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Decision Making in Determining the Best Field Development Scenario using Analytical Hierarchy Process (AHP): Case Study of SANDHIGH Field

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Abstract

The SANDHIGH field is one of the fields owned by PT Pertamina EP in West Java. This field was discovered in 1987 and is a gas-producing field with peak production reaching 45-50 mmscfd in 2002-2003 and cumulative gas production up to December 2020 reaching 200.1 BSCF. Gas production from this field has decreased drastically after 2003, until March 2022, the production is only under one mmscfd, an apprehensive condition. Problem analysis has been carried out using the Kepner-Tregoe method. The leading potential cause of the decline in production in this field is the absence of a Plan of Development (POD). So, exploitation activities that aim to increase production cannot be carried out or even restrain the decline rate in production. In mid-2021, an initiation was made to make the SANDHIGH field POD by involving the Subject Matter Expert (SME) from the subsurface and surface engineers and advisors. Discussions with SKK Migas as government representatives were also carried out intensively to produce the best development scenario based on Value Focus Thinking (VFT). From these discussions emerged three alternative development scenarios. The Analytical Hierarchy Process (AHP) method is used to help select the best scenario from the three available options. The assessment criteria used include capital expenditure, operation expenditure, expected profit, implementation time, operability, and safety. Based on the results of the AHP analysis, it was found that Scenario-C was the best choice, with a value reaching 54.4

Index terms— SANDHIGH field, plan of development, AHP analysis.

1 Introduction

T Pertamina EP is one of the largest gas producers among Sub Holding Upstream of PT Pertamina (Persero) subsidiaries. One of the gasproducing structures is the SANDHIGH Field. It is geographically located in West Java (Appendix-1). NorthCILA, EastCILA, and BaGung border the northwest. SANDHIGH field is proven to produce oil and gas after the SH-01 exploration drilling was carried out in 1987 from the P prospect. At its peak production, the SANDHIGH field can produce a gas of 45-50 mmscfd with a cumulative total gas production up to December 2021 of BSCF, which is a large enough gas for a field measuring only 5x3 km. However, until this year, the field's production has plunged to its lowest point of just under 1 mmscfd.

Efforts to increase production from the SANDHIGH field must include additional drilling wells in new areas around this field. However, company regulations require a field to have a Plan of Development (POD) and Final Investment Document (FID) as the basis for developing an oil and gas field. The main problem with this field is that it does not have the POD & FID document. Therefore, in the end of 2021, it was initiated to create the SANDHIGH field POD & FID document, which includes several field development scenarios. Then one best scenario must be selected, which will be applied in field development.

Gas production from the SANDHIGH field has decreased drastically from 2006 to 2022. A comprehensive plan for the development scenario is needed to increase gas production in this field. Selection of the optimal field development scenario is the essential step. In the SANDHIGH field case, a study of the subsurface potential and the needs of production facilities was carried out. Based on Forum Group Discussion within subject matter expert, conical on 3 alternative scenarios including: This study will select the best scenario applied to the SANDHIGH field using the decision-making methods. It is hoped that SANDHIGH field gas production can increase and provide additional company revenue Decision-making in the development plan related to the SANDHIGH field uses Value Focused Thinking (VFT) and Analytic Hierarchy Process (AHP). The decision alternatives were made based on the Forum Group Discussion results as explained in the previous section, while the criteria chosen for consideration are: cost, expected profit, time to implement, operability, and safety. The four criteria mentioned before will be considered to choose the best alternative from the three development scenario options mentioned earlier.

2 II.

3 Methods

A POD/FID document provides a field development strategy divided into two sections, discussing the subsurface potential and surface facility development. In the end of 2021, a focus group discussion was held with Subject Matter Experts (SMEs) from various related fields and scientific backgrounds. The problem will be solved by generating alternatives utilizing the Value Focused Thinking (VFT) method.

On the subsurface, sensitivity analysis was performed on numerous possible workovers and drilling scenarios to determine their cumulative effect on gas production, as illustrated in appendix-2. Based on the subsurface modeling performed by SMEs in the subsurface field, it was determined that adding one workover, two infill drilling, and two step-out drilling is the most optimal solution. As a result, there is only one subsurface alternative.

