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Oil Production Curtailment Scenario Selection Using Multicriteria Decision-making Analysis

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***Abstract*— Covid-19 restrict human mobility. With two-thirds of oil consumption accounted by transportation, global oil consumption declines from 100 to 80 million barrels per day. This impacted oil surplus level in 2020 increased three times compare in 2018. PT. CPI might be forced to curtail its production rate. Scope of this research is to develop optimum curtailment scenario. Focus Group Discussion (FGD) was conducted to develop problem tree analysis. It is concluded that improper curtailment become core problem that have safety, compliance, and economic consequences. Root cause of problem related with guideline unavailability to shutdown wells and facility. Converting to objective tree analysis, guideline for shutdown wells and facility during curtailment will be developed. This research combines Value Focused Thinking (VFT) and Analytic Hierarchy Process (AHP). VFT is used to generate curtailment alternatives while AHP to select the best alternative. There are 6 attributes that guides selection: Avoid oil spill, injury, start-up problem, maintain profitability, minimize loss production opportunity, and maintain steam backbone. From 4 scenario generated VFT, AHP determines that scenario 2 has the highest score. Curtailment scenario 2 involves running min. capacity in facilities, shutdown low risk producer wells, shutdown mature injector wells. PT CPI accepted this recommendation and will develop executable Standard Operating Procedure for Scenario 2.**

Keywords*— *Oil Surplus, Curtailment, Shutdown Scenario, VFT, AHP

INTRODUCTION

Based on data from International Energy Agency, oil and gas consistently contributed to around 50% of world's total energy supply for the last 30 years (1990 – 2018). Another 50% are distributed between other energy contributors such as coal, nuclear and biofuel (IEA, 2020). The significant contribution of oil and gas implies how the world is still very much dependent to it, but in the other hand it also means that oil and gas (industry) also very much dependent on how the world behave. That is exactly what happened when the Pandemic Covid-19 hits the world in early 2020.

Pandemic Covid-19 impacted whole aspect of human life, more specifically related to human transportation behavior. Lockdown and area restrictions that were and still applied in many parts of the world limited the movement of people from one place to another. The need for transportation was clearly reduced which can be reflected by the steep decline of global fuel consumption ranging from 20% for diesel, 40% for gasoline and up to 70% for Jet Fuel. Given that two-thirds of oil consumption is accounted by transport it was no surprise that global oil consumption also decline from 100 million barrels per day to 80 million barrels per day (Nagle, P. 2020).

Lower oil demand correlates with the increasing of oil inventories because oil producer may not instantly decrease its production capacity. Total surplus of oil production capacity of OPEC's country reaches 6.15 million barrels per day in 2020, more than three times compare in 2018 around 1.56 million barrels per day (US Energy Information Administration, 2020). Other data from Organization for Economic Co-operation and Development (OECD) countries shows similar profile where the oil inventories in 2020 reach 3.2 MMstb compare to 2.8 MMstb in 2018.

Lower oil demand correlates with the increasing of oil inventories because oil producer may not instantly decrease its production capacity. When maximum inventories reached, oil company – where in this research focus on PT.CPI – shall perform production curtailment by shutting down their producer wells to reduce production capacity. As simple as it may sound, production curtailment scenario needs to be assessed to find the optimum scenario in that meets safety, compliance, and economic aspects.

The objective of this research is to develop the most optimum curtailment scenario that meet safety, compliance, and economic requirements. This research is expected to recommend and establish an executable scenario when the curtailment is mandated to be executed.

LITERATURE REVIEW

In this chapter, will explain the theory on four main items that will help readers understand the research. First is about the process flow of an Oil Company, second is about concept of production curtailment, third and fourth is about tools that is used in this research: Value Focused Thinking (VFT) and Analytic Hierarchy Process (AHP).

A. Oil and Gas Operation Process Flow – PT. CPI

Figure 1 below shows a simplified schematic of PT. CPI. It started with the Production Wells and end up in the Shipping Tankers out to customers. Since the pandemic Covid-19, although oil demand at the end customer (vehicle owner, industry fuel consumer) declined, PT. CPI still operate at normal rate which means relatively constant oil volume send from production wells as well as relatively stable oil volume send out to customers. Hence the oil stocking occurred at PT. CPI's direct customer, until to the point that they feel need to notify PT. CPI the possibility of production curtailment.

Fig. 1. PT. CPI Operation.

There are around 6000 production wells categorized in 45 quadrants of PT. CPI heavy oil fields. Almost 97% of that wells used artificial lift equipment to bring the oil from the ground. The function of an artificial lift unit is to convert the rotating motion of the prime move into the up-and-down motion of the polished rod (Unlimited Petroleum Consulting Inc, n. D). Volume of oil will rise to the surface during this-up-and-down motion.

