Improving The Operation & Maintenance Performance of BDG CO2 Removal Plant Using Multi-Criteria Decision-Making Approach

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ABSTRACT

BDG CO2 removal plant, serving as a gas purification facility, is one of the backbones for Pertamina EP Zone 7. Finding the best operation and maintenance (O&M) strategy is challenging due to the numerous factors that must be considered and the alternative solutions themselves which are not readily available at that point.

This final project aims to propose a strategy to improve the O&M performance by finding the best alternative of O&M method by implementing a multi-criteria decision-making (MCDM) approach. Experts and decision makers are involved for identification of important factors, gathering ideas and opportunities. Alternatives are generated by implementing value-focused thinking (VFT) to ensure a structured and objective decision-making process that prioritizes values and fundamental objectives.

The VFT resulting in 3 potential alternatives, namely Full-Coverage Service Contract with enhancement on maintenance, Full-Coverage Service Contract with enhancement on plant optimization and Full-Coverage Service Contract with enhancement on CO2 quality. The AHP method is applied to assess these alternatives based on criteria generated from semi-structured interview with decision makers and FGD with experts, these criteria are O&M Cost, Performance, Revenue and Compliance. The analysis reveals that Full-Coverage Service Contract with enhancement on plant optimization is the most appropriate solution.

INTRODUCTION

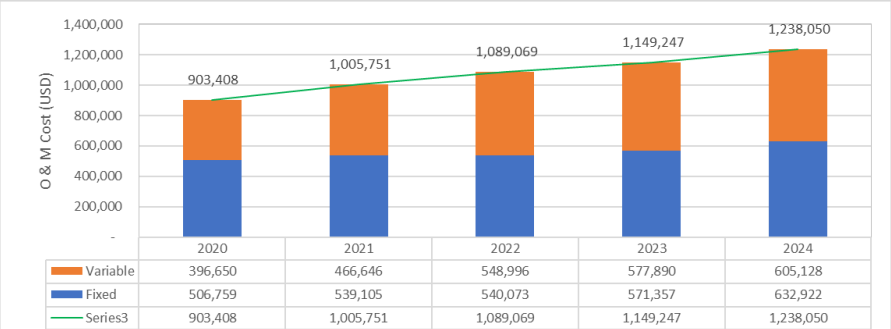
Built in 2003, Bandung (BDG) carbon dioxide (CO2) removal plant is one of the main facilities at Pertamina EP Zone 7, serving as a gas purification facility for BDG structure. It has two trains, with capacity of each train reaching 100 MMSCFD of natural gas. Gas from BDG structure is gas with rich CO2 content of ± 23%, which makes the CO2 removal plant mandatory for gas purification. Currently, 85 MMSCFD of natural gas from the BDG structure is being fed to both trains resulting in 69 MMSCFD of sweet gas and 200 barrels of condensate per day (BCPD). The following is a simplified flow diagram of the CO2 removal plant facility.

Currently, the operation and maintenance (O&M) of BDG CO2 removal plant is carried out by an O&M contractor with Full-Coverage Service Contract. It means that the contractor responsible to maintain operational continuity and reliability of equipment at BDG CO2 removal plant, so that the Plant can operate properly, in accordance with the required process parameters, reliable and safe in accordance with HSSE provisions.

The performance of O&M in BDG CO2 removal plant can be evaluated using two main parameters, they are:

1. Plant availability (PA) refers to the degree to which a facility is in the state of performing as its intended function (target 98%)

2. CO2 content refers to carbon dioxide contained in natural gas which can be measured using an analyzer located at the outlet of the CO2 removal plant. This plant is designed to reduce the CO2 content in natural gas from ± 23% to below 5%.



	2020	2021	2022	2023	2024
Variable	396,650	466,646	548,996	577,890	605,128
Fixed	506,759	539,105	540,073	571,357	632,922
Series3	903,408	1,005,751	1,089,069	1,149,247	1,238,050

Figure 1. Operating cost of BDG CO2 removal plant.

Currently, the condition of BDG CO2 removal plant is relatively good (decent performance), which the plant can reduce the CO2 content from 23% to below 5% (4.32%, in average) with the plant availability maintained above 98% (99.19% in average). Even so, the O&M method, which is currently conducted by contractors lead to several issues, namely: high operating cost, process inefficiency, intellectual knowledge loss and targets are usually short term.

H1 : What are the key factors to improve the O&M performance of BDG CO2 removal plant

H2 : How to improve the O&M performance of BDG CO2 removal plant

H3 : What is the best alternative to improve the O&M performance of BDG CO2 removal plant

RESEARCH METHOD

The research method contains the research design/ type of research, research object, operational definition of research variables and measurements,

The purpose of this study is to propose a strategy to improve the O&M performance by finding the best alternative of O&M method. Here is the research design that will guide the author to answer the research questions.

