ISBN*: 978-623-92201-2-9*

Implementation of Multi-Objective Decision Analysis and Value Focused Thinking to Improve Decision Quality in Complex Project

Hans Gunawan Rimbualam* and Santi Novani

School of Business and Management, Institut Teknologi Bandung, Indonesia

E-mail address: hans.onleave@gmail.com

Abstract - **Multiple Objective Decision Analysis (MODA) and Value Focused Thinking (VFT) is well suited for projects with multiple stakeholders and objectives with considerations across different domains. In the Produced Water Management program for marginal fields, there was a disconnect between corporate campaigns, local regulations, and partner expectations. This made high-quality decision-making became more complex and challenging. The project team initially evaluated only tried-and-true, facility-focused alternatives. However, the decision-makers identified significant gaps in 3 Decision Quality aspects: creative, feasible alternatives; clarity in values and trade-offs; logically correct analysis.**

The implementation steps for MODA-VFT are identifying values/objectives hierarchy, identifying value measures/decision criteria, generating alternatives from objectives, evaluating alternatives based on value measures, incorporating decision maker's preference through value function and weighting, and evaluating the overall alignment values.

The project team has managed to close the decision quality gaps by generating and evaluating more creative alternatives based on decision makers' values and enabling decision-makers to see the connection of the recommended alternatives to the values and prioritize trade-offs. The project team also had clear and logically structured reasoning to justify the preferred alternative.

Keywords - **Alternative evaluation, environmental strategy, multiple objective decision making, objective hierarchy, value function**

I. INTRODUCTION

The upstream oil and gas industry conducts exploration and production of crude oil and natural gas. Some of the fields are located in the land (on-shore), while some are located in the sea (off-shore). From the producer wells, the production fluid (consists of oil, gas, and water) will be treated at the processing facility (Gathering Station). The crude oil will be stored and shipped to customers through pipelines or oil tankers. The natural gas is either being transported to pipeline or other means to reach customers. It can also be used to generate electricity to power the treatment facilities (own-use). Meanwhile, the produced water is either being reused for oil production enhancing injection (Enhanced Oil Recovery/EOR), disposed to a water-tight underground reservoir, or being discharged to the surface water bodies (such as canal or river). The typical process is shown in Fig. 1.

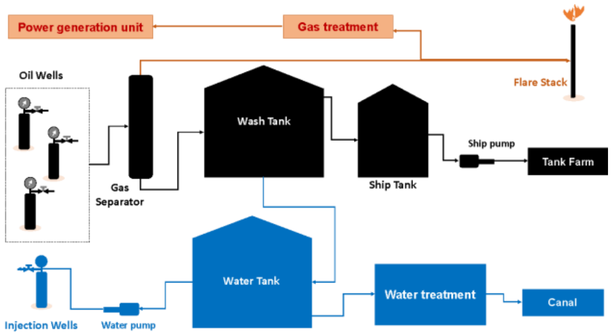

Fig. 1 Typical processing steps in on-shore oil and gas

By 2021, the onshore upstream oil and gas industry in Indonesia is still allowed to release its produced water to the nearby canals as long as it meets certain quality requirement. However, industries have been slowly moving away from onshore discharge to minimize overall risk from the activities.

This case example occurs in one of the upstream oil and gas companies in the country. Over the years, the company has been able to reuse about 95% of its produced water, mostly for production-enhancing injection. However, identifying reuse cases for the remaining produced water has been challenging. The water was coming from more marginal fields with little opportunity for economical production enhancing injection. The fields are also located in remote areas, making consolidating water treatment is also challenging and costly.

Without any regulatory mandates, there is not much incentive for the company's partners to fund the projects as it has more interest in projects that focused on a production-enhancing project, new field development, facility upgrade/refurbishment, and mandatory compliance projects. It also has the interest to sustain the existing production, making the option to close down these marginal fields to achieve no produced water discharge is less likely to be supported. Some local communities have also expressed their interest to keep the produced water discharge as it was used for their fish pond, plantation, and sanitary activities.

With these challenges, this program/project could be considered as a complex project, not from the technical or technological perspective, but the following considerations:

1. Significant investment was required for the company to completely eliminate the risk from produced water discharge activities, while there was no regulatory mandate as the program's driver.
2. The program/project has multiple stakeholders with different objectives, interests, and focus. Some of these objectives are also not financial/monetary driven.
3. The decision-making process required to include technical analysis in various domains/aspects (HSE, financial/operational, and regulatory/reputation aspect) with many uncertainties.

Initially, the project team only evaluated several alternatives focused on various facility options and production curtailment. These alternatives are based on past experiences in more productive fields, which certainly have different circumstances than these marginal fields, such as larger reserves and more potential for economic production enhancing injection.

