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Kepner-Tregoe and Analytic Hierarchy Process for Decision Support in Selecting Low-Capacity Pumps at Refinery Unit Vi Balongan

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Abstract

Following the execution of the RDMP Phase-1 project in early 2022, the crude distillation unit (CDU) RU-VI Balongan experienced operational issues. All of the CDU equipment was inspected, and observations showed that there was a difference between the designed capacity and the operational capacity needed for the LGO and HGO product pumps. This difference may result in operational losses for RU-VI Balongan due to limited CDU capacity. This issue requires prompt attention to ensure the sustainable achievement of the operational assignment targets for the RU-VI Balongan Refinery. This study aims to assist management in addressing the capacity limitations of the LGO and HGO product pump. In this article, the author utilizes many methodological approaches for a more extensive and thorough understanding. The author employs the Kepner Tregoe problem analysis methodology, focus group discussions, and structured interview procedures to investigