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# Decision Analysis for Bumi Hitam Field Development by Using Analytical Hierarchy Process (AHP): Case Study of Pt Pertamina Ep

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***Abstract:***
*Zone 7 continues to decline. The achievement of gas production for PEP Zone 7 is only 94%. The gas balance shows that the gas supply from PEP Zone 7 cannot keep up with gas demand from consumers. PEP Zone 7, through the Subsurface Development Department, conducted a study on potential structures to increase gas production and supply capability. One of them is the Bumi Hitam Complex, consisting of the Bumi Hitam Structure and Cililin Selatan Structure. The estimated recoverable reserve is about 24 BSCF and 150 MBO. This comes from one workover, two infill well drilling, and two step-out drilling activities. The current issue is how to handle the produced fluid. The VFT (Value Focused Thinking) approach is used to resolve the problem. It generates three scenarios:*

- *Build a new gathering station and transport the fluid to compressor suction,*
- *Transport gross fluid to GS CLU,*
- *Build a new gathering station, and transport the fluid to compressor discharge.*

*Those scenarios consider cost, hydrocarbon recovery, net present value, and operability. Analytical Hierarchy Process (AHP) is used to find the best solution. Four subject matter experts (SMEs) conducted FGD (Focused Group Discussion) to assess each scenario considering those criteria. It generates a scenario to build a new gathering station and transport the fluid to compressor suction as the best scenario, with the value reaching 59.3%. The consistency ratio is also valid with the value of 0.07 (the valid value requirement is less than 0.1).*

***Keywords:*** *Gas field development, decision making, analytical hierarchy process*

## 1. Introduction

Pertamina EP (PEP) Zone 7, as the largest gas producer, is responsible for providing a certain amount of gas in accordance with technical specifications, including the agreed composition and pressure of the gas supplied. To meet the demand for natural gas, PEP Zone 7 undertakes field development efforts that have found resources that are considered to have the potential to be produced in a techno-economical manner. However, existing gas production in PEP Zone 7 continues to decline (Appendix-1). The achievement of gas production for PEP Zone 7 is only 94%.

In supporting the fulfillment of natural gas demand in the West Java area, Subsurface Department conducts a study and analysis of structures to be developed. One of the structures carried out by the study is the Bumi Hitam (BMH) Group structure, which consists of the adjacent BMH and Cililin Selatan (CLS) structures. Geographically, BMH is located ± 90 km from the city of Cirebon, West Java. In the northwest, it is bordered by North Cililin (CLU), East Cililin (CLT), and Bubulak Unggul (BBU) fields (Appendix-2). By volumetric calculation, the total in-place resources of the BMH and CLS structures are as follows.

| Structure | Layer | Volumetric Gas (MMSCF) | Volumetric Oil (MSTB) |
|---|---|---|---|
| BMH | ABC | 37,396.90 | |
| | FRB | 14,087.90 | |
| | FAT | | 28,058.00 |
| CLS | FRB | | 1,363.72 |
| | FRB -1 | | 1,176.73 |

*Table 1: Inplace Volumetric of BMH Kompleks*

Based on the table above, the largest gas volume is at the ABC Layer of the BMH Structure. Therefore, PEP Zone 7, through SSDP Department, plans the following work program.

| No | Well | Job Type | Target Rate | |
|---|---|---|---|---|
| | | | Qoi (BOPD) | Qgi (MMSCFD) |
| 1 | BMH-01 | Workover | | 4 |
| 2 | BMH-INF1 | Drilling | | 4 |
| 3 | CLS-INF | Drilling | 250 | |
| 4 | BMH-STOA | Drilling | | 2 |
| 5 | BMH-STOB | Drilling | | 2 |

*Table 2: Work Program of BMH Group Development*

The current concern is the handling of produced fluids. The closest production facility to the BMH structure is the Gathering Station (GS) of North Cililin (CLU), which is 17 kilometers (km) away. Near GS CLU, there is also a Gas Compression Station (GCS) Cilamaya to compress the gas so that the pressure is sufficient to reach the consumer. Therefore, it is necessary to consider the production fluid flow scenario technically and economically. The produced fluid can be directly sent on a gross basis to GS CLU. The produced fluid can also be processed first by building a new facility in the BMH area. Then the pure gas can be sent to the Cilamaya GCS. Produced fluid can also be flowed to the nearest network within 10 km. However, the network is a discharge from the Cilamaya GCS, so it is a high-pressure network.