Casing Vapor Collection (CVC) and Automatic Well test (AWT) Station are located downstream of the production wells. Main objective of CVC station is to separate liquid from vapor and resulted with two main products: light and heavy oil. While AWT station function is to measure the oil production rate of every production wells.

Central Gathering Station (CGS) located downstream of the CVC & AWT Station. It is the last processing facility prior to sending the oil to customer. In CGS there are two sub-plant that have equally important function. Oil Treatment Plant (OTP) aim to separate water and solid from the oil until it meets the specification required by customer which is BSW (Base, Sediment and Water) less than 1%. Another sub-plant is Water Treatment Plant (WTP) that aim to treat the separated water until the oil content is less than 3% prior injection to water disposal well or oil content less than 1% used for steam generation.

B. Production Curtailment

Curtailment is the act of restricting or reducing something or cutting it short. A company may impose a curtailment on production in response to short-term market conditions. This is particularly common in the oil and gas industry, where the supply and demand are known to be very volatile and any company that produced oil and gas need to respond quickly to this kind of changes (Investopedia, 2020). Global pandemic Covid-19 added more pressure to the oil market that was already volatile. Many oil producers around the world such as United States already shutting in wells and cutting expenses up to at least 2 million barrel per day of oil curtailment in June 2020 (Natural Gas Intelligence, 2020). Typically, oil producers may use several combinations of measures to reduce oil production such as delaying drilling of new wells, moderating output from producing wells, holding oil on a storage tanks or temporarily shutting in lower margin wells.

C. Value Focused Thinking (VFT)

There are several concepts of value-focused thinking that are important to define. These several items can be considered as the essence of value-focused thinking framework (Keeney, 2008, p.8):

1) Values
Values represents list of all that we care to achieve in regards with the related problem. Values are decomposition of the fundamental objectives which construct the building block of value hierarchy (Jurk, 2012, p.27)
2) Objectives
Objectives define values in a more specific and coherent manner which will be useful for decision making. It is helpful if objectives are stated using a verb and an object.
3) Attributes
Attributes is a scale to measure whether objective is met. There are attributes that can easily be measured such as total cost, length, or weight. However, there is also proxy attribute that does not directly indicate the achievement of an objective.

A conceptual model of how VFT can help to generate alternatives can be seen from Figure 2 which was derived from Buchanan (Buchanan, 1998). Alternatives are potential solution designs that could have outcomes measured in terms of the criteria. The criteria reflect the values of the decision makers and key stakeholders. Attributes are defined as the objectively measurable features of an alternative.

Buchanan's model separates the subjective from the objective components. Without VFT, there is a danger that the generated alternatives may only consider the criteria or value that only reflect certain values and ignore other possibilities. Although, there is a challenge that with VFT approach the stakeholder values may not be sufficiently well formed. However, if we design something for the future, value-focused approach is the best way to encourage innovation solutions (Parnell, West, 2008, p.3).

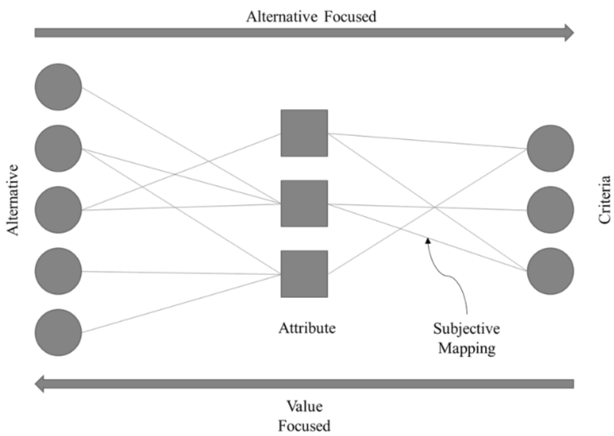

Fig. 2. VFT Conceptual Model.

D. Analytic Hierarchy Process (AHP)

Pairwise comparison from AHP provides a model to synthesize the decision maker's opinion into a numerical value. The value is obtained from a comparison of the importance level between two criteria and assigns an absolute number to represent the relative degree of importance.