The decision executive as the project's ultimate decision-maker identified decision quality issues in 3 following aspects based on Decision Quality (DQ) assessment:

1. **Creative and feasible alternatives**
   The project team has only considered tried-and-true, facility-focused alternatives.

2. **Clarity in values and trade-offs**
   Decision-maker has not been able to visualize the connection with the values and prioritize the trade-offs.

3. **Logically correct analysis**
   There has been a desire to have comprehensive analysis but the existing decision analysis method has not enabled to include all technical analysis in a structured and transparent manner.

Since these gaps were deemed critical enough, the decision-maker decided to recycle the project and asked the team to focus on closing these gaps. The project team will have to determine which decision analysis framework that will close the gaps and enable high-quality decision to be made.

This paper will discuss the project team's approach to answer these 3 main questions:

1. Which framework could help the project team to communicate the values and trade-offs to the decision-makers and stakeholders, while also demonstrate logical, transparent, and comprehensive analysis in the alternatives evaluation?
2. Has the project team identified all the creative and feasible alternatives for this program?
3. Using the selected framework, which alternative will be proposed by the project team as the preferred alternative?

II. LITERATURE RESEARCH

The process where an individual, group, or organization achieves a common conclusion about which plans to act on based on certain "givens" (objectives and limits on resources) is called decision-making [1]. The success of a company is often relied on the capability of its decision-maker in making high-quality and fast decisions [2]. Decision analysis will support the project team and decision-makers to get clear understanding of the frame and alternatives, ensure the establishment of creative, feasible alternatives, provide a systematic approach managing risk and uncertainty on critical aspects, enable adequate understanding of the strengths and weaknesses of alternatives, and help to get buy-in from decision-makers and stakeholders [3].

Depending on the number of decision criteria, there are two approaches/models in decision making: single and multiple criteria decision making. If there are multiple attributes involved, the multiple attribute decision analysis framework will be utilized. However, if there are multiple objectives involved, the proper framework is Multiple Objective Decision Analysis (MODA) [4].

MODA is an approach to help decision-makers make a decision aligned with their values despite multiple, potentially conflicting objectives or decision criteria [5] [6]. MODA is often used by government agencies since the projects or initiatives often involves complex issues (in term of technical and social aspects) with multiple differing stakeholders [7]. Other than government agencies and the military world, the MODA-VFT framework can also help environmental-related work [8]. This technique has also been implemented to optimize policy prioritization in contaminated sites remediation, reduction of contaminants in the aquatic environment, optimization of water and coastal resources in the period 1992-2002 [9]. Typically, environmental projects required decisions that are often complex and require multi-disciplinary knowledge (such as human health, social sciences, politics, and regulatory).

Value Focused Thinking (VFT) is a framework in decision making that starts with deciding what the important or desired goals area (values/objectives) are, then continues with the evaluation of ways to achieve it. This is in contrast with Alternative Focused Thinking (AFT) which starts with a set of alternatives then chooses the best among them [10].

MODA/VFT is the recommended framework/approach for this program as it could help to improve the alternatives generation and evaluation process and close the 3 gaps identified in decision quality assessment:

- **Creative and feasible alternatives**
  The project team starts with identifying the project's values/objectives and then use those values to identify more creative and feasible alternatives (instead of evaluating only tried-and-true alternatives), which aligns with the Value Focusing Thinking (VFT) framework.

- **Clarity in values and trade-offs**
  The decision-making framework can include stakeholders' values and objectives and prioritize trade-offs.

- **Logically correct analysis**
  The framework will become a structured and transparent process to document the decision rationale.

The steps of implementing MODA-VFT are as follow:

1. Identify the values/objectives and develop the objectives hierarchy
2. Determine the value measure/decision criteria for each of objective.
3. Use the objectives to identify creative and feasible alternatives
4. Evaluate the alternatives based on the identified decision criteria/value measures
5. Incorporate decision maker's priority and risk perception through value function and weightings.
6. Calculate the overall alignment values
7. Calculate the overall efficiency score based on the overall alignment values and required budget/ expenditure
8. Determine the top alternative for each facility/field (gathering station)

This process is adapted from several processes, such as the 7 steps of effective decision making developed by the University of Massachusetts [11] and the general framework for MODA ([12], [13] and [14]). The summary of the process is shown in Fig. 2. These works of literature are more focused on explaining the concept and framework for MODA/VFT. However, there is few specific examples of implementation in a particular project. This paper will discuss the step-by-step process of implementing MODA/VFT for this particular example project so that the process and tool used in this process will be more apparent for project teams with intent to implement this framework in their projects and conduct necessary adjustments to suit specific project's needs.

Decision-makers and stakeholders will be involved in most of the steps, especially when determining the values, establishing values hierarchy, describing the scales, selecting the value function, and determining the weightings. Meanwhile, some of the processes (such as assigning scores based on established scales for decision criteria with constructed units, brainstorming possible alternatives, and building the value model) were done in collaboration with related subject matter experts.