## 2. Methods

The scenario of developing a gas field is not as easy as developing an oil field, wherein the development of a gas field, there must be adequate facilities for selling gas to consumers. Kepner-Tregoe (KT) Problem Analysis and fishbone diagram is used to understand the problem better. (Appendix 3 and Appendix 4)

The issue that arises from the planned development of the BMH structure is the location of the area, which is relatively far from the existing production facilities that are actively operating (Appendix 5). The Value Focused Thinking (VFT) framework is used to generate alternative solutions. Focused group discussions are conducted by involving several subject matter experts who have sufficient competence and experience to be able to produce the right decisions. The composition of the subject matter expert consists of the subsurface team, surface team, and development and planning team.

| Member | Position | Experience |
|---|---|---|
| Expert 1 | Sr. G&G Engineer | 11 years |
| Expert 2 | Sr. Reservoir Engineer | 11 years |
| Expert 3 | Sr. Project Engineering Engineer | 15 years |
| Expert 4 | Sr. Dev. & Planning Engineer | 15 years |

*Table 3: Subject Matter Experts*

Values are what we care about. Therefore, they must be the driving force for making our decision. Alternatives are simply means of achieving better value (Keeney, 1996). Value-Focused Thinking (VFT) is a way of thinking that focuses on the fundamental objectives of a decision maker. VFT starts with identifying the objectives, then criteria and/or sub-criteria identification, and finally, creating alternatives. From the discussion among the experts, Appendix-6 is an illustration of VFT to get alternatives.

Based on the VFT above, it has developed three scenarios (Appendix-7) to handle the produced fluid to commercialize BMH Structure.

- Scenario 1: New Gathering Station (GS) and transport to the suction of Gas Compression Station (GCS)
  A new facility is built in this scenario to process the produced fluid. The gas is flowed to the compressor suction in Cilamaya. The length of the gas pipeline required is about 17 km. Meanwhile, oil and water are pumped to Booster Cililin using a 17 km long liquid pipeline.
- Scenario 2: Transport gross
  In this scenario, there is no construction of new facilities in the BMH area. Instead, the produced gas is brought to the Cililin Gathering Station (GS) using a 23 km gas pipeline.
- Scenario 3: New Gathering Station (GS) and transport to the discharge of Gas Compression Station (GCS)
  This scenario is similar to scenario 1, except that the gas processed in the new GS will be channeled to the nearest gas pipeline at a distance of 10 km. However, that pipeline has a relatively high pressure because it is in the discharge position from the compressor.
  As stated in each scenario above, the criteria and sub-criteria are described as follows.

| Criteria/Sub-Criteria | Description |
|---|---|
| Cost | Sum of the cost needed to apply the alternative (capital and operating cost) |
| Capital Expenditure | Cost for investment such as purchasing material, fabricating, and commissioning |
| Operating Expenditure | Cost related alongside operating phase, such as maintenance, chemical consumption, operator salary, transportation, etc. |
| Benefit | The advantage that can be obtained |
| Hydrocarbon Recovery | The amount of cumulative hydrocarbon that can be produced from chosen alternative |
| Net Present Value | Cumulative cash flow over a period of time projected to the present considering the discount factor. |
| Risk in Operation | The potential danger that can occur at the chosen alternative |

*Table 4: Description of Criteria/Sub-Criteria*

After several alternatives are generated, the next step is to select the best alternative using Analytical Hierarchy Process (AHP). Thomas Saaty developed this method in the 1970s. AHP has been widely used in decision-making in several areas such as planning, economics, material handling, energy policy, project selection, and budget allocation (Goodwin & Wright, 2010).

*2.1. Step-1: Setting up the Decision Hierarchy*

The hierarchy design consists of goals, criteria, sub-criteria, and alternatives. (Appendix-8)

*2.2. Step-2: Making a Pairwise Comparison*

This step collects the data from subject matter experts (Table 3) regarding the relative importance rating from a criterion compared to another criterion and from an alternative to another based on the attributes. The importance rating is defined as follows.

| Importance | Rating |
|---|---|
| Equally important | 1 |
| Weakly more important | 3 |
| Strongly more important | 5 |
| Very strongly more important | 7 |
| Extremely more important | 9 |

*Table 5: Importance Rating*

The collected data from the experts are as follows.