The surface facility analysis becomes more complicated than subsurface since there are multiple viable methods for transporting gas and liquid production from the west area to the east area gathering station. The other issue is how to handle liquid production at the existing production facility where there is no such facility yet. In every scenario, the construction of a flowline from the west to the east is a solid solution, the only difference being handling liquid production after 2033. The following are the alternatives that resulted:

1. Scenario-1 (liquid handling by pipeline to the SBG Station) In this scenario, the following production facilities will be constructed: Production using existing facilities in the east area; construction of flowline from west area to east area; adding separation facilities, storage tanks, and water injection plans in the eastern area in 2031; construction of a condensate trunkline from the production facility in the east area to the SBG station, which is 18 km 2. Scenario-2 (liquid handling by trucking to the JAS Station)

In this scenario, the following production facilities will be constructed: production using existing facilities in the east area; construction of flowline from west area to east area; adding separation facilities, storage tanks, and water injection plans in the eastern area in 2031; rent a road tank from the production facility in the east area to the JAS station, which is 25 km 3. Scenario-3 (No liquid handling, only producing gas until 2033) In this scenario, the following production facilities will be constructed: production using existing facilities in the east area; construction of flowline from west area to east are Value-Focused Thinking aids in the discovery of hidden objectives and results in more productive collecting information. It can facilitate communication between parties affected by a decision, facilitate the involvement of various stakeholders, and facilitate the coordination of related decisions. Addressing underlying values would result in a more nuanced alternatives assessment and improved communication amongst stakeholders (Keeney, 1994).

The most critical and significant criteria affecting the decision analysis must be chosen to determine the best alternative when making a decision. The developed alternatives must meet the primary objectives of selecting the best field development scenario for increased production and safer operation. However, various criteria and sub-criteria will determine the optimum scenario. The primary criterion is cost-benefit analysis. Costs are divided into CapEx and OpEx, whereas benefits are divided into expected profit, implementation time, operability, and safety. Multiple criteria and sub-criteria will be used in the AHP process to identify the best alternative among three development scenarios for increasing gas production in the SANDHIGH Field. AHP consists of several stages, as described in the appendix-4.

Thomas L. Saaty developed AHP as a decision support model. This decision support approach will use a hierarchy to classify complex multi-factor or multicriteria problems. The term "hierarchy" refers to depicting a complicated problem in a multi-level structure, with the objective at the top, followed by factors, criteria, sub-criteria, and the final level of alternatives. A complex problem can be split into groups and organized hierarchically to appear more ordered and systematic (Saaty, 2008).

4 Step-1

The AHP method begins by constructing a decision hierarchy that depicts the link between alternatives and criteria/sub-criteria. Appendix-5 depicts the decision hierarchy tree.

5 Step-2

This stage is carried out by conducting interviews with SME, a member of the FGD, to determine the root of the problem and alternative solutions along with the criteria used in determining the best development scenario. In this interview process, an objective assessment of each SME is obtained, which helps make pairwise comparisons. Six experts were interviewed during the prioritization process to determine the number of times more significant or dominant an alternative is compared to another alternative using a specified criterion. A similar technique is used to provide judgments on sub-criteria, and the prioritization procedure is conducted using a 1-9 numerical rating scale. The following is a list of the SMEs that were interviewed for this study: As input in the pairwise comparison process, a questionnaire is made, used as material for interviews with each SME. The questionnaire contains the 1 to 9 scale used in AHP as the numerical rating for the prioritization process. The description of each value scale is given in Table-4. Very strongly more preferred 9 Extremely more preferred Six experts were interviewed throughout the discussion to judge how much preferred, or essential one alternative is compared to another alternative based on a given criterion. This technique was also used to prioritize sub-criteria and criteria. Following that, the geometric mean is calculated to obtain the average value among the experts.

As in the previous explanation, the pairwise comparison is conducted to assess which alternative is more important. This step is also carried out to prioritize each criterion and sub-criteria. The following are pairwise comparisons which are the results of the assessments of the six interviewed SMEs

6 a) Cost VS Benefits (prioritization between criteria)

At this stage, it aims to prioritize the two main criteria used as the basis for evaluating alternative solutions. The two criteria are costs and benefits. The cost criteria are further divided into two sub-criteria: capital expenditure (CapEx) and operational expenditure (OpEx). While the criteria for benefits are divided into four sub-criteria, namely expected profit, time to implement, operability, and the last is safety. Each SME was asked to prioritize costs compared to benefits at the interview stage. Appendix-6 are the results of the interview.