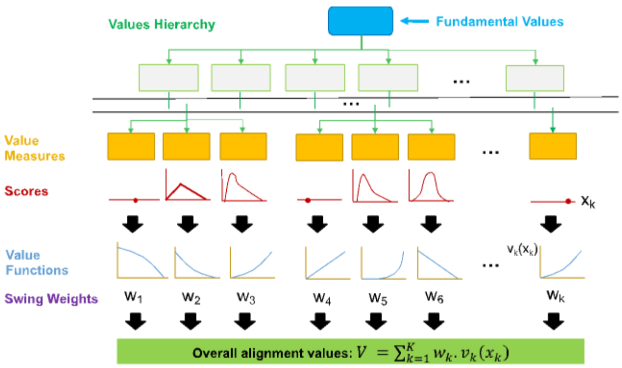

Fig. 2 Summary of MODA-VFT implementation steps

The overall alignment values/scores (V) will be calculated as summation of weighted value scores, using "(1)":

$$V = \sum_{k=1}^{K} w_k . v_k(x_k) \quad (1)$$

where:

- V = overall alignment score/value
- w_k = weighting factor
- $v_k(x_k)$ = value score based on result of the value function
- x_k = input value/score

Meanwhile, the overall efficiency score (E) is calculated with "(2)":

$$E = \frac{V}{Expense} \quad (2)$$

Since the project team is selecting an alternative which will have the incremental benefit of existing condition (business as usual), the alignment value/score and efficiency score will be calculated as incremental alignment value/score and incremental efficiency score by comparing the score for each alternative with the score for the reference case (business as usual/do nothing case).

Generally, the top alternative for each location/facility is the one with the highest incremental efficiency score. However, decision-maker has also requested the project team to compare the values of top alternatives from the value-based approach (based on its overall alignment values). If the values from the value-based top alternative are deemed significantly higher than the values from the efficiency-based top alternative, the decision-maker may consider the incremental values worth pursuing and the top alternatives will be based on the highest incremental alignment values (instead of the highest incremental efficiency scores).

III. METHODOLOGY

A. Overview

After conducting the literature review and establish the step-by-step MODA/VFT implementation (8 steps in Section II), the necessary data is collected (such as field/operational data, risk assessment result, preferences from decision-maker (objectives and sub-objectives, weightings), etc. From the collected information, we can build the value model and assess the alternative based on value and efficiency. From the model, the preferred alternative can be determined and presented to the decision-maker for approval.

The overview of the overall process is shown in the following flowchart (Fig. 3).

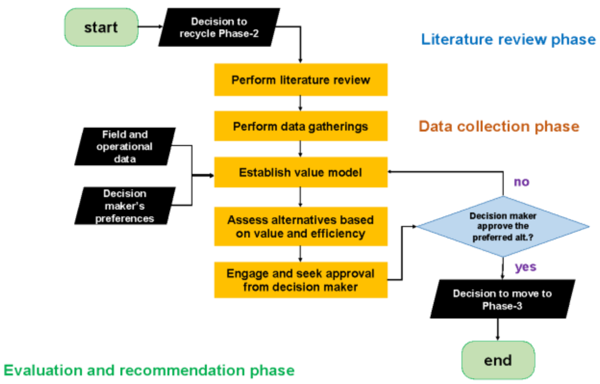

Fig. 3 Overall flowchart of the process

B. Objectives hierarchy

Based on interview and discussion with decision-maker for this Produced Water Management (PWM) program, there are 4 main objectives to be met: protect people & environment, manage potential impacts related to local water supply, sustain project financial and operational aspects, and manage company's long term risk. There are 12 decision criteria/value measures from these 4 objectives as shown in Fig. 4.

C. Alternatives

From the identified objectives, the project team and subject matter experts (SMEs) identified the key components that will enable the company to achieve the objectives. These key components are also called the strategic decisions, which will include the possible component that later will be grouped into themes. These themes will become the alternatives.

In this case, the team has identified 5 strategic decisions: intended usage of the produced water, primary enabling strategy, secondary enabling strategy, national-level engagement, and local-level engagement. The team then brainstormed all feasible options related to this PWM program. From there, the team could identify 10 themes, which become 10 alternatives. The strategy table in Fig. 5 shows the 5 strategic decisions/key components with all the feasible options and 10 alternatives.