Figure 2. Research design

To answer the first research question, data obtained from semi-structured interviews was processed using FGD with experts to determine criteria/ sub-criteria. Then, to obtain key factors, weight of criteria / sub-criteria needs to be identified using pairwise comparison with decision makers through a survey.

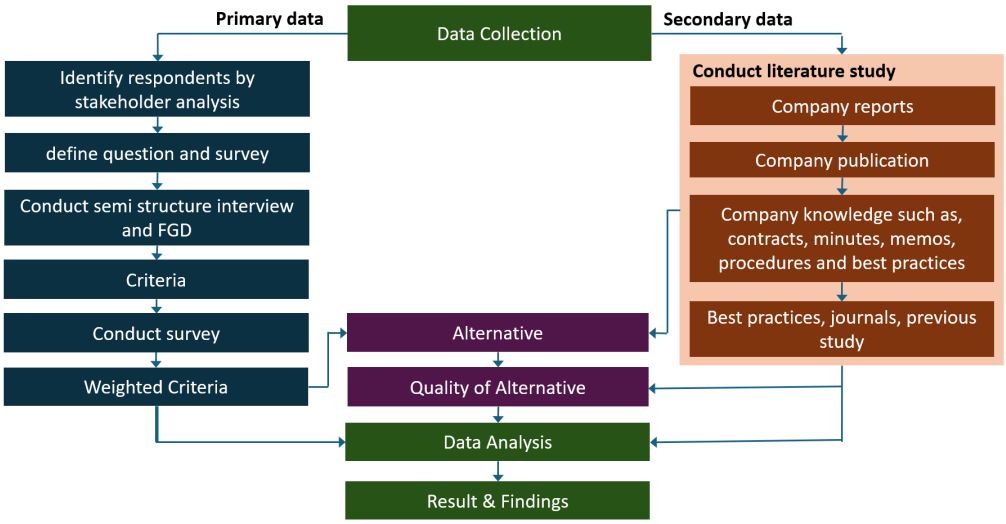


Figure 3. Primary and secondary data collection methods

To answer the second research question, data collected also from semi structured interviews supported with literature study and VFT to develop alternatives to improve O&M performance. While, to answer the third research question, data from literature study, combined with the answer of first research question are processed to determine the quality of alternatives, then implement consistency check continued by AHP approach to determine the best alternative.

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Table 1. Identification of stakeholder's role

Respondent	Reason
GM	As General Manager of Pertamina EP Zone 7, he has a strategic interest in improving the O&M performance of the plant
SM P&P	As Senior Manager at Production & Project Department, he has full control over the choice of action
SM Subang	As Senior Manager of Subang Field where the plant is located, who will be impacted by the consequence of using the solution
RAM Ast. Man.	As subordinate of SM Subang Field, who is responsible to manage maintenance department
PO Ast. Man.	As subordinate of SM Subang Field, who is responsible to manage operation department
OSF Man.	As manager of Operation & Surface Facilities Department, who analyzes the plant to improve its performance and develop a solution
Pertagas GM	As leader of Pertagas, one of the consumers which receive the gas the plant
O&M Contractor	As the existing contactor who runs O&M activity in the plant and executes the decisions
SKK Migas	As supervisory body (government) responsible in carrying out management of upstream oil and gas business

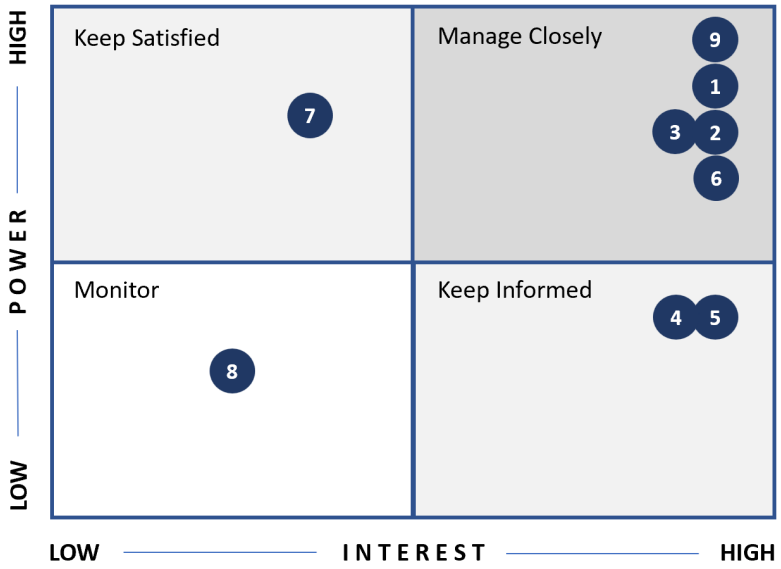

Figure 4. Stakeholder analysis using power interest grid.