From the results of the interview, pairwise comparisons were then made as summarized in Table-3 as follows: From the results above, all SMEs agree that "benefits" are prioritized over "costs." Because from the perspective of PT Pertamina EP as a company with a Production Sharing Contract (PSC) scheme with SKK Migas. The state will reimburse all costs through a cost recovery mechanism. Therefore, this project's decisionmaking prioritizes the "benefits" aspect rather than the "cost." In addition, the sub-criteria in "benefits" is indeed an important aspect that must be considered in deciding whether this project can be implemented or not.

7 b) Cost Attribute

8 i. CapEx vs OpEx (sub-criteria weighting)

The first question on the cost attribute prioritizes the two sub-criteria, namely CapEx and OpEx. CapEx is all costs used for investments such as the construction of production facilities, construction of flowlines, land acquisition for drilling, and drilling materials. While OpEx is all costs needed to run daily operations, such as maintenance costs, rental fees, employee salaries, and other expenses required to run the operations of each alternative. The results of this interview are helpful as a weighting sub-criteria. Appendix-7 are the results of the interview.

From the results of the interview, pairwise comparisons were then made as summarized in Table-4 as follows: The interview results show that CapEx is prioritized over OpEx because the return of CapEx with a cost recovery mechanism can be done faster than OpEx. Besides that, OpEx will directly affect oil and gas lifting costs, which will reduce the company's profit.

9 ii. CapEx

SMEs were interviewed about their preferences or the relative importance of several alternatives in CapEx costs. It was graded from least expensive to the most expensive alternative. Appendix-8 are the results of the interview: Furthermore, a pairwise comparison was made based on the results of the interview above with the following results: The scenario with the lowest OpEx costs is Scenario-3 because this scenario only takes into account OpEx until 2033, the impact of gas production being stopped only for that year. Meanwhile, the total OpEx calculation is up to 2035 or the end of the PT Pertamina EP PSC contract period in another scenario.

10 c) Benefits Attribute i. Expected profit VS Time to implement VS Operability VS Safety (sub-criteria weighting)

As was done in the "cost" attribute interview, for the first time, SMEs are asked for opinions regarding the priorities of the four existing sub-criteria, namely expected profit, time to implement, operability, and safety. The results of this interview will be used as a weighting sub-criteria in the subsequent analysis.

Expected profit is the estimated profit that the company will get in each scenario. Time to implement is the estimated time required to complete the project and start providing revenue for the company. Operability or level of complexity is the ease and flexibility of the operation process of each alternative. Safety is a risk related to work safety and environmental sustainability. Appendix-10 are the results of the interview: Furthermore, from the results of the above interview, a pairwise comparison was made, as summarized in the table-7 below. All SMEs agree that safety is the primary concern for field development scenarios. This aligns with the company policy that prioritizes occupational health and safety and caring for others, the social and natural environment as a way of life. The next priority in a row is expected profit, operability, and finally, time to implement.

11 ii. Expected profit

SMEs were interviewed about their preferences or the relative importance of several alternatives in expected profit. It was graded from the highest to the lowest profit. Here are the results of the interview:

The interview results above are then stated in a pairwise comparison, as shown in the table-8 below. It can be seen that the scenario that provides the most considerable profit for the company is scenario-2 because the maximum oil and gas production is obtained until 2035 (end of PSC) and does not develop a flowline for liquid produced in 2033-2035. Liquid production is transferred to the JAS station by renting a road tank.

12 iii. Time to implement

For the sub-scenario of time to implement, SMEs are asked to assess the priority of each scenario based on the length of time required to complete the project to generate revenue for the company. The assessment is carried out in time from the shortest to the longest. The results of the interview can be seen in appendix-12.

As with the other sub-criteria, a pairwise comparison was made after the interview, as shown in the table-9. Scenario-3 is the scenario that has the fastest time in project completion because this scenario does not involve building a liquid flowline and leasing a road tank. The scope of work in scenario-3 is only to construct a flowline from the west area to the east area, while production facilities use existing facilities.

13 iv. Operability

SMEs were surveyed regarding their preferences or the relative importance of numerous alternative scenarios in operability. This criterion determines how adaptable and straightforward an operation or facility is. It was ranked from simplest to most complex operation. Appendix-13 are the interview's findings:

The following are pairwise comparisons for operability obtained from the interview results above. Same with the time to implement sub-criteria, for operability scenario-3 is also the most straightforward scenario in operation for the same reason. In terms of work, scenario-3 is the easiest because it only involves making a flowline from the west area to the east area.

14 v. Safety

The last sub-criteria is safety, where in this aspect, SMEs are asked to estimate the potential hazards, work accidents, and environmental pollution from each scenario and then make priorities based on the safest to the most dangerous scenarios, as seen in the results of the interview in appendix-14.

Then, as detailed in table-11 below, a pairwise comparisons table is created.

15 Synthesize the Result

This is the third step in the AHP process, in which the alternatives are prioritized. Synthesizing the results entails calculating the consistency ratio and ranking the alternatives. It begins by normalizing the pairwise comparison matrices and averaging each row to obtain the relative priority or Eigen vector for each criterion/sub-criteria.

While synthesizing the results, it is critical to check the degree of consistency of judgments (consistency ratio) to ensure the ultimate decision is of high quality. A consistency ratio is generated to quantify the consistency of paired comparison judgments. The ratio is designed if the ratio values are greater than 0.10, indicating that the judgment is inconsistent and cannot be accepted. As a result, confirmation from SMEs that the consistency ratio is less than 0.10 must be acquired. For pairwise comparison matrixes with more than two rows/columns, the consistency ratio must be determined. The steps for calculating the consistency ratio are as follows:

1. Normalize the pairwise comparison by dividing each element in the pairwise comparison by the total number of all elements in the same column. 2. Make sure the sum of all normalized pairwise comparison elements in the same column is worth one. 3. Calculate the average in each row, and make this average value as an "eigenvector." 4. Calculate the matrix multiplication between the eigenvector values and each pairwise comparison element in the same column. The first-row eigenvector is multiplied by all elements of the first column in pairwise comparison, and so on.

5. Do the summation of the matrix results from Step 4. Furthermore, this result is called the "weighted sum." 6. Divide each weighted sum value by the eigenvector value. 7. Calculate the average of all the values obtained from Step 6. Then this value is called ?max. 8. Calculate the Consistency Index (CI) using the equation below:???? = ? max ? n ?? ? 1

Where n is the number of items being compared 9. Calculate the Consistency Ratio (CR) using the equation below:???? = ???? ????

Where RI is the Random Index, which is the consistency index of a randomly generated pairwise comparison matrix. It can be shown that RI depends on the number of elements being compared and takes on the following values n 1 2 3 4 5 6 7 8 9 10 RI 0.00 0.00 0.58 0.90 1.12 1.24 1.32 1.41 1.45 1.49

The following are the results of the consistency ratio calculation for each criterion and sub-criteria. We can conclude from the calculation that all CRs are less than 0.1, indicating that all data are already consistent. The technique can be continued to get the alternative's ranking rate. The hierarchy tree in appendix-15 illustrates the weights assigned to all alternatives and criteria/sub-criteria.

The last step in AHP is to do priority ranking. The ranking rate of alternatives is calculated by multiplying all of the weights in each path and then summing the options' results. The scenario with the highest score is the selected scenario. Based on the decision analysis above, it can be stated that Scenario-3 is the best alternative strategy for resolving the issue of decreased gas production in the SANDHIGH Field by utilizing a combination of VFT and AHP. Scenario-3 is envisioned as a project that would utilize existing production facilities in the east area and include the construction of a flowline connecting the west and east areas.

IV.

16 Conclusion

Based on all the discussions carried out, the following conclusions can be drawn from this research:

1. Based on the focus group discussion with multidisciplinary SMEs, selection of the best development scenario based on cost and benefit analysis. The cost criteria are divided into two subcriteria, namely CapEx and Opex. Meanwhile, the benefit criteria are divided into four sub-criteria: expected profit, time to implement, operability, and safety.

Based on the AHP analysis, the benefit has a higher weight than cost, with a numerical value of 0.869 for benefit and 0.131 for cost, respectively. Cost is not a priority because PT Pertamina EP has strong financial support from the state as a subsidiary of a state-owned company. Investment decisions are more focused on how much benefit the company will get. On the cost criteria, CapEx has a higher weight than OpEx, with a numerical value of 0.841 for CapEx and 0.159 for OpEx. Meanwhile, the priority benefit criteria resulting from the AHP analysis are safety (0.558), expected profit (0.263), operability (0.122), and time to implement (0.057). 2. The best scenario chosen is scenario-3, with a weight of 0.544. This scenario is superior to the other two scenarios, namely scenario-2 with a value of 0.246, and the last priority is scenario-1 with a value of 0.210. In scenario-3, There are two infill drilling, two stepout drilling, Production using existing facilities in the east area, and the construction of flowline from the west area to the east area. This scenario will provide additional cumulative gas gross production of 25.6 bscf. [1] [2]