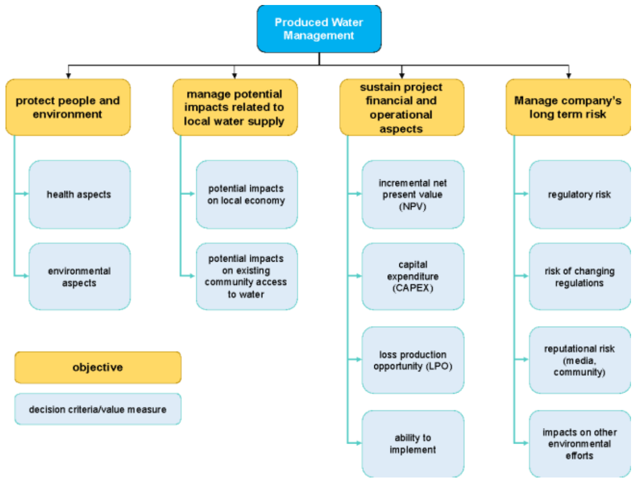

Fig. 4 PWM objectives hierarchy

***ISBN**: 978-623-92201-2-9*

Strategy / Theme	Intended Use	Primary Enabling Strategy	Secondary Enabling Strategy	National Government Engagement	Regional Stakeholder Engagement
No new facilities	none: continue discharge/BAU	none	none	none	nothing beyond existing activities
Improve water aesthetics	none: downhole disposal	injection to reservoir	monitoring	minimal engagement	provide alternative water source
Water provider	community non-potable use	water treatment/polishing	restrict access	inform national government	partner with local university
Produced Water Discharge Elimination (PWDE)	Industrial (external to company) use	water transfer	injection at other field	focused engagement	partner with industry
Beneficial reuse (community)	Other internal environment efforts	wet shipment	optimize operational practices	advocate for shutting down the field	create new industry
Beneficial reuse (ecological)	waterflood/pressure maintenance	elimination/ reduction by shutting down the field		define policy framework for water reuse	local permit discussions
Beneficial reuse (3rd party industrial)	ecological reuse, e.g., stream recharge			change regulation	relocate community
Beneficial reuse (internal)	none: shutting down the field				
Community resettlement					
Business as usual (BAU)					

Fig. 5 Strategy table for PWM

Due to the difference in field condition of each facility/location, not all 10 alternatives will be applicable at each facility. Therefore, screening criteria will be developed to which alternatives are applied at each location. The applicable alternatives are shown in Fig. 6.

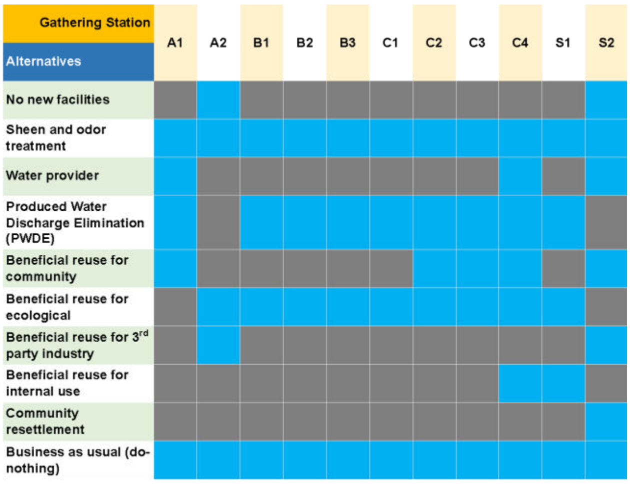

Fig. 6 Applicable alternatives for each gathering station

D. Scoring

For decision criteria without natural units, scales will be constructed. The highest score represents the most ideal condition, while the lowest score represents the least ideal condition. Each scale has to be accompanied by a detailed explanation to ensure consistent scoring between alternatives and locations.

E. Value Function

Scores will be converted into value scores by value function. Value function (also known as risk-based utility function) represents the risk tolerance of decision-maker in each decision criteria [15]. Some value function shapes will be more sensitive than other value functions, meaning that small changes in the input score will produce larger changes in the output value score. Several types of value function shapes are shown in Fig. 7.

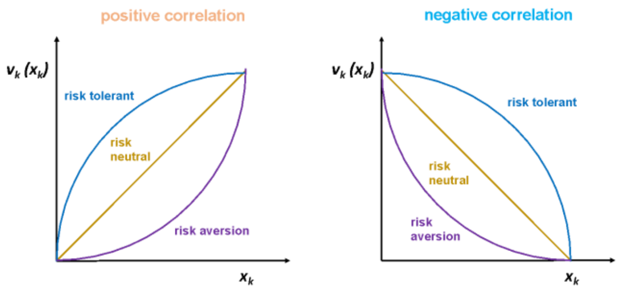

Fig. 7 Various value function shapes, representing different risk tolerance

F. Weightings

Weighting is determined based on relative priority and variability. The relative priority is meant to show the relative importance of each decision criteria. Variability is the range of variance within each decision criteria. Decision criteria will be placed in the respective box representing their relative priority and variability. The weighting score will become smaller as it goes from the top left to the bottom right box. The worksheet used by decision-maker is shown in Fig. 8.