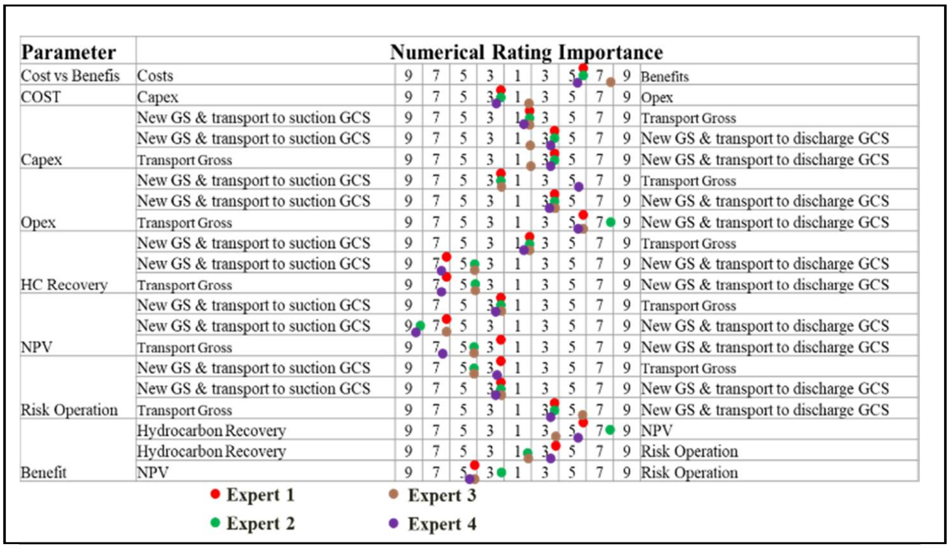


*Table 6: Collected Data for Pairwise Comparison*

Based on the data collected, as shown in Table 7, the next step is to process the data in every criteria/sub-criteria.

2.2.1. Cost versus Benefit

| Cost Vs. Benefits | Cost | Benefits |
|---|---|---|
| Cost | 1.000 | 0.184 |
| Benefits | 5.439 | 1.000 |
| Total | 6.439 | 1.184 |

*Table 7: Comparison of Cost versus Benefit*

From the data above, all experts agreed that benefits are more important than the cost.

2.2.2. Cost Criteria Analysis

| Capex VS Opex | Capex | Opex |
|---|---|---|
| Capex | 1.000 | 2.280 |
| Opex | 0.439 | 1.000 |
| TOTAL | 1.439 | 3.280 |

*Table 8: Comparison of Capex versus Opex*

Capex is considered more important than Opex. This is reasonable because the value of Capex is greater than Opex in this project.

2.2.3. Capex Analysis

| Capex attribute | New GS & transport to suction GCS | Transport Gross | New GS & transport to discharge GCS |
|---|---|---|---|
| New GS & transport to suction GCS | 1.000 | 1.000 | 0.439 |
| Transport Gross | 1.000 | 1.000 | 0.439 |
| New GS & transport to discharge GCS | 2.280 | 2.280 | 1.000 |
| Column Total | 4.280 | 4.280 | 1.877 |

*Table 9: Comparison in Capex*

Building a new gathering station in the BMH area and transporting the fluid to discharge of compressor is preferable.

2.2.4. Opex Analysis

| Opex attribute | New GS & transport to suction GCS | Transport Gross | New GS & transport to discharge GCS |
|---|---|---|---|
| New GS & transport to suction GCS | 1.000 | 1.524 | 0.333 |
| Transport Gross | 0.656 | 1.000 | 0.184 |
| New GS & transport to discharge GCS | 3.000 | 5.439 | 1.000 |
| Column Total | 4.656 | 7.963 | 1.517 |

*Table 10: Comparison in Opex*

Building new GS & transport to discharge GCS is preferable based on operating cost criteria. Therefore, that alternative gave the cheapest operating cost.

2.2.5. Benefit Criteria Analysis

| | Hydrocarbon Recovery | NPV | Risk Operation |
|---|---|---|---|
| Hydrocarbon Recovery | 1.000 | 0.209 | 0.577 |
| NPV | 4.787 | 1.000 | 4.401 |
| Risk Operation | 1.732 | 0.227 | 1.000 |
| Column Total | 7.519 | 1.436 | 5.978 |

*Table 11: Comparison of Benefit criteria*

NPV is considered the most important attribute compared to other attributes.

2.2.6. Hydrocarbon Recovery Analysis

| | New GS & Transport to Suction GCS | Transport Gross | New GS & Transport to Discharge GCS |
|---|---|---|---|
| New GS & transport to suction GCS | 1.000 | 1.000 | 5.916 |
| Transport Gross | 1.000 | 1.000 | 5.916 |
| New GS & transport to discharge GCS | 0.169 | 0.169 | 1.000 |
| Column Total | 2.169 | 2.169 | 12.832 |

*Table 12: Comparison of HC Recovery*

Scenario 3 is: it resulted in the lowest hydrocarbon recovery.