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The whole process of pairwise comparison is explained in the following steps:

1. Generate a paired comparison matrix. A paired comparison matrix is expressed in the following equation:

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \quad (1)$$

2. Compare the importance of one criterion relative to another criterion
3. Describe importance level by assigning an absolute number from 1 to 9 to more critical criterion and the reciprocal value of that number to its pair criterion
4. Normalize and average the value to obtain the weight for each of the criterion
5. Check consistency of the obtained degree of importance for the attributes to confirm that pairwise comparison is rational and suitable. Let C signify an n-dimensional column vector relating to the sum of weighted values for the importance degrees of criteria:

$$C = [c_i]n * 1 = A * WT, \quad i = 1,2, \dots .n, \quad (2)$$

where,

$$W^T = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} . [w_1, w_2, w_n], \quad (3)$$

$$T = \begin{bmatrix} c_1 \\ c_2 \\ \dots \\ c_n \end{bmatrix}$$

Vector CV = $[cv_i]_{1*n}$, specify consistency values for customer demand cluster which computed as follows:

$$cv_i = \frac{c_i}{w_i}, \quad i = 1,2, \dots, n. \quad (4)$$

Saaty also recommend application of maximal eigenvalue λ_{max} to assess the validity of measurements. The maximum eigen value λ_{max} can be determined by using the following equation:

$$\lambda_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}, i = 1,2, \dots, n. \quad (5)$$

To obtain the consistency ratio, first, the Consistency Index (CI) needs to be calculated. For each of the pairwise comparison matrix, the consistency index is calculated using the below equation where λ_{max} is the maximum value obtained from the Eigenvalue matrix, and n is the total number of criteria.

$$CI = \frac{\lambda_{max} - n}{n - 1}, \quad (6)$$

The final consistency ratio (CR) is calculated using the following equation:

$$CR = \frac{CI}{RI}, \quad (7)$$

RI is the random index based on the average value for CI on a random pairwise matrix for each of n criteria. The value of RI for each n criteria are as follow:

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Fig. 3. Random Index for AHP

Methodology

Based on a problem root cause analysis and objective tree analysis, to achieve research objective in developing "the most optimum curtailment scenario" a guideline to select wells and facilities to be shutdown need to be developed. This guideline will help PT. CPI to properly execute curtailment when required. This guideline will consider multiple aspects that is considered critical by PT. CPI to maintain operational excellence during curtailment period.

In developing the solution, a research methodology is designed to lay out the flow process for each of the step, as described in Figure 4. The process is started by generating alternatives using Value Focused Thinking (VFT) Method. It will then continue with developing criteria or attributes to achieve optimum shutdown scenario. Using multi-criteria decision making (MCDM), the specific weight will be determined and assigned to each of the criterion or attributes to reflect the relative importance among each criterion. After all the criteria have appropriate weights, the scoring process will be conducted for all production wells along with its related facility that will be represented as curtailment scenario alternatives subject to be selected. The selected curtailment scenario will define the operational scenario of wells and its related facility during the curtailment period. The decision-making process was conducted through cross function group discussion that were attended by several different teams in PT. CPI. There is representative from Asset Optimization Teams who deals with reservoir impact of this curtailment, representative from Subsurface Integrity Teams who deals with well integrity risk, representative from Heat Team who deals with impact to steam distribution, representative from Operation Teams who deals with daily operation of the facilities, Facility Engineering who review process engineering aspects of curtailment and finally the Hydrocarbon Transportation Team who is the direct counterpart to PT. CPI's buyer.

After curtailment scenario is developed, this guideline can be integrated into PT. CPI Operational Procedures. This updated procedure will be ready to use when curtailment is finally mandated. PT. CPI can execute the shutdown comfortably, knowing that all necessary aspects to achieve operational excellence had been considered and assessed.

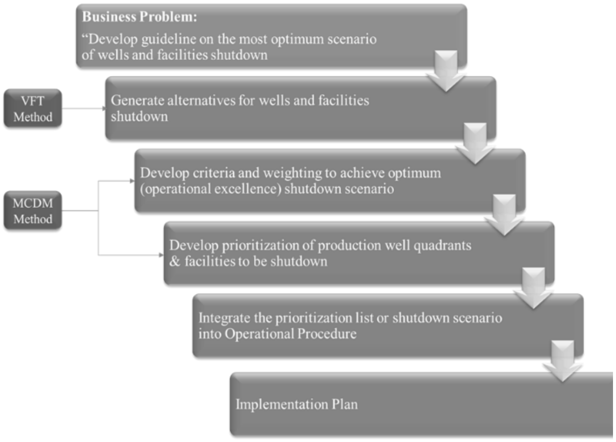

Fig. 4. Research Methodology

FINDINGS AND DISCUSSION

This research aims to establish shutdown guideline that can meet expected value from all stakeholders. Value Focused Thinking (VFT) is a framework that is selected on this research to ensure that alternative generated for decision making will comprehensively serve the expected value. Figure 5 shows the process flow of alternative generation using VFT where it started from the right (expected value) and move to the center (establish objective to meet the value) which end at the left part of the process flow (enlist executable alternatives to achieve objective).