The primary data collection starts by identifying respondents using stakeholder analysis. The appropriate respondents are the stakeholders that have high interest regarding the issue of O&M performance of BDG CO2 removal plant. Then to capture different perspectives, the author will increase the diversity of respondents by adding experts from the department identified before in the stakeholder analysis as additional respondents.

Table 2. Respondent for primary data collection method

Respondent	Interview	FGD	Survey
GM	Yes	No	Yes
SM P&P	Yes	No	Yes
SM Subang	Yes	No	Yes
RAM Ast. Man.	Yes	Yes	No
PO Ast. Man.	Yes	Yes	No
OSF Man.	Yes	No	Yes
RAM Staff (additional)	Yes	Yes	No
PO Staff (additional)	Yes	Yes	No
SKK Migas	Yes	No	Yes
OSF Staff	Yes	Yes	No

For qualitative study, the author will conduct semi-structured interviews by employing the questions to all the respondents separately and FGD with experts from company internals to identify the criteria / sub criteria.

Table 3. Question list for qualitative study

No	Question	Respondent
1	How do you think the O&M of BDG CO_2 removal plant currently performs? Any challenges?	All
2	How is maintenance currently scheduled and prioritized at the plant? What improvements can be made to increase reliability availability and minimize downtime of the plant?	4,5,7,8,10

3	What improvements can be made to enhance safety and compliance in the plant?	4,5,7,8,10
4	Do you feel that resources (labor, budget, equipment material) are optimally allocated for O&M? What improvements can be made to optimize the performance and efficiency of the plant?	4,5,7,8,10
5	What improvements can be made to extend the asset lifespan in the plant?	4,5,7,8,10
6	What improvements can be made to minimize operation costs of the plant?	4,5,7,8,10
7	What improvements can be made to support sustainability and environmental goals of the plant?	4,5,7,8,10
8	What important factor affects the decision to select O&M method?	1,2,3,6,9
9	How does the O&M contractor perform in terms of procurement and spare part management?	4,5,7,8,10
10	How do you think of the current communication and coordination with the O&M contractor? How about data security?	4,5,7,8,10
11	What are your hopes for O&M of BDG CO_2 removal plant in the future?	1,2,3,6,9

While, to obtain weighted criteria, the author will conduct a survey by giving them questionnaires to measure the importance of each criterion. The respondents must do pairwise comparison which criterion compared in pair to evaluate the most preferred. Let assume there will be four criteria in the same level of the hierarchy, the pairwise comparison of the criteria will be as shown below.

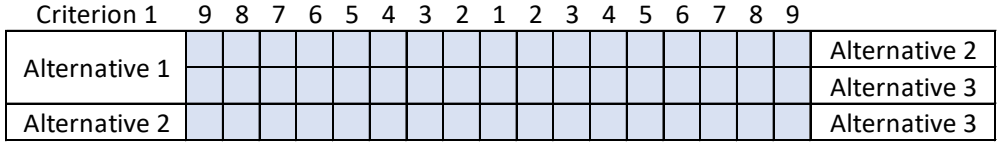

Figure 5. Pairwise comparison of three alternatives to criterion 1

To obtain quality of each alternative, the author conducts a quantitative study to measure the quality of each alternative at each criterion supported with literature study from reports, company knowledge, best practices and journals. Then, conduct a pairwise comparison in which the alternatives are compared in pairs to evaluate their quality relative to others.

The secondary data collection in this research was obtained from literature study. The author uses previous research by Saputra (2022) which uses extended project constraint from Project Management Institute (2017) as the basis to determining criteria. While, to develop alternatives, the author uses publication of PECI (1997) as the basis to be combined with VFT later.

Data Analysis Method

Alternatives are potential choices to achieve the fundamental objectives. According to PECI (1997) there are 4 O&M methods used in industry, they are: Full-Coverage Service Contract, Full-Labor Service Contract, Preventive-Maintenance Service Contract and Inspection Service Contract. However, in this research the author does not immediately use these four types of contracts as alternatives but rather use VFT to focus on values to develop better alternatives.

Criteria are the factors or standards used to measure and evaluate alternatives. In this research, there are two mandatory criteria which are O&M cost and performance, the other criteria obtained from semi-structured interview with decision makers supported with FGD with experts of company internal.

The weight of criteria obtained from quantitative study using a questionnaire to apply pairwise comparison to each criterion identified before. The purpose of this comparison is to evaluate the

importance of a criterion compared to others. The weight of criteria obtained by calculating geometric means of survey results from all respondents.