	Priority		
Variability	Critical	Very Important	Important
Expect LARGE variation between alternatives			
Expect LESS variation between alternatives			

Fig. 8 Worksheet used to determine weighting score

G. Overall alignment values

The incremental alignment values were calculated by subtracting the overall alignment values for a particular alternative with the overall alignment values for the reference (business-as-usual) case.

The incremental alignment values from all applicable alternatives in the "S1" Gathering Station are shown in Fig. 9. The overall incremental alignment values are

ISBN*: 978-623-92201-2-9*

repre-sented by the black triangle (▲), while the red dashed line (- - - - -) shows the associated investment (CAPEX) for each alternative.

The overall alignment value chart shows the contribution of each value measure (decision criteria) to the overall alignment value. Value measures below the zero alignment scoreline are the ones that do not align positively to the objectives, while value measures above the zero alignment scoreline are the ones that align positively to the objectives.

From this chart, the alternative "Sheen and odor treatment" shows the highest overall alignment score compared to other alternatives, while the alternative "Beneficial reuse for internal need" has the lowest overall alignment score. This means the top alternative for the "S1" Gathering Station based on value assessment is the "Sheen and odor treatment" alternative.

The lowest cost among all the alternatives for the "S1" Gathering Station is the "Beneficial reuse for internal need" alternative, while the highest cost is for the "Produced Water Discharge Elimination (PWDE)" alternative. This shows that there may be conflicting conditions between the overall alignment scores (values) and the cost. However, cost/financial aspects will be considered later in the efficiency assessment.

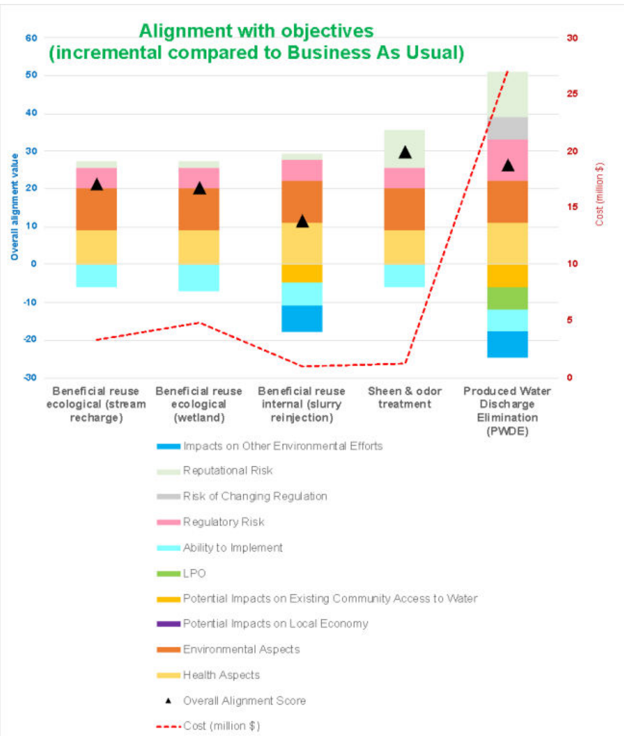

Fig. 9 Overall alignment with objectives/values for "S1" Gathering Station

H. *Efficiency scores*

Incremental efficiency scores were calculated by subtracting the overall efficiency scores for a particular alternative with the overall efficiency scores for the reference (business-as-usual) case.

The incremental efficiency scores from all applicable alternatives in the "S1" Gathering Station are shown in Fig. 10. The overall incremental alignment values are represented by the **blue bar**, while the red dashed line (- - - - -) shows the associated investment (CAPEX) for each alternative.

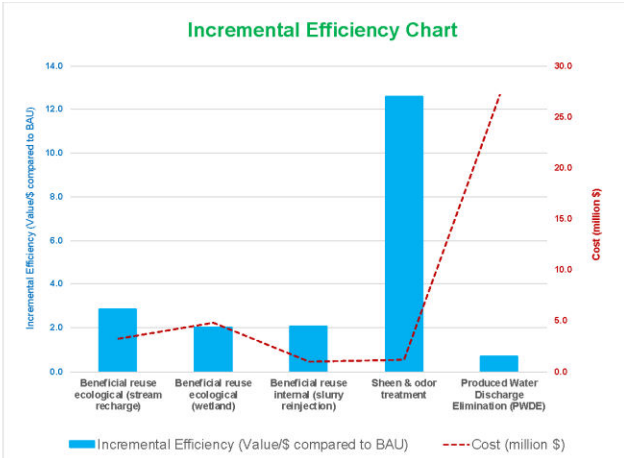

Fig. 10 Incremental efficiency chart for "S1" Gathering Station

In this chart, the alternative "Sheen and odor treatment" has the highest incremental efficiency value among other alternatives. Meanwhile, the alternative "PWDE" has the lowest incremental efficiency value. This means the top alternative from the efficiency assessment for the "S1" Gathering Station is the "Sheen and odor treatment" alternative.