2.2.7. NPV Analysis

| | New GS & Transport to Suction GCS | Transport Gross | New GS & Transport to Discharge GCS |
|---|---|---|---|
| New GS & transport to suction GCS | 1.000 | 3.000 | 7.937 |
| Transport Gross | 0.333 | 1.000 | 5.439 |
| New GS & transport to discharge GCS | 0.126 | 0.184 | 1.000 |
| Column Total | 1.459 | 4.184 | 14.376 |

*Table 13: Comparison of NPV*

Scenario to build new GS & transport to suction GCS gives the highest NPV. So, all the experts agreed that that scenario is preferable to the others.

2.2.8. Risk Operation Analysis

| | New GS & Transport to Suction GCS | Transport Gross | New GS & transport to discharge GCS |
|---|---|---|---|
| New GS & transport to suction GCS | 1.000 | 3.873 | 3.000 |
| Transport Gross | 0.258 | 1.000 | 0.293 |
| New GS & transport to discharge GCS | 0.333 | 3.409 | 1.000 |
| Column Total | 1.592 | 8.282 | 4.293 |

*Table 14: Comparison of Risk Operation*

All experts agreed that the scenario of building new GS & transport to suction GCS is preferable.

**3. Synthesize the Result**

The third AHP step contains data processing from comparison to weighing by making a matrix of comparison, representing it as a relative priority vector or Eigen Vector, and then checking the Consistency Ratio (CR). The stages in this step are:

- Step A: Multiplying the Eigen Vector and the importance rating in each criterion and alternative.
- Step B: Dividing the result in Step A by the Eigen Vector in each row.
- Step C: Calculate the average value in step B as $\lambda$ max.
- Step D: Calculate the consistency index.

$$CI = \frac{\lambda \max - n}{n - 1}$$

n is the number of items compared

- Step E: Calculate the Consistency Ratio

$$CR = \frac{CI}{RI}$$

| 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 |

When CR is less than or equal to 0.1, then it is acceptable.

| Attribute | Consistency Ratio |
|---|---|
| Cost versus Benefit | - |
| Cost | - |
| Benefits | 0.021 |
| Capex | 0.000 |
| Opex | 0.003 |
| HC Recovery | 0.000 |
| NPV | 0.050 |
| Risk Operation | 0.092 |

*Table 15: Recap of Consistency Ratio*

The CR of all attributes is less than 0.1. So, the analysis of the consistency ratio showed that experts' judgment has already been consistent. Therefore, the process of AHP can continue to the next step, determining the priority ranking. The chart in Appendix 9 describes the hierarchy tree of weighed of all criteria/ sub-criteria and alternatives.

Each value of the Eigen Vector of each scenario is multiplied by the value of the normalized weight of a sub-criteria. The result is as follows.

| Criteria | | | Sub-Criteria | | | | Alternatives | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | New GS & transport to suction GCS | | Transport Gross | | New GS & transport to discharge GCS | |
| | Weigh | CR | | Weigh | Normalized | CR | Weigh | Normalized | Weigh | Normalized | Weigh | Normalized |
| Cost | 0.155 | - | Capex | 0.695 | 0.108 | 0.000 | 0.234 | 0.025 | 0.234 | 0.025 | 0.533 | 0.058 |
| | | | Opex | 0.305 | 0.047 | 0.003 | 0.209 | 0.010 | 0.129 | 0.006 | 0.662 | 0.031 |
| Benefits | 0.845 | 0.021 | HC Recovery | 0.125 | 0.106 | 0.000 | 0.461 | 0.049 | 0.461 | 0.049 | 0.078 | 0.008 |
| | | | NPV | 0.690 | 0.583 | 0.050 | 0.651 | 0.380 | 0.282 | 0.164 | 0.067 | 0.039 |
| | | | Risk Operation | 0.185 | 0.157 | 0.092 | 0.598 | 0.094 | 0.117 | 0.018 | 0.285 | 0.045 |
| | | | | | | | | 0.557 | | 0.263 | | 0.180 |

*Table 16: Priority Ranking*

The normalized value in each alternative is summarized. The biggest value is 0.557 with a new GS construction scenario and gas transport to the suction of GCS. The second rank is transporting gross right away to Cililin Gathering Station with the value of 0.263. Finally, the least priority with the value of 0.180 is building a new gathering station and transporting gas to the discharge of GCS.

## 4. Conclusion

By using the fishbone diagram tool and discussion among experts, there are several possible root causes from the Method, Tool, Man, and Environment aspects.

- Method: The scenario to handle the produced fluid is not defined yet.
- Tool: License number of software to design surface facilities is limited
- Man: Employee placement is unbalanced after the new reorganization.
- Environment: The area of BMH is relatively far from nearby facilities.

The true controllable cause of the problem is that the scenario to handle the produced fluid is not defined yet.