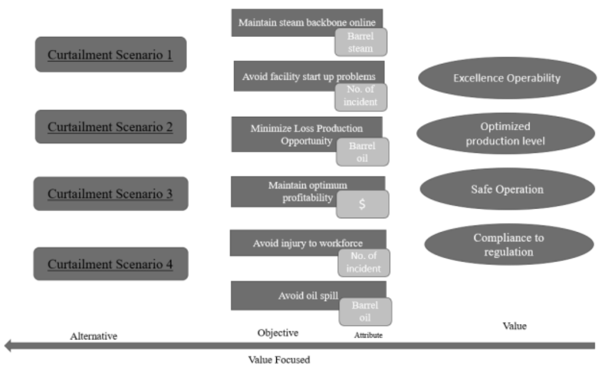

Fig. 5. Process Flow of alternatives generation using VFT

Seven pairwise comparison matrices are generated in the process of selecting curtailment scenario. One matrix is for comparison of the objectives / attributes with respect to the values, the other six matrices are for the alternatives in respect to the objectives / attributes. Each objective is represented in one table: Avoid Oil Spill, Avoid Injury to Workforce, Maintain Optimum Profitability, Minimize Loss Production Opportunity, Avoid Facility Start-up Problem, Maintain Steam Backbone.

Having completed all the pairwise comparison up to consistency check for each alternative and objective, now we know criteria weight for each alternative and objective. Figure 5 shows summary of the criteria weights. Next step to achieve decision making of the best curtailment scenarios is by synthesizing all the criterial weight, multiplying each criteria weight with the alternative rank on those criteria. Alternative with the highest total sum of weighted aggregate value is the best alternative.

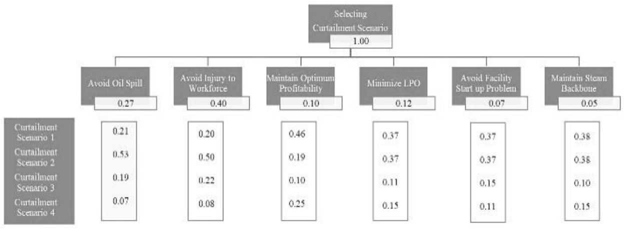

Fig. 5. Objectives Weight and Curtailment Scenario Aggregate

Calculation of weighted aggregate value of each scenario alternative in respect to the objectives resulted in Figure 6 which shows Curtailment Scenario 2 as the best alternative for curtailment. Curtailment scenario 2 involves major activities such as shutting down producer wells but only wells with low subsurface integrity risk. It also involves shutting down the related steam injector wells but will ensure steam pipeline backbone from North to South is still in operation. Finally, it will not shutdown Central Gathering Station (CGS) rather it will keep all CGS running but at its safe minimum capacity. Scenario 2 met the objective and value better than other scenarios.

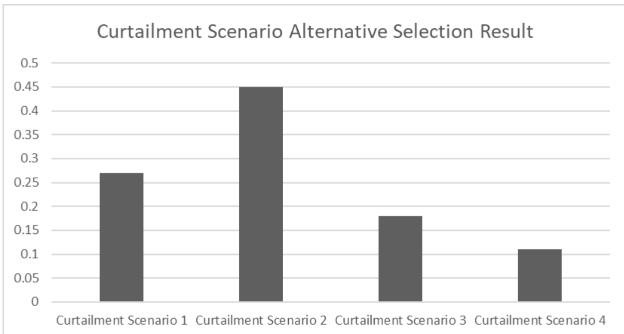

Fig. 6. Alternative Selection Result

CONCLUSION

Final synthesized result from AHP methods has shown that curtailment scenario 2 is the best alternative that able to meet the stakeholder's expected objective of an optimum curtailment scenario. Curtailment scenario 2 involves major activities such as shutting down producer wells but only wells with low subsurface integrity risk. It also involves shutting down the related steam injector wells but will ensure steam pipeline backbone from North to South is still in operation. Finally, it will not shutdown Central Gathering Station (CGS) rather it will keep all CGS running but at its safe minimum capacity. PT. CPI accepted the curtailment scenario proposal and will develop an executable standard operating procedure scenario 2 to be used when it is deemed necessary. Prior to this research, PT. CPI did not have detailed shutdown scenario to anticipate curtailment issue.

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