I. *Sensitivity analysis*

A sensitivity assessment is done to evaluate the possible outcomes of value model assessment with different stakeholders' focus. This program has multiple objectives with many stakeholders. Each stakeholder may have different interests and focuses. This will result in differing objectives prioritization. In the objectives hierarchy of this program, there are 4 main objectives: protecting people and the environment, managing impact to local water supply, sustain financial & operational aspects and manage long-term risk. Several scenarios have been established to reflect this differing interest and focus of decision-maker and stakeholders, such as:

- Health/environmental focus (Health/Safety/ Environment's interest)
- Enterprise risk focus (Legal/public affairs' interest)
- Cost/LPO focus (Operation/Maintenance/engineering's interest)

***ISBN**: 978-623-92201-2-9*

From the sensitivity assessment for the value-based approach, the baseline scenario is closely aligned with the scenario that prioritizes health/environmental aspects. In the scenario where the decision-maker prioritized minimizing cost or loss production, about half of the top alternatives are aligned with the baseline scenario. In the scenario where decision-maker prioritized eliminating corporate long-term risk, the top alternatives are mostly different and the cost is very high.

From the sensitivity assessment for the efficiency-based approach, the baseline scenario is closely aligned with 2 other scenarios (focusing on health/environment and long-term corporate risk). The scenario that prioritizes cost/LPO is also not very different compared to other scenarios. Based on this assessment, the outcome is less dependent on the weighting scenario.

IV. FINDINGS AND DISCUSSION

A. *Selecting preferred alternative*

From the overall alignment score and incremental efficiency value, the top alternative for each Gathering Station can be determined. The top alternative based on value is the alternative with the highest overall alignment score (incremental value). Meanwhile, the top alternative based on efficiency is the alternative with the highest incremental efficiency value.

Typically, the common approach for determining the best alternative is based on the efficiency aspect (value/investment cost). However, decision-maker may ask the project team to evaluate the incremental value of the top alternative resulted from efficiency assessment compared to the top alternative resulted from overall alignment value assessment. If the values from the value-based top alternative are deemed significantly higher than the values from the efficiency-based top alternative, the decision-maker may consider the incremental values worth pursuing and the top alternatives will be based on the the highest incremental alignment values (instead of highest incremental efficiency scores).

For example, in the “B2” Gathering Station, the incremental value from the top alternative from the alignment value approach and the top alternative from the efficiency approach is about only 1 value-point higher (~5%). In this particular case, decision-maker prefers the alternative based on the efficiency approach, as the top alternative has lower cost without significant reduction in the value-point. However, in the “C3” Gathering Station, the incremental value from the top alternative from the alignment value approach and the top alternative from the efficiency approach is more than 5 value-point higher (~17%). In this situation, decision-maker decided that the increased value-point is worth pursuing despite the higher cost. Therefore, in this case, the top alternative for the “C3” Gathering Station is based on the value approach, instead of based on the efficiency approach.

B. *Decision Quality Assessment*

By the end of the project phase, decision-maker has reassessed the decision quality, to determine if a high-quality decision could be made after the improvement in the decision analysis. The difference in each decision quality aspect is shown in Fig. 11.

The decision quality spider diagram shows the improvement in many dimensions, especially the ones that became the major concerns from decision-makers, such as creative & feasible alternatives, clarity in values & trade-offs, and logically correct analysis.

The feedbacks from Decision Executive (DE) and other Decision Review Board (DRB) members are:

- This program has series of complex decisions as there are many drivers and multiple locations. This complexity has been challenging for high-quality decision-making.
- The Value Focused Thinking (VFT) approach has helped to clarify stakeholder priorities and generated more feasible alternatives.
- The use of scales has provided a way to use specific technical evaluation to generate and differentiate the alternatives.
- MODA-VFT approach is a logical approach that enabled inclusive participation from all stakeholders and decision-makers, gathering a large amount of various analyses, visualization of trade-offs, and sensitivity analysis.
- This approach can be used in other programs/projects that require decision analysis to non-traditional and non-linear factors to help to improve the decision quality.