What distinguishes one solution from another can be seen from the criteria/sub-criteria used. The summary of the criteria/ sub-criteria for each alternative is as follows.

| Criteria | Scenario 1 | Scenario 2 | Scenario 3 | Weigh |
|---|---|---|---|---|
| Capex | USD 35.82 Million | USD 35.19 Million | USD 34.07 Million | 0.108 |
| Opex | USD 19.6 Million | USD 23 Million | USD 15.65 Million | 0.047 |
| HC Recovery | 23.5 BSCF | 23.5 BSCF | 18.83 BSCF | 0.106 |
| NPV | USD 15.85 Million | USD 14.82 Million | USD 9.99 Million | 0.583 |
| Risk Operation | Low to Medium | Medium to High | Medium | 0.157 |

*Table 17: Result Summary*

Based on the data processing results on the AHP, the best alternative for handling the produced fluid from BMH is to build a new gathering station in the BMH area and transport the gas to the suction of the gas compression station. The preference result is 55.7%.

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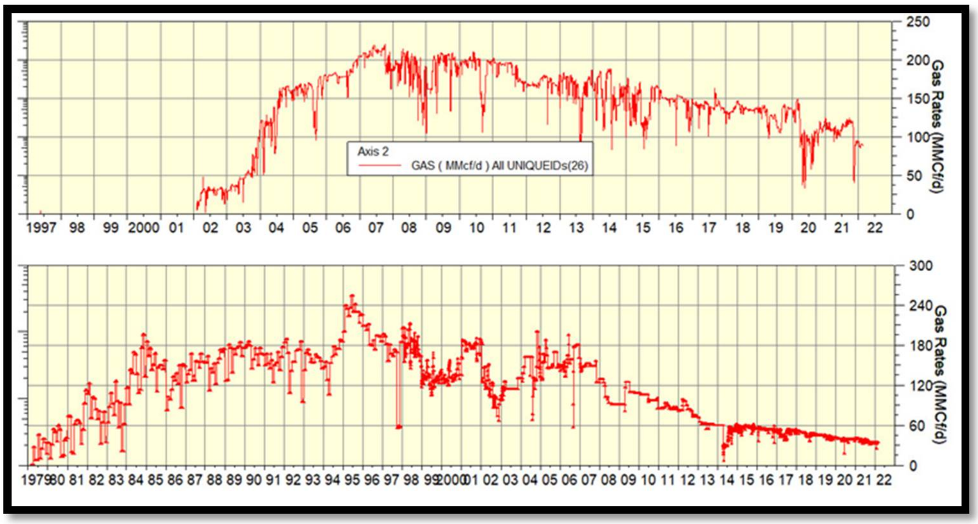
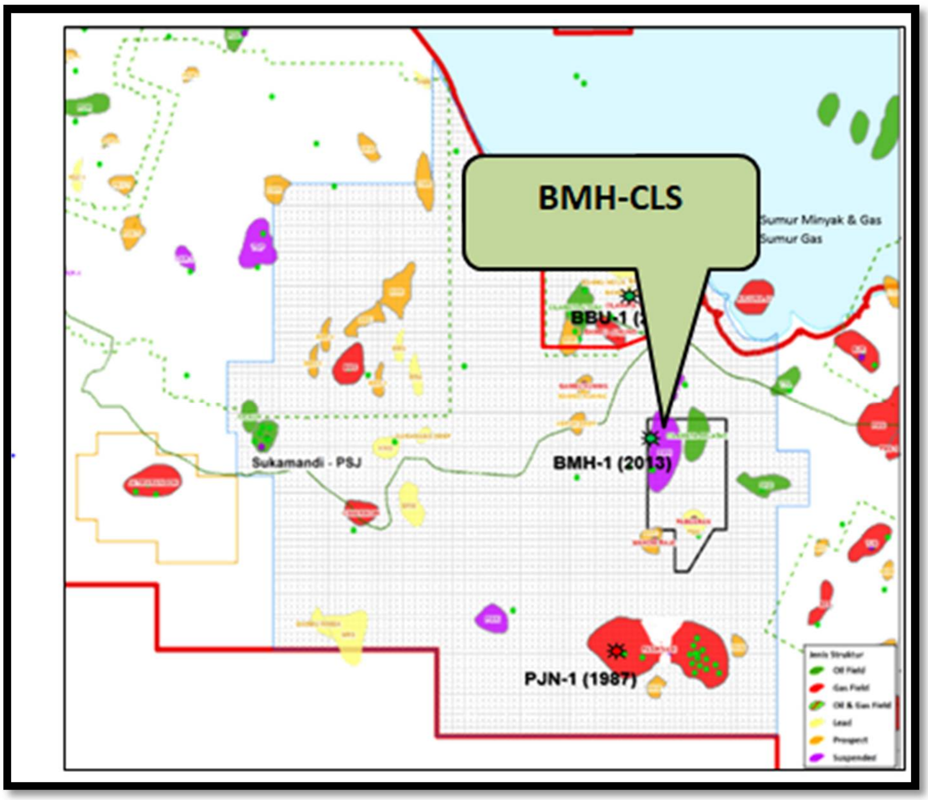
## Appendices