1

No.	Name	Position	Background Study	Experience
1	WW	Subsurface Development Manager Area-1	Petroleum Engineering	20 years
2	BNA	Sr G&G Engineer	Geophysics	15 years
3	LFD	Sr Reservoir Engineer	Petroleum Engineering	17 years
4	AFF	Sr Surface Facility Planning Engineer	Civil & Construction Engineering	18 years
5	BA	Sr Development Planning Analyst	Petroleum Engineering	12 years
6	AH	Sr Drilling Engineer	Mechanical Engineering	18 years

Figure 1: Table 1 :

2

Numerical Rating	Verbal Judgments
1	Equally preferred
3	Moderately more preferred
5	Strongly more preferred
7	

Figure 2: Table 2 :

3

Cost VS Benefits	Cost	Benefits
Cost	1000	0.151
Benefits	6.618	1.000
Total	7.618	1.151

Figure 3: Table 3 :

4

CaPex VS OpEx	CaPex	OpEx
CaPex	1.000	5.288
OpEx	0.189	1.000
Total	1.189	6.288

Figure 4: Table 4 :

5

CaPex	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1.000	0.333	0.143
Skenario-2	3.000	1.000	0.200
Skenario-3	7.000	5.000	1.000
Total	11.000	6.333	1.343

Scenario-3 is the scenario with the lowest cost of CapEx. This alternative only produces gas until 2033 using existing production facilities without the construction of additional facilities. Meanwhile, other scenarios require additional costs to construct a new liquid flowline from existing facilities to other fields or rent a road tank.

Figure 5: Table 5 :

6

OpEx	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1	0.200	0.143
Skenario-2	5	1	0.333
Skenario-3	7	3	1
Total	13.000	4.200	1.476

Figure 6: Table 6 :

7

Benefits	Profit	Time to Implement	Operability	Safety
Profit	1.000	5.000	3.000	0.333
Time to Implement	0.200	1.000	0.333	0.143
Operability	0.200	3.000	1.000	0.200
Safety	3.000	7.000	5.000	1.000
Total	4.533	16.000	9.333	1.676

Figure 7: Table 7 :

8

Profit	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1.000	0.306	4.217
Skenario-2	3.267	1.000	6.257
Skenario-3	0.237	0.160	1.000
Total	4.504	1.466	11.474

Figure 8: Table 8 :

9

Time to Implement	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1.000	0.218	0.143
Skenario-2	4.592	1.000	0.306
Skenario-3	7.000	3.267	1.000
Total	12.592	4.484	1.449

Figure 9: Table 9 :

10

Operability	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1.000	3.267	0.237
Skenario-2	0.306	1.000	0.184
Skenario-3	4.217	5.433	1.000
Total	5.523	9.700	1.421

Figure 10: Table 10 :

11

Safety	Skenario-1	Skenario-2	Skenario-3
Skenario-1	1.000	3.267	0.237
Skenario-2	0.306	1.000	0.184
Skenario-3	4.217	5.433	1.000
Total	5.523	9.700	1.421
Once again, scenario-3 is the winner because this scenario is considered the safest, both in terms of potential work accidents and environmental pollution. III.			

Figure 11: Table 11 :

12

Criteria	CR	Sub-Criteria	CR
Cost	-	CapEx OpEx	0.057 0.056
		Profit	0.061
		Time to Implement	0.057
Benefits	0.044	Operability Safety	0.085 0.085

Figure 12: Table 12 :

13

Criteria			Sub-Criteria				Alternatives					
							Scenario-1		Scenario-2		Scenario-3	
	Weight	CR		Weight	Normalized	CR	Weight	Normalized	Weight	Normalized	Weight	Norm
			CapEx	0.841	0.110	0.057	0.083	0.009	0.193	0.021	0.724	0.080
Cost	0.131	-										
			OpEx	0.159	0.021	0.056	0.074	0.002	0.283	0.006	0.643	0.013
			Profit	0.263	0.229	0.061	0.266	0.061	0.061	0.149	0.083	0.019
Benefits	0.869	0.044	Time to Implement	0.057	0.049	0.057	0.076	0.004	0.266	0.013	0.658	0.033
			Operability	0.122	0.106	0.085	0.228	0.024	0.096	0.010	0.676	0.072
			Safety	0.558	0.485	0.085	0.228	0.111	0.096	0.047	0.676	0.328
								0.210		0.246		0.544

Figure 13: Table 13 :

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