Finally, AHP is implemented to obtain the best alternative to improve the O&M performance of BDG CO2 removal plant. Weighted sum of the alternatives calculated by multiplying weighted criteria with quality of alternatives. The alternative with the highest total sum of weighted aggregate value is the best alternative.

RESULTS AND DISCUSSION

This chapter contains the findings of the research and in-depth discussions in which the primary and secondary data are analyzed and processed to answer the research questions.

Analysis

Decision Makers Identification. Decision makers are the stakeholders with high power and interest, located on the upper right quadrant of the grid in stakeholder analysis mentioned in Fig. 7. There are five decision makers identified in this research, they are General Manager, Senior Manager Production & Project, Senior Manager Subang Field, Manager, Operation & Surface Facilities Manager and SKK Migas.

Fundamental and Mean Objective Identification. With the research objective to propose a strategy to improve the O&M performance by finding the best alternative of O&M method in BDG CO2 removal plant, first, the author needs to determine the fundamental objective of decision context. Based on:

1. Pertamina EP vision to become an exploration company and world class oil and gas production which can be achieved by conducting upstream oil and gas sector activities to provide added value to stakeholders through superior and commercially oriented operation by emphasizing health, safety, security, and environmental (HSSE) aspect, including in O&M activity and
2. Business issue, which there is gap between current condition and ideal condition in the performance of BDG CO2 removal plant O&M.

The fundamental objective is to improve the O&M performance of BDG CO2 removal plant by improving operational continuity and reliability of equipment at the plant, so that the plant can operate properly, in accordance with the required process parameters, reliable and safe in accordance with HSSE provisions. The fundamental objective can be achieved by:

1. Improve reliability and availability of the plant to operate properly with minimal downtime. The availability of the plant must be above 98%.
2. Improve performance and efficiency to reduce the CO2 content to below 5%, while minimizing operating and maintenance cost, including resource such as, material, fuel, labor, consumable and chemical.
3. Enhance safety and compliance by maintaining operational safety that comply to regulatory, environmental, and industry standards.
4. Extend asset lifespan by operating the plant by considering the long-term asset life and implement preventive and predictive maintenance to reduce premature equipment failure.
5. Support sustainability and environmental goals by reducing energy consumption, emissions, and waste released to the environment.

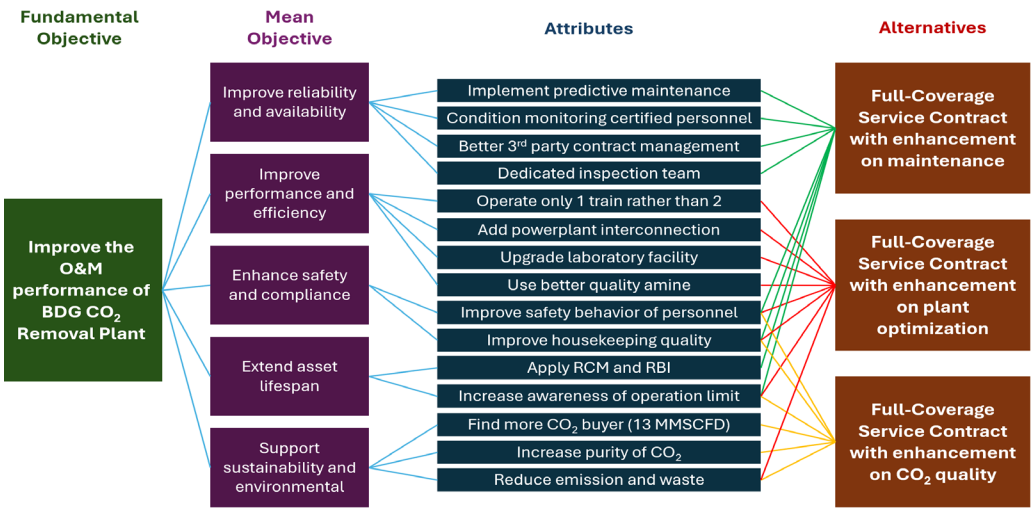

Figure 6. VFT map to generate alternatives.

Value-Focused Thinking Implementation. After fundamental and mean objectives have been identified, alternatives generated by first gathering information about how to achieve the mean objectives through semi-structured interview. The respondents are experts in their field which they work directly to supervise O&M every day, they are: Subang RAM Assistant Manager, Subang RAM Staff, Subang PO Assistant Manager, Subang PO Staff and OSF Staff. The data obtained then processed using VFT to generate alternatives.

From the VFT map shown above, the fundamental objective is to improve the O&M performance of BDG CO2 removal plant which can be achieved by improving reliability and availability, improving performance and efficiency, enhancing safety and compliance, extending asset lifespan and supporting environmental sustainability, resulting in alternatives which is the answers to the second research question as summarized in the table below.