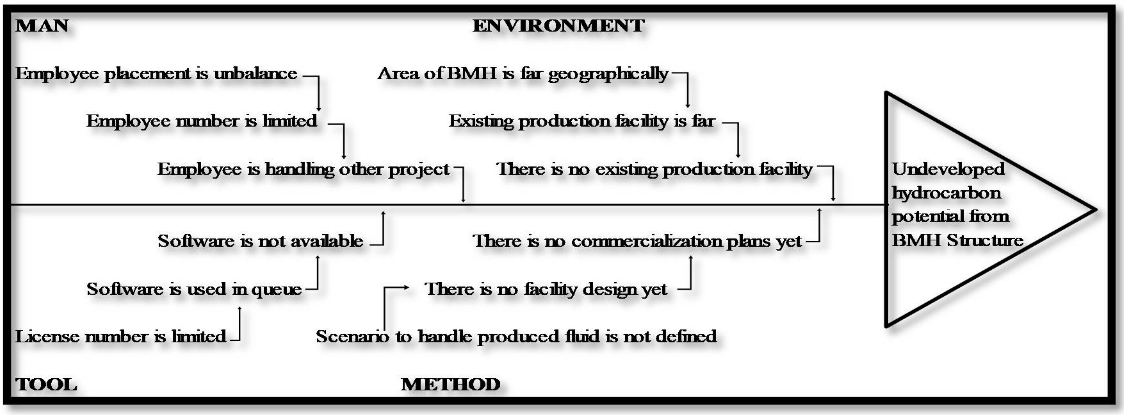

*Appendix 1: Existing Gas Production in PEP Zone 7*



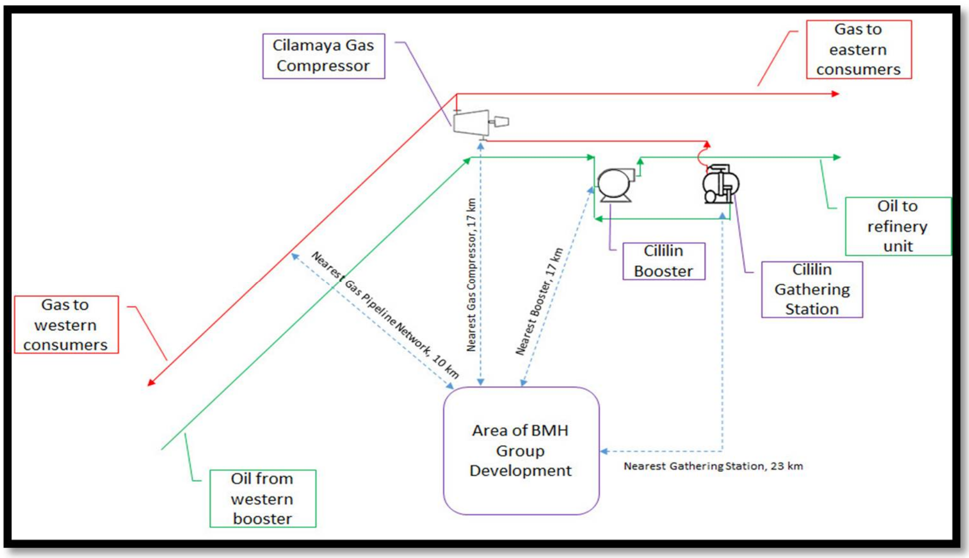

*Appendix 2: Location of Bumi Hitam and Cililin Selatan Structure*

| Problem Statement: Undeveloped Hydrocarbon Potential from BMH Structure | | | | |
|---|---|---|---|---|
| **Specification** | **Is** | **Is Not** | **Distinction** | **Changes** |
| What Object | New Structure that has the potential amount of hydrocarbon | New Structure that does not have the potential amount of hydrocarbon | Gas volume in place and gas reserve | The volume of hydrocarbon is good but not as big as Subang or L-Parigi |
| What deviation | The scenario to handle the produced fluid is not defined yet | The scenario to handle the produced fluid is defined yet | Still in progress to define the best scenario | Distance to the nearby facility is relatively far |
| Where | BMH Structure | Other structure than BMH | Other structure with bigger potential is prioritized | Employee placement is unbalanced |
| When | Before development phase | After development phase | Production activity within the phase | The development phase has production activity |
| Extent | Achievement of gas production target of Pertamina EP | Achievement of gas production target other than Pertamina EP | Gas deliverability of each subsidiary of Pertamina Upstream Sub-holding | Gas deliverability of Pertamina EP Zone 7 cannot meet the target |

