the most optimum alternative for drilling contract that can result in minimum cost, minimum risk, minimum effort and maximum peace of mind. Figure 6 shows the value tree and the criteria of the decision analysis.

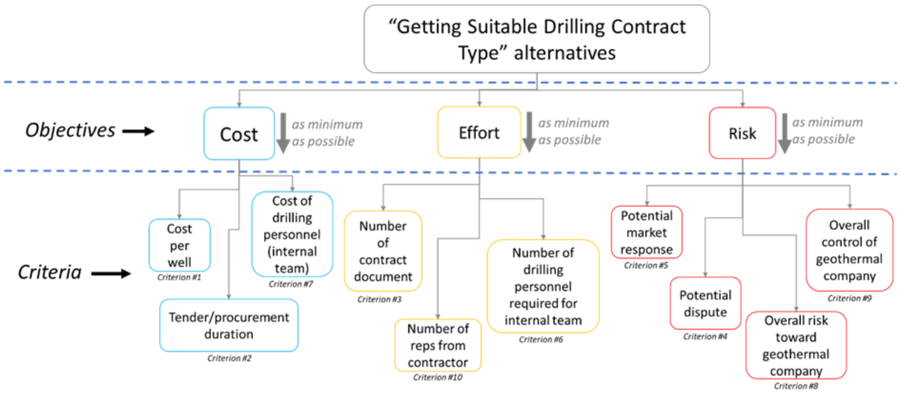


Figure 6: Value tree and criteria of the "Getting Suitable Drilling Contract Type" decision analysis

Based on the value tree above, the criteria measurement is described as follows:

1. Cost

   a. *"Cost per well"* is the cost of wells that includes tangible and intangible costs but does not cover infrastructure costs and the costs of internal drilling teams. In this study a discrete contract with a day rate scheme is used as a baseline, where other types of contracts will experience an increase in costs due to the handling fees and risk compensations. This cost assumption uses figures from studies that have been carried out by EBTKE (Purwanto et al., 2018), which is US$ 2,930 per meter as the baseline for drilling standard hole and applying the discrete contract type combined with the unit rate payment scheme. Table 2 shows the cost per well assumptions used in this study. The least cost, the better.

Table 2: Cost assumption of each alternative

No	Alternative Name	Contract type	Baseline well cost (standard hole with 2,000m depth)	Handling fee applied by rig (25%)	Handling fee applied by service companies (25%)	Footage risk compensation applied by rig (50%)	Footage risk compensation applied by service companies (50%)	Turnkey risk applied by the contractor (75%)	Total
1	1-DU	Discrete w/ Unit Rate	$5,860,000	0	0	0	0	0	$5,860,000
2	2-ISU	Integrated service w/ Unit Rate	$5,860,000	0	$487,845	0	0	0	$6,347,845
3	3-ISF	Integrated service w/ Footage	$5,860,000	0	$487,845	$1,552,900.0	$975,690	0	$8,876,435
4	4-SubU Rig	Sub contracted w/ Unit Rate (Rig as leader)	$5,860,000	$487,845	0	0	0	0	$6,347,845
5	5-SubU SC	Sub contracted w/ Unit Rate (Service company as leader)	$5,860,000	0	$776,450	0	0	0	$6,636,450
6	6-SubF Rig	Sub contracted w/ Footage (Rig as leader)	$5,860,000	$487,845	0	$2,930,000	0	0	$9,277,845
7	7-SubF SC	Sub contracted w/ Footage (Service company as leader)	$5,860,000	0	$776,450.0	0	$2,930,000	0	$9,566,450
8	8-Turnkey Rig	Full turnkey (Rig as leader)	$5,860,000	$487,845	0	0	0	$4,395,000	$10,742,845
9	9-Turnkey SC	Full turnkey (Service company as leader)	$5,860,000	0	$776,450.0	0	0	$4,395,000	$11,031,450

   b. *"Tender/procurement duration"* is the duration, referred in month, required to conduct the procurement process in obtaining contract for drilling rig and other drilling services. The duration of contract is correlate directly to the cost. The longer the procurement process the higher the cost of internal drilling personnel, therefore the least duration the better.

   c. *"Cost of drilling personnel"* is the total cost that needs to be spent to maintain or sustain all drilling personnel in the company to run the exploration drilling project. The least cost of drilling personnel, the better. Table 3 shows the assumption used in estimating the cost of drilling personnel in each alternative, for drilling 3 (three) wells with the estimate of 45 days per well, where all personnel is hired from the beginning of procurement activities to the end of the last well.

Table 3: Assumption of drilling personnel cost during procurement period

Alternative name	Estimate tender/procurement duration (months)	Number of personnel required	Procurement specialist	Contract Engineer	Drilling Engineer	Sr. Drilling Engineer	Day Drilling Supervisor	Night Drilling Supervisor	Drilling Superintendent	Drilling Manager	Monthly Cost	Total Cost
		Monthly payment	$ 3,000	$ 3,000	$ 4,000	$ 9,000	$ 14,000	$ 9,800	$ 12,000	$ 12,000		
1-DU	9	14	2	2	3	1	2	2	1	1	$ 104,600	$ 1,516,700
2-ISU	11	11	1	1	2	1	2	2	1	1	$ 94,600	$ 1,560,900
3-ISF	12	5	1	1	1	1	0	0	0	1	$ 31,000	$ 542,500
4-SubU Rig	16	11	1	1	2	1	2	2	1	1	$ 94,600	$ 2,033,900
5-SubU SC	16	11	1	1	2	1	2	2	1	1	$ 94,600	$ 2,033,900
6-SubF Rig	18	5	1	1	1	1	0	0	0	1	$ 31,000	$ 728,500
7-SubF SC	18	5	1	1	1	1	0	0	0	1	$ 31,000	$ 728,500
8-Turnkey Rig	20	3	1	0	0	1	0	0	0	1	$ 24,000	$ 612,000
9-Turnkey SC	20	3	1	0	0	1	0	0	0	1	$ 24,000	$ 612,000

Note: drill 3 (three) exploration wells with assumption 45 days per well with close out duration 30 days after the last well

2. Effort

   a. *"Number of contract document"* shows the quantity of contract documents required by an alternative. The geothermal developer will not have to deal with so many contractors if they apply an alternative that requires only a minimum amount of contract, in which in this study, this is preferable. The assumption used is based on authors experiences and Hartono (2019).

   b. *"Number of contractor reps"* is the total number of representatives assigned by the drilling contractors for the project. This number is directly related to the number of contracts. The authors of this study assume that the geothermal developer prefers to communicate with less people to avoid information confusion and minimize man-hours consumption. The less the number of contractor reps the better.

   c. *"Number of internal drilling personnel"* shows how many drilling personnel assigned to the project by the geothermal developer, that is shown in Table 3. It expresses the difficulties a geothermal developer must handle in the recruitment process due to limited supply of experienced geothermal drilling personnel in Indonesia. The less amount of drilling personnel employed would be the better.

3. Risk

   a. *"Potential market response"* is one of the main components of managing risk where it gives an idea of how successful the tender process will be. The decision-maker may determine any type of contract that they prefer, but whether contractors are willing to participate in the tender process, due to this, must be considered. The value of this criterion uses direct rating resulted from authors discussion. The alternative with the highest market response is preferable.

   b. *"Potential dispute"* expresses the likelihood of dispute between all parties involved in the contract. Authors of this study believe that the discrete type has the lowest possibility of dispute, due to each service company is directly in contract with the geothermal developer. The lower the likelihood of potential dispute the better. Same as "potential market response" criterion, the "potential dispute" is valued using direct rating in a subjective way by the authors.

   c. *"Overall risk toward geothermal company"* shows the inevitable consequence of how big the risk a type of contract places towards the geothermal developer. Same as the other two risk criteria, this criterion is also valued using direct rating in a subjective way by the authors and is shown in the performance matrix criteria. Authors believe that as the developer has more control, most of the risk will be on the developer's side. However, with a proper mitigation plan, those risks should be able to be managed. In contrary, by transferring control to the contractors such as in IPM-type or turnkey-type contract, developer will rely solely on the contractor's ability to manage the risk. One thing that people tend to overlook in Indonesia is that the consequences of the said risk will be back to the developer again, not transferred to the contractor, unless stated clearly in the contract. As far as the authors' knowledge, as per today there is no such IPM contract in Indonesia that fully transfer the risk to the contractor side.

Based on discussion above a performance matrix of each criteria that can be measured can be developed as shown in Table 4.