Table 4. Alternatives generated from VFT.

Alternative	Description
Full-Coverage Service Contract with enhancement on maintenance	The contractor's scope of work is the same as the existing O&M contract, but with addition: a. The contractor must implement RCM and RBI with condition monitoring certified dedicated team and apply predictive maintenance to critical equipment in the plant. b. The contractor must actively coordinate with third party contractor to make sure the maintenance can be executed as scheduled. c. The contractor must improve the safety behavior of personnel, competence in terms of maintenance and improve the quality of housekeeping in the plant area through upskilling and socialization.
Full-Coverage Service Contract with enhancement on plant optimization	The contractor's scope of work is the same as the existing O&M contract, but with addition: a. The contractor must optimize the resources (labor, budget, equipment, material) in the plant by optimizing train and equipment used in the plant which leads to emission and waste reduction. b. The contractor must optimize power utilization through centralization of powerplant by integrating the powerplant with

	BDG Gathering Station (GS) and enhance the maintenance program on critical equipment to ensure its performance to support plant optimization. c. The contractor must upgrade the laboratory facility for better and faster analysis. Also find better amine solution (chemical for CO_2 absorption) so it can perform better with minimum make up. d. The contractor must improve the safety behavior of personnel, competence of their personnel in terms of process optimization and improve the quality of housekeeping in the plant area through upskilling and socialization.
Full-Coverage Service Contract with enhancement on CO_2 quality	The contractor's scope of work is the same as the existing O&M contract, but with addition: a. The contractor must improve the purity of CO_2 extracted to meet food grade specification, so it can be sold to the buyer. b. The contractor must improve the safety behavior of personnel, competence of their personnel in terms of process optimization and improve the quality of housekeeping in the plant area through upskilling and socialization.

In this research, there are two types of criteria / sub-criteria. Mandatory criteria / sub-criteria are essential criteria / sub-criteria need to be included in this research, namely: O&M cost and performance. While desirable criteria / sub-criteria are additional criteria / sub-criteria wanted by decision makers obtained from semi-structure interview and FGD, namely: revenue and compliance. Here are the explanations of the criteria / sub-criteria:

1. O&M Cost, refers to the cost incurred by O&M activities in BDG CO2 removal plant annually, it includes fixed and variable cost.
2. Performance, refers to the ability of O&M to operate BDG CO2 removal plant to reduce CO2 content to below 5% and maintain the plant availability above 98%.
3. Revenue, refers to additional revenue generated by operating activities due to improvements in O&M, such as additional revenue from CO2 or gas sales increase.
4. Compliance, refers to how the improvements in O&M enhance compliance with the rules and regulations of health, safety, and environment.

Analytical Hierarchy Process Implementation. Here, the hierarchy structure is generated using the criteria / sub-criteria identified in previous section. This structure shows the correlation between objective, criteria / sub-criteria, and alternatives hierarchically as shown above. As can be seen the performance, revenue and compliance sub-criteria are under the quality criteria.

Table 5. Overall Weight of Criteria / Sub-criteria

	O&M Cost	Performance	Revenue	Compliance
Weight	0.205	0.257	0.088	0.450

The weight of criteria / sub-criteria obtained by applying pairwise comparison based on hierarchy structure on Figure 10. Here the Cost is compared to Quality, while Performance, Revenue and Compliance are compared each other. The result of pairwise comparison from decision makers then averaged to find the overall value using geometric means. The weighting result is shown below represents the degree of importance or influence in a decision-making process. This is the answer to the first research question.