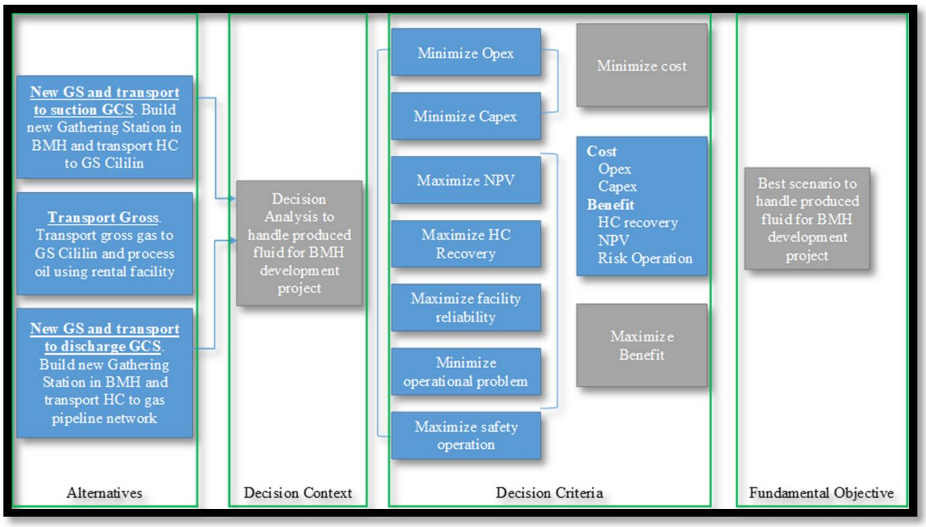
*Appendix 3: KT Problem Analysis Worksheet*