Table 4: Performance matrix with measurement of each criteria

PERFORMANCE MATRIX	Criterion-1	Criterion-2	Criterion-3	Criterion-4	Criterion-5	Criterion-6	Criterion-7	Criterion-8	Criterion-9	Criterion-10
ALTERNATIVES	Estimated cost per well	Estimate tender/procurement duration	Number of contract document	Potential dispute	Potential market response	Number of personnel required from geothermal company	Cost of drilling personnel hired by geothermal company	Overall risk toward thegeothermal company	Overall control of geothermal company on the project	Number of project coordinator/reps provided by the contractor
	USD	*months*	*count*	*direct rating*	*direct rating*	*count*	*USD*	*direct rating*	*direct rating*	*count*
1-DU	5,860,000	9	20	95	95	14	1,516,700	40.0	90.0	8
2-ISU	6,347,845	11	5	75	75	11	1,560,900	40.0	80.0	2
3-ISF	8,876,435	12	4	30	30	5	542,500	70.0	60.0	2
4-SubU Rig	6,347,845	16	4	60	65	11	2,033,900	50.0	50.0	1
5-SubU SC	6,636,450	16	4	65	60	11	2,033,900	50.0	50.0	1
6-SubF Rig	9,277,845	18	3	40	35	5	728,500	60.0	35.0	1
7-SubF SC	9,566,450	18	3	45	40	5	728,500	60.0	35.0	1
8-Turnkey Rig	10,742,845	20	1	10	10	3	612,000	90.0	5.0	1
9-Turnkey SC	11,031,450	20	1	10	10	3	612,000	90.0	5.0	1

Table 4 also shows that criterion 4 (potential dispute), criterion 5 (potential market response), criterion 8 (overall risk toward the geothermal company) and criterion 9 (overall control of geothermal company on the project) are measured using direct rating method. The value of direct rating is determined by authors consensus, where most authors have experiences involved in more than 1 (one) geothermal drilling project in Indonesia. The brief description of how authors put the direct rating measurement value on each criterion mentioned above are shown in Table 5.

Table 5: Brief explanation of direct rating measurement

Criterion	Highest	Lowest	Reason
4 – potential dispute	1-DU with score 95 (preferable)	8- Turnkey rig and 9-Turnkey SC with score 10 (less preferable)	The authors believe that the potential dispute between the geothermal company and the drilling contractors are more likely when the contract documents are bundled. Based on authors experience, most of the company that chose bundling or turnkey contract type are companies with minimum number of people, which does not have the resource to properly handling the bundling process, thus creates a lot of unclear or grey area in the contract documents, especially in the matrix of responsibilities. The very broad scope covered in bundling the contract further worsen the issue. Therefore, the discrete contract type is believed to result in less potential dispute compared to bundling or turnkey type of contract, as each service will be on separate contract, leaving less room for unclear matrix of responsibilities.

5 – potential market response	1-DU with score 95 (preferable)	8- Turnkey rig and 9-Turnkey SC with score 10 (less preferable)	Since in Indonesia discrete contract type is very common, authors are convinced that the level of response from drilling contractors to submit a bid to this kind of contract type will be higher compared to bundling or turnkey type. For some geothermal companies in Indonesia, especially state-owned company, less than 3 (three) bid submission from drilling contractors or drilling service companies will result in tender failure, thus requiring the company to repeat the procurement/tender process. On the other hand, as for competing in an IPM or turnkey-type contract tender requires vast amount of capital, the potential bidder is limited to a few companies only, or nothing at all such as in turnkey-type.
8 – overall risk toward the geothermal company	8- Turnkey rig and 9-Turnkey SC with score 90 (preferable)	1-DU and 2-ISU with score 40 (less preferable)	Although seems contradictive with reason described for criterion 4, authors believe that in a turnkey contract, if prepared appropriately, will results in less project risk to the geothermal company. This happens when the turnkey drilling contractor manage to quantify all the risks and absorb it through the contract value and both parties have successfully produced a matrix of responsibility that addressing all possible scenarios. In this case, turnkey type contract is preferable compared to the discrete or bundling contract since the risks are assumed to be transferred from the geothermal company to the drilling contractor.
9 – overall control of geothermal company on the project	1-DU with score 90 (preferable)	8- Turnkey rig and 9-Turnkey SC with score 5 (less preferable)	In terms of control on the project, authors confident that the control is related to the number of major drilling contracts directly managed by the geothermal company. It will be difficult for the geothermal company to control the sub-contractor since they do not have legal basis to communicate directly. Therefore, the more contract managed directly by the geothermal company, especially for big value contract such as rig, mud, directional drilling, or cementing, the more control the company has on the project.

Table 6 shows matrix of scores for each criterion which for the quantifiable criteria the value is be derived using the linear function.

Table 6: Matrix of score of each criterion

MATRIX OF SCORE *[using linear function = 100/(best-worst)*(criterion_value - best)+100]*	Criterion-1	Criterion-2	Criterion-3	Criterion-4	Criterion-5	Criterion-6	Criterion-7	Criterion-8	Criterion-9	Criterion-10
ALTERNATIVES	**Estimated cost per well**	**Estimate tender/procurement duration**	**Number of contract document**	**Potential dispute**	**Potential market response**	**Number of personnel required from geothermal company**	**Cost of drilling personnel hired by geothermal company**	**Overall risk toward the company**	**Geothermal company control on the project**	**Number of project coordinator/reps provided by the contractor**
1-DU	100.0	100.0	0.0	100.0	100.0	0.0	34.7	0.0	100.0	0.0
2-ISU	90.6	81.8	78.9	76.5	76.5	27.3	31.7	0.0	88.2	85.7
3-ISF	41.7	72.7	84.2	23.5	23.5	81.8	100.0	60.0	64.7	85.7
4-SubU Rig	90.6	36.4	84.2	58.8	64.7	27.3	0.0	20.0	52.9	100.0
5-SubU SC	85.0	36.4	84.2	64.7	58.8	27.3	0.0	20.0	52.9	100.0
6-SubF Rig	33.9	18.2	89.5	35.3	29.4	81.8	87.5	40.0	35.3	100.0
7-SubF SC	28.3	18.2	89.5	41.2	35.3	81.8	87.5	40.0	35.3	100.0
8-Turnkey Rig	5.6	0.0	100.0	0.0	0.0	100.0	95.3	100.0	0.0	100.0
9-Turnkey SC	0.0	0.0	100.0	0.0	0.0	100.0	95.3	100.0	0.0	100.0

3.2.3 Specify the weighs for each different criterion

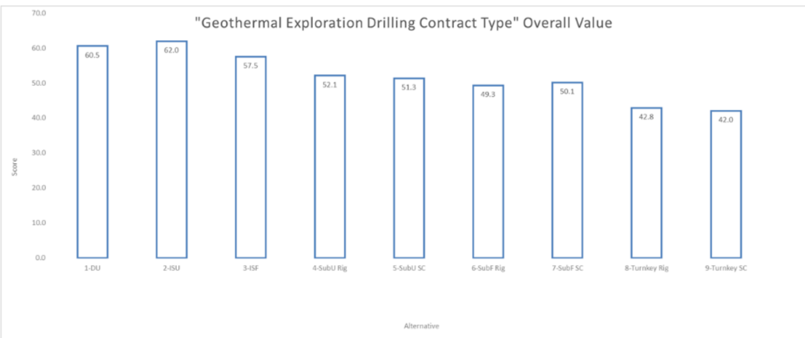
The next step is to weigh each alternative accordingly to the criteria. "Well cost" (Criterion-1) and "Potential dispute" (Criterion-4) are given the highest weight in this study since the authors believe that, in the exploration phase, uncertainty is still high and the geothermal developer prefers to spend minimal investment, avoid conflict with business partners and tends to share risk. Furthermore, the developer also wants to have a successful procurement process, which is indicated by market response and procurement duration. That is the reason why "Potential market response" (Criterion-5) and "Tender/procurement duration" (Criterion-2) weight ranked the second and third consecutively. The detailed work is shown in Table 7.

Table 7: Weight of Each Criterion

WEIGHT	Criterion-1	Criterion-2	Criterion-3	Criterion-4	Criterion-5	Criterion-6	Criterion-7	Criterion-8	Criterion-9	Criterion-10
	Estimated cost per well	**Estimate tender/procurement duration**	**Number of contract document**	**Potential dispute**	**Potential market response**	**Number of personnel required from geothermal company**	**Cost of drilling personnel hired by geothermal company**	**Overall risk toward the company**	**Geothermal company control on the project**	**Number of project coordinator/reps provided by the contractor**
Weight	100.0	85.0	20.0	100.0	95.0	80.0	60.0	80.0	20.0	55.0
Normalized Weight	14.4	12.2	2.9	14.4	13.7	11.5	8.6	11.5	2.9	7.9

3.2.4 Overall Score for Each Alternative

The last step is deriving the overall scores for each of the alternatives for the decision problem given by our value tree (Figure 7).



OVERALL SCORES		
ALTERNATIVES	**Overall Score**	**Normalized Score**
1-DU	6054.8	60.5
2-ISU	6196.5	62.0
3-ISF	5751.8	57.5
4-SubU Rig	5208.9	52.1
5-SubU SC	5132.8	51.3
6-SubF Rig	4928.4	49.3
7-SubF SC	5013.2	50.1
8-Turnkey Rig	4284.7	42.8
9-Turnkey SC	4204.4	42.0

Figure 7: Bar Chart of Normalized Scores of Each Alternative and Overall Scores of Each Alternatives.

Authors was initially expecting the alternative 1-DU to come up as the best alternative since it gives the lowest well cost and the lowest potential of contract dispute. However, Figure 7 shows that the highest total score is alternative 2-ISU. Upon further inspection, it does make sense since the cost of alternative 2-ISU is not significantly different from alternative 1-DU and still ranked second in term of potential dispute. The determining factor of alternative 2-ISU from alternative 1-DU are in the "number of contract document" and "number of drilling personnel required" which scored higher than 1-DU alternative.

3.2.5 Sensitivity Analysis on Cost Criterion

An example of a sensitivity analysis on "Well cost" (Criterion-1) is conducted by changing the weight of "Well cost" criterion from 0 to 100 percent. The overall score value of each changes is recorded on Table 8.

Table 8: Sensitivity Analysis to Changes in "Well cost" (Criterion-1) Weight

1-DU											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	53.9	54.7	55.4	56.1	56.8	57.5	58.1	58.8	59.4	60.0	60.5
2-ISU											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	57.2	57.7	58.2	58.8	59.3	59.7	60.2	60.7	61.1	61.5	62.0
3-ISF											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	60.2	59.9	59.6	59.3	59.0	58.7	58.5	58.2	58.0	57.7	57.5
4-SubU Rig											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	45.6	46.4	47.1	47.8	48.5	49.1	49.7	50.4	50.9	51.5	52.1
5-SubU SC											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	45.7	46.3	47.0	47.6	48.1	48.7	49.3	49.8	50.3	50.8	51.3
6-SubF Rig											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	51.9	51.6	51.3	51.0	50.7	50.5	50.2	50.0	49.7	49.5	49.3
7-SubF SC											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	53.8	53.4	53.0	52.6	52.2	51.8	51.5	51.1	50.8	50.4	50.1
8-Turnkey Rig											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	49.1	48.4	47.7	47.0	46.4	45.7	45.1	44.5	44.0	43.4	42.8
9-Turnkey SC											
Weight	0	10	20	30	40	50	60	70	80	90	100
Normalized Score	49.1	48.3	47.5	46.8	46.0	45.3	44.6	43.9	43.3	42.7	42.0

It is shown on the Figure 8, for "Well cost" criterion weight range of 0 to 100, alternative 1-DU is always having the highest overall score until the weight become less than 40%. When the "Well cost" weight is less than 40%, alternative 3-ISF becomes the winner with overall score 59.3 at 30% weight.

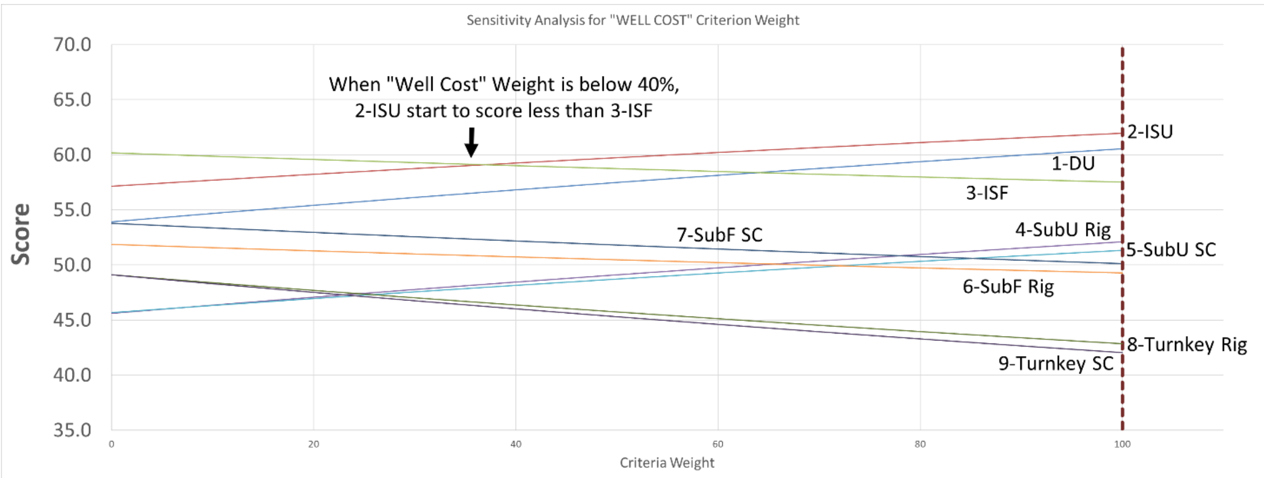


Figure 8: Sensitivity Analysis on "Well cost" (Criterion-1)

It can be said that the decision-making process is sensitive to the changes of "Well cost" criterion weight. However, in this study, the decision maker is assumed eager in getting the lowest well cost that resulting in put high weight in "Well cost" criterion. In this exercise, the decision-maker is suggested to use the highest overall score, which is alternative 2-ISU. This alternative refers to integrated service contract type with day rate payment scheme, described in Table 1.

Figure 6 also shows that the alternatives 2-ISU, 1-DU, 4-SubU Rig, 5-SubU SC give a downward trend when the "Well cost" weight is lowered. This shows that the alternative that uses the unit rate (day rate) payment scheme is superior on the side of the well cost because it delivers cheaper costs than the alternative that uses a footage or turnkey scheme such as 7-SubF SC, 6-SubF Rig, 8-Turnkey Rig and 9-Turnkey SC.

DISCUSSION

Selecting contract type for geothermal drilling in Indonesia is a complex process with a lot of factors to be considered. MCDA as one of the decision-making tools is suitable for assisting such process as it does not require monetized measurement. MCDA itself relies on two types of scoring for its criteria:

- Measurable criteria (objective); in this case such as well cost, number of contract document, number of personnel. This scoring comes from quantitative data that can be directly applied to the process.
- Direct rating scoring (subjective). This scoring is based on qualitative aspects of the criteria, and in this case came from consensus of the project team. This is when the experience of the team member come into play, as in theory, the more experienced personnel can better assess the criteria (even though there is no guarantee if that will be the case). The direct rating score can also be derived from qualitative assessment from literature study.

This study showed that MCDA is applicable for selecting drilling contract type for geothermal project in Indonesia. Yet, as there is still human subjectivity in MCDA in this case, it is crucial for the decision maker to consistently follow the same procedure applied in scoring the direct rating criteria to ensure its reliability. The quantitative data accuracy is also paramount to the MCDA reliability. Thus, in this case, it is advised to conduct market survey update prior to utilising MCDA or any decision-making tools to obtain accurate well cost estimate. The aforementioned human subjectivity factor and data accuracy are the limitation of MCDA method that has to be considered and managed if someone intend to apply MCDA for geothermal drilling contract selection.

Other way to ensure reliability of the MCDA is to conduct sensitivity analysis for each criterion to see whether the decision maker put an unbalanced weight or score in one criterion. In this paper, only well cost was subjected to sensitivity analysis, but for a more thorough assessment, all criteria can be a subject for sensitivity analysis. However, it should be noted that the MCDA or any decision-making tools does not relieve the decision-maker to make difficult judgement. The process itself does not make the decision; the decision-maker is the one who make the final decision.

CONCLUSION

The authors of this study applied MCDA for selecting drilling contract type for geothermal project in Indonesia to demonstrate the suitability of MCDA application in geothermal drilling. This means that other team or person can apply this method by adjusting value tree, performance matrix, criterion weight, or even criteria according to the data availability and their own personal judgement. As a result, authors of this study concluded that MCDA tool is relevant to assist the decision maker in selecting a drilling contract type for geothermal exploration project in Indonesia.

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