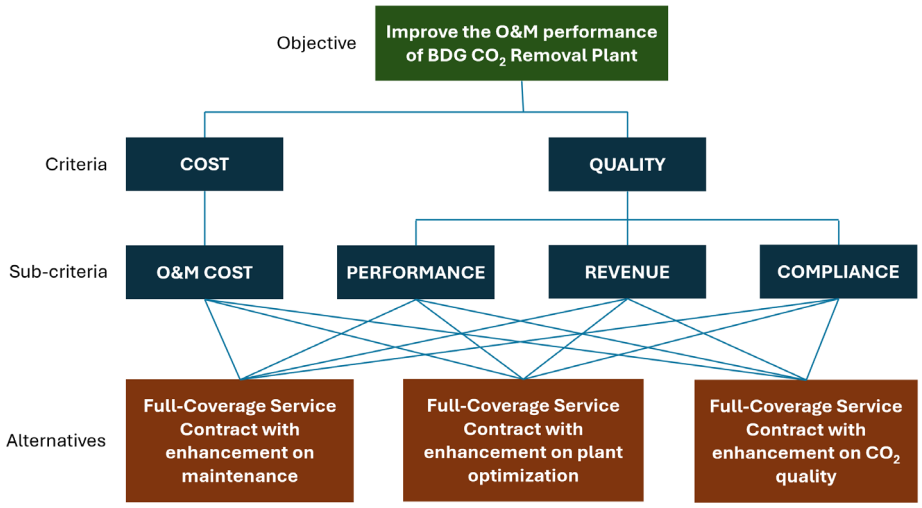

Figure 7. Hierarchy structure of decision context

Quality of Alternatives Evaluation. Here, the alternatives are evaluated to measure how well each alternative satisfies the criteria set for decision-making. The evaluation was carried out by conducting a quantitative study supported by reference to literature such as reports, company knowledge, best practices and journals. The result of quality of alternatives evaluation is shown in the table below.

Table 6. Quality of Alternatives Evaluation

Alternative	Improvement	O&M Cost (US$/year)	Performance (%)	Revenue (US$/year)	Compliance
Full-Coverage Service Contract with enhancement on maintenance	Implement RCM and RBI with condition monitoring certified dedicated team and apply predictive maintenance to critical equipment in the plant.	210,476	Increased equipment availability		
	Actively coordinate with third party contractor to make sure the maintenance can be executed as scheduled.	26,444	Improved maintenance execution		
	Improve the safety behavior of personnel, competence in terms of maintenance and improve the quality of housekeeping in the plant area through upskilling and socialization.	41,106			Increase safety and health behavior
Total Alternative 1 Full-Coverage Service Contract with enhancement on maintenance (Maintenance)		278,026	PA: 99.99% CO_2 Content: 4.50%	-	Increased safety and health compliance
Full-Coverage Service Contract with enhancement on plant optimization	Optimize the resources (labor, budget, equipment, material) in the plant by optimizing train and equipment used in the plant which leads to fuel saving, emission and waste reduction.	-365,856	Increased equipment availability	159,651	Reduce engine exhaust gas and maintenance waste
	The contractor must optimize power utilization through centralization of powerplant by integrating the powerplant with BDG GS and enhance the maintenance program on critical equipment to ensure its performance to support plant optimization.	104,607	Increased equipment availability	461,214	Reduce engine exhaust gas and maintenance waste

	Upgrade the laboratory facility for better and faster analysis. Also find better amine solution (chemical for CO_2 absorption) so it can perform better with minimum make up.	71,125	Better CO_2 absorption		
	Improve the safety behavior of personnel, competence of their personnel in terms of process optimization and improve the quality of housekeeping in the plant area through upskilling and socialization.	41,106			Increase safety and health behavior
Total Alternative 2 Full-Coverage Service Contract with enhancement on plant optimization (Optimization)		-149,019	PA: 99.89% CO_2 Content: 3.50%	620,865	Increased safety, health and slightly environment compliance
Full-Coverage Service Contract with enhancement on CO_2 quality	Improve the purity of CO_2 extracted to meet food grade specification, so it can be sold to the buyer.	618,867	Better CO_2 absorption and purity	1,031,444	Eliminate CO_2 emission to environment
	Improve the safety behavior of personnel, competence of their personnel in terms of process optimization and improve the quality of housekeeping in the plant area through upskilling and socialization.	41,106			Increase safety and health behavior
Total Alternative 3 Full-Coverage Service Contract with enhancement on CO_2 quality (CO_2 Quality)		659,972	PA: 99.61% CO_2 Content: 2.00%	1,031,444	Increased safety, health and environment compliance

Then, the results from the evaluation in Table VI are plotted to pairwise comparison as shown above. It is necessary to check the consistency of pairwise comparisons before going any further. The calculation shows that the CR are 0.038, 0.025, 0.016 and 0.025. Next, the pairwise comparisons are processed using matrix operation to calculate the weight (quality of alternatives). The detailed calculation is described in Appendix.

Table 7. The Result of Quality of Alternatives

	O&M Cost	Performance	Revenue	Compliance
Maintenance	0.186	0.575	0.065	0.082
Optimization	0.737	0.343	0.341	0.343
CO_2 Quality	0.077	0.082	0.593	0.575
	1.000	1.000	1.000	1.000

Weighted Aggregate Value Calculation. The best alternative is alternative with the highest weighted aggregate value. Weighted aggregate value can be obtained by multiplying weight of criteria / sub-criteria with quality of alternatives.

$$\begin{vmatrix} 0.186 & 0.575 & 0.065 & 0.082 \\ 0.737 & 0.343 & 0.341 & 0.343 \\ 0.077 & 0.082 & 0.593 & 0.575 \end{vmatrix} \text{ x } \begin{Vmatrix} 0.205 \\ 0.257 \\ 0.088 \\ 0.450 \end{Vmatrix}$$

Resulting

Table 8. Weighted Aggregate Value

	Maintenance	Optimization	CO_2 Quality
Weighted Aggregate Value	0.229	0.424	0.348

From the calculation above, the highest value is obtained by Optimization alternative with a value of 0.424, followed by CO2 Quality alternative in the second place with a value of 0.348 and Maintenance alternative in the third place with a value of 0.229. This is the answer to the third research question.