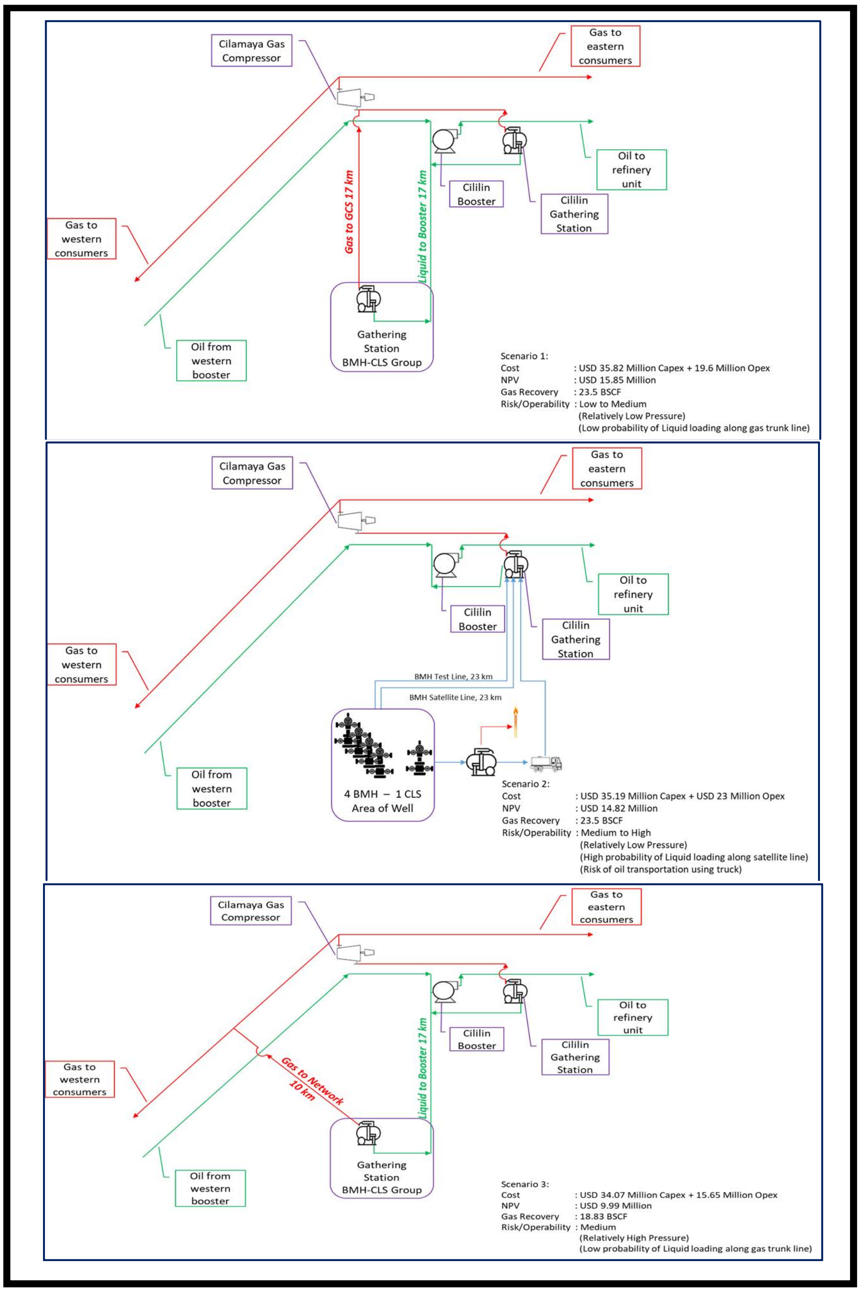

*Appendix 4: Fishbone Diagram*



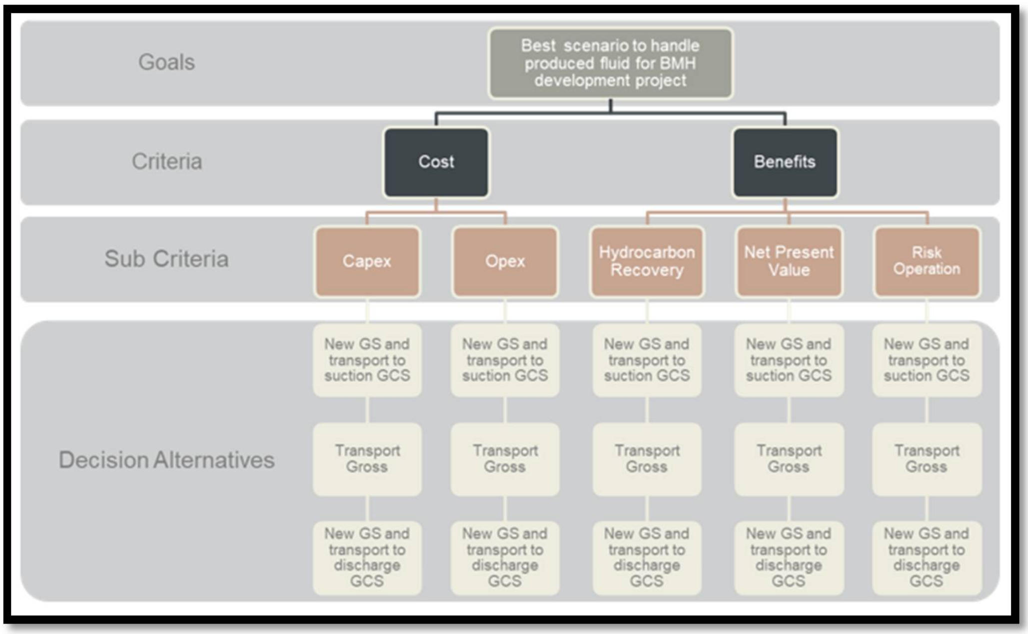

*Appendix 5: Illustration of Nearby Facilities*




*Appendix 6: Value-Focused Thinking (VFT) Process of BMH Development Scenario*




*Appendix 7: Three Scenarios to Develop BMH Structure*




*Appendix 8: Hierarchy Design*

| The Best Scenario to Develop BMH Group Structure | | | | |
|---|---|---|---|---|
| Cost 0.155 | | Benefit 0.845 | | |
| Capex 0.695 | Opex 0.305 | HC Recovery 0.125 | NPV 0.690 | Risk Operation 0.185 |
| New GS & transport to suction GCS 0.234 | New GS & transport to suction GCS 0.209 | New GS & transport to suction GCS 0.461 | New GS & transport to suction GCS 0.651 | New GS & transport to suction GCS 0.598 |
| Transport Gross 0.234 | Transport Gross 0.129 | Transport Gross 0.461 | Transport Gross 0.282 | Transport Gross 0.117 |
| New GS & transport to discharge GCS 0.533 | New GS & transport to discharge GCS 0.662 | New GS & transport to discharge GCS 0.078 | New GS & transport to discharge GCS 0.067 | New GS & transport to discharge GCS 0.285 |

*Appendix 9: Hierarchy Tree of Weighed of All Criteria/Sub-Criteria and Alternatives*