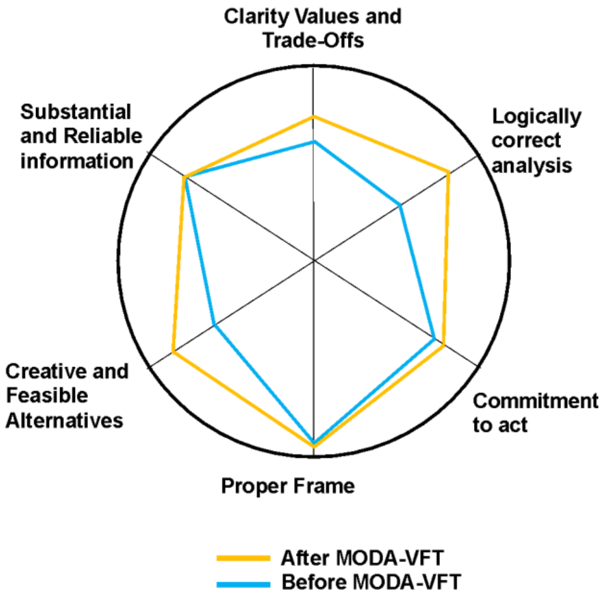

Fig. 11 Improvement in Decision Quality (DQ) assessment

With this improvement in Decision Quality assessment, decision-maker felt confident that a high-quality decision could be made and approved the project team to move on to the next project phase (maturing technical scope of preferred/top alternative before final investment decision).

C. Implementation Plan

The project organizational capability (OC) has four main components: organizational planning (identifying the required project organizational structure, roles and responsibilities, communication flow), staffing the project team (identifying, recruiting, relocating required personnel), establishing the project team (conducting team building, workshop, training to strengthen the members' bonding), and leading the project team (communication, negotiation, decision making, etc.) [16]. To ensure that the preferred alternative will be executed on time, the project manager will have to complete the project OC.

Based on the stakeholder analysis, the project organization comprises representatives from Health, Safety and Environment (HSE) team, Operation and Maintenance (O&M) team, Construction and Design engineering team, supporting the core project management team (project engineers, cost controller, and scheduler).

To estimate the execution schedule, the program's Work Breakdown Structure (WBS) has to be established first. WBS is a structural approach to "decomposes" project activities into smaller segments/groupings [17]. These smaller segments will then be assigned to be under responsibility of a specific group/team within the organization. At this project phase, the project team will identify WBS until Level 4 for each preferred alternative.

The execution strategy is to conduct the program at all locations/Gathering Stations in parallel. However, locations with different recommended alternatives will take different times to complete as the involved activities are also different.

The Key Performance Index (KPI) for the project implementation includes:

- Zero safety incident (process safety and personnel safety-related incident)
- The actual cost and project duration for implementation is within +/- 10% of the estimate (as established during the Final Investment Decision)
- Achieve business objective of each alternative

V. CONCLUSION

MODA/VFT framework has helped the project team in improving the decision quality of this program. The project team has met the 3 objectives in Phase-2 Recycle:

1. The project team has implemented MODA/VFT framework to communicate the values and trade-offs to the decision-maker and stakeholders through the value/objective hierarchy, value model, value function, and weightings. This has enabled the project team to demonstrate logical, transparent, and comprehensive analysis in the alternative evaluation to the decision-maker.
2. The project team has identified and assessed more creative and feasible alternatives, other than the tried-and-true alternatives, based on the value/objective hierarchy.
3. Using the MODA/VFT framework, the project team has identified the preferred alternative based on the combination of value and efficiency assessment.

The decision-making for this program has been postponed for several years due to an inadequate decision-making framework, reflected from inadequate overall DQ scores. With this MODA/VFT approach, the quality of information required to make high-quality decisions has been improved. This is demonstrated from a higher overall score of DQ dimensions, especially in 3 aspects/ dimensions (creative and feasible alternatives; more clarity in values and trade-offs; logical and transparent analysis). High DQ results will help boost the decision maker's confidence that high-quality decisions can be made and the project is ready to proceed to the next step (execution phase). With MODA/VFT framework, the decision-making process has been completed in less than 1 year. This certainly helps the company to establish its clear business plan.

This paper has shown how MODA/VFT framework has been implemented in a project. This information can help other project teams who are considering implementing MODA/VFT to improve decision quality for their projects/programs by providing step-by-step processes and tools to be utilized.

MODA/VFT approach has been demonstrated to be suitable for projects that require high-quality decision with multiple drivers and objectives, especially for non-revenue generating projects. Unlike revenue-generating project (which has clear-cut objectives on profit generation), non-revenue generating projects tend to have more stakeholders and multiple objectives that often in various domains (such as financial, community, reputation, technical/operational, future regulatory requirement, etc.) and misaligned to one another. In this situation, the application of MODA-VFT was able to help decision-making process to be more structured and transparent.

MODA-VFT approach is also suitable for group decision-making situations. Group decision-making tends to be more complex as each decision-maker has their perspective, focus, and interest. The general strategy is project team will seek the individual preference first, and then try to combine these to become the group's preference. Since this MODA-VFT is a well-structured and transparent process, decision-makers could participate in each critical step, negotiate about the preferences and trade-offs, and have clarity in how their agreement will affect the selection of the top alternatives. The tools/framework used in developing the objective/value hierarchy, scales, value function, and weighting scenarios were designed to facilitate discussion and transparently communicate the process to reach the final agreement/conclusion at each of these steps. With this benefit of MODA-VFT, group decision making become more inclusive, transparent, and logical, which tends to enable common agreement to be reached

The primary challenge is that the MODA-VFT approach tends to be more complicated and sufficient times should be allocated to bring decision maker/stakeholders familiar enough with the process and how their intermediary decisions will affect the outcome.