In this research, the sensitivity analysis is performed by changing one variable at a time, they are the weight of O&M Cost, Performance, Revenue and Compliance, to observe the stability of the solution and identify which inputs have the most significant impact on the outcome. Sensitivity analysis is calculated using an excel spreadsheet by changing one variable to zero while keeping others constant. The detailed calculation is described in Appendix.

Table 9. Result of Sensitivity Analysis

Aggregate Value	Case 0	Case 1	Case 2	Case 3	Case 4
Maintenance	0.229	0.240	0.109	0.244	0.349
Optimization	0.424	0.343	0.452	0.432	0.490
CO_2 Quality	0.348	0.418	0.440	0.324	0.161

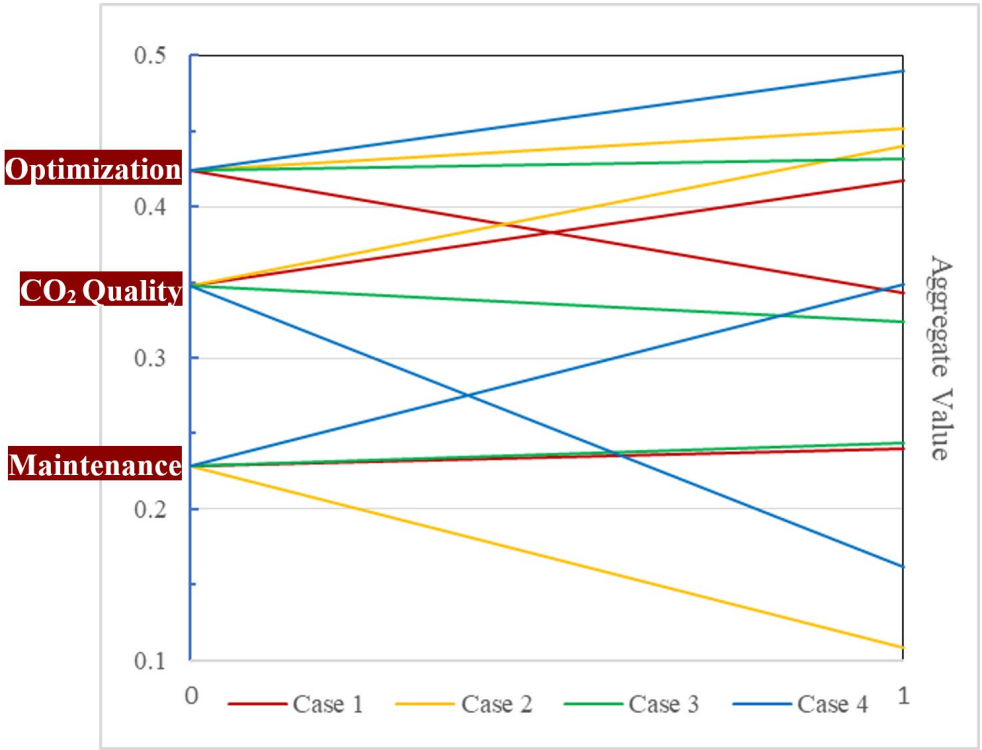

Figure 8. The Weighted Aggregate Value Graph

The table and figure above show that when Performance = 0 (Case 2). Revenue = 0 (Case 3) and Compliance = 0 (Case 4), the result is the same as the initial condition (Case 0) where the highest value is obtained by Optimization alternative. While, when the O&M Cost = 0 (Case 1). The highest value obtained by CO2 Quality alternative. It means that O&M Cost variable has the most significant impact on the outcome.

Business Solution

The pairwise comparison of the criteria above shows that decision makers think that Quality is more important than Cost. This is aligned with the fundamental objective which is to improve the O&M performance of BDG CO2 removal plant which can be achieved by improving reliability and availability, improving performance and efficiency, enhancing safety and compliance, extending asset lifespan and supporting environmental sustainability.

While the pairwise comparison of the sub-criteria above shows that decision makers think that Compliance is the most important factor, followed by Performance in second place and Revenue in third place in terms of improving the O&M performance of BDG CO2 removal plant. This is aligned with the company mission which put HSSE into every aspect of operation, above all else. The performance is more important than revenue because they think if the plant performs good, the revenue will come by itself.

Considering all the criteria and sub-criteria, Optimization alternative has the highest weighted aggregate value of 0.424. The sensitivity analysis also shows that the solution is quite stable where the result of Case 2, 3 and 4 is the same. The results of Case 1 show that the result can change when the value of O&M Cost variable is reduced. This is because Optimization alternative main strength is O&M Cost variable with the value of 0.737 from Table IV.3, by optimizing equipment used in the plant and optimizing power utilization through centralization of powerplant. So, when the value of O&M Cost weight is reduced, it significantly impacts (reduce) the weighted aggregate value of Optimization alternative.

Based on this analysis, the best alternative that the author would like to propose to improve the O&M performance of BDG CO2 removal plant is Optimization alternative. This is the answer to the third research question.

Implementation Plan

To optimize the train and equipment used in the plant, especially in aging facility like BDG CO2 removal plant. It is essential to ensure its integrity by inspecting them to identify its actual condition, potential failures, and necessary maintenance actions. After that, ensure equipment capacity through an adequacy check to meet current and future demand.

To optimize power utilization through centralization of powerplant by integrating the powerplant with BDG GS. Start by contacting each manufacturer to ensure its compatibility and support in the integration process to maintain seamless plant operations and minimize risks. Continue with identifying the requirements and perform a pilot / small scale integration before full deployment.

While, to enhance the maintenance program on critical equipment, it is essential to conduct RCM and RBI to them according to critically ranking to determine the most effective maintenance strategy for each equipment and optimize inspection schedules based on the likelihood and consequences of failure. Then to ensure effective monitoring, maintenance planning, and risk management it is important to assign a dedicated inspection team.

To upgrade the laboratory facility for better and faster analysis, start by identifying the function required by the laboratory, design the facility and continue by laboratory equipment procurement. While, to find the better amine solution so it can perform better with minimum make up, start gathering information and conduct FGD with experts, both from internal and external companies, including amine solution vendors. Then, conduct a field test and evaluate the result before full scale implementation.

To improve the safety behavior of personnel, competence of their personnel in terms of process optimization, start by identifying what skill needs to be upgraded and discuss is with HC (Human Capital) Department for the implementation. While, to improve the quality of housekeeping, start by scheduling a routine site visit by management to increase awareness and foster a culture of cleanliness especially in the

working area. It is also important to implement regular audit and reward teams that maintain excellent housekeeping.

CONCLUSION

In this research, an AHP framework has been applied to evaluate and rank three potential alternatives which are generated using VFT. The evaluation was based on four key criteria, namely O&M Cost, Performance, Revenue and Compliance, all tailored to BDG CO2 removal plant specific context as the criteria are obtained from semi-structured interview with decision makers and FGD with experts. This structured approach allows for a systematics decision making process to improve the O&M performance by finding the best alternative of O&M method in BDG CO2 removal plant.

In this decision-making process, decision makers and experts' input played a crucial role. This research gathered information from oil and gas professionals consisting of various levels and disciplines in organizations, including professionals from outside of organization, which in this case as a representative of government. These professionals contributed their knowledge and experience, ensuring the efforts to improve the O&M performance were based on real-world situation and aligned with the company's vision. This information was processed using VFT resulting in three potential alternatives, namely Full-Coverage Service Contract with enhancement on maintenance, Full-Coverage Service Contract with enhancement on plant optimization and Full-Coverage Service Contract with enhancement on CO2 quality.

The analysis reveals that Full-Coverage Service Contract with enhancement on plant optimization is the most appropriate solution. This alternative was selected based on the strong performance across multiple criteria, especially O&M Cost. This alternative can reduce operating costs by optimizing the operating train and equipment used, which leads to less O&M cost as well as fuel consumption. This alternative also can improve performance by enhancing RCM and RBI to critical equipment to increase availability and reliability, while optimizing maintenance costs. The revenue also will be increased by selling gas that was previously going to be used for fuel. The compliance also can be improved by this alternative through improvement of safety behavior and quality of housekeeping.

Here are recommendations for the Company:

1. To ensure the implementation of optimization by O&M contractor. They must put optimization clause in the contract. Thus, it can be a common concern by top-to-bottom management of both O&M contractors and Company.
2. If necessary, RCM and RBI can be excluded from the scope of O&M contractor and run by the company itself. O&M contractors only carry out maintenance programs according to the results of the RCM and RBI analysis that are issued by the company.
3. To ensure the performance of the amine solution, they must require chemical suppliers to conduct periodic tests on the supplied chemicals and make payments based on performance, not volume.
4. To ensure that the culture of safety behavior and housekeeping can be embedded by personals in the field, a champion must be appointed from each location. Increase awareness periodically through engagement and recognition from management from the Company.

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