ACKNOWLEDGMENT

I would like to thank my thesis supervisor, Santi Novani, S.Si., MT, PhD., for her guidance, review, and feedback on the original thesis manuscript. I would also thank Dr. Eng. Pri Hermawan S.T., M.T. and Nila Armelia Windasari S.A., M.B.A., Ph.D. who have evaluated and provided feedback on the original thesis manuscript.

I sincerely thank my fellow classmates, friends, colleagues, and advisors who have provided suggestions, ideas, advice, and support to the development of this paper and the thesis manuscript.

REFERENCES

[1] Schoemaker, P. J. H., & Russo, J. E. (2014). decision-making. *The Palgrave Encyclopedia of Strategic Management*. https://doi.org/10.1057/9781137294678.0160

[2] Negulescu, O., & Doval, E. (2014). The Quality of Decision Making Process Related to Organizations' Effectiveness. *Procedia Economics and Finance, 15*,. https://doi.org/10.1016/S22125671(14)005486

[3] Howard, R. A., Matheson, J. E., & Strategic Decisions Group. (1989). *Readings on the principles and applications of decision analysis*. Strategic Decisions Group.

[4] Gade, P. K., & Osuri, M. (2014). *Evaluation of Multi Criteria Decision Making Methods for Potential Use in Application Security* [MSc Thesis]. https://www.diva-portal.org/smash/get/diva2:831025/FULLTEXT01.pdf

[5] Scala, N., Kutzner, R., Buede, D., Ciminera, C., & Bridges, A. (2012). Multiobjective Decision Analysis for Workforce Planning: A Case Study. In *62nd IIE Annual Conference and Expo 2012* (p.).

[6] Mattiussi, A., Rosano, M., & Simeoni, P. (2014). A decision support system for sustainable energy supply combining multi-objective and multi-attribute analysis: An Australian case study. *Decision Support Systems, 57*, 150–159. https://doi.org/10.1016/j.dss.2013.08.013

[7] Kurth, M. H., Larkin, S., Keisler, J. M., & Linkov, I. (2017). Trends and applications of multi-criteria decision analysis: use in government agencies. *Environment Systems and Decisions, 37*(2), 134–143. https://doi.org/10.1007/s10669-017-9644-7

[8] Huang, I. B., Keisler, J., & Linkov, I. (2011). Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. *Science of the Total Environment, 409*(19), 3578–3594. https://doi.org/10.1016/j.scitotenv.2011.06.022

[9] Linkov, I., Satterstrom, F. K., Kiker, G., Seager, T. P., Bridges, T., Gardner, K. H., Rogers, S. H., Belluck, D. A., & Meyer, A. (2006). Multicriteria Decision Analysis: A Comprehensive Decision Approach for Management of Contaminated Sediments. *Risk Analysis, 26*(1), 61–78. https://doi.org/10.1111/j.1539-6924.2006.00713.x

[10] Keeney, R. L. (1992). *Value-focused thinking : a path to creative decision* making. Harvard Univ. Press.

[11] Hashem, T., & Alqirem, A. (2018). *The Role of Restructuring in Enhancing The Information Experience*. *7*,.

[12] Dillon-Merrill, R. L., Parnell, G. S., Buckshaw, D. L., Hensley, W. R., & Caswell, D. J. (2008). Avoiding Common Pitfalls in Decision Support Frameworks for Department of Defense Analyses. *Military Operations Research*, *13*(2), 19–31. https://doi.org/10.5711/morj.13.2.19

[13] Keeney, R. L., Raiffa, H., & Meyer, R. F. (2003). *Decisions with multiple objectives : preferences and value tradeoffs*. University Press.

[14] Dodgson, J., Spackman, M., Pearman, A., & Phillips, L. (2009). *Multi Criteria Analysis: A Manual*.

[15] Bossuyt, V., Hoyle, C., Tumer, I., Dong, A., Doolen, T., & Malak, R. (2012). Toward Considering Risk Attitudes in Engineering Organizations Using Utility Theory. In *Proceedings of the ASME Design Engineering Technical Conference* (Vol. 7, p.). https://doi.org/10.1115/DETC201270399

[16] Anantatmula, V. (2010). Project Manager Leadership Role in Improving Project Performance. *Engineering Management Journal, 22*, 13–22. https://doi.org/10.1080/10429247.2010.11431849

[17] Globerson, S. (1994). Impact of various work breakdown structures on project conceptualization. *International Journal of Project Management*, *12*, 165–171. https://doi.org/10.1016/02637863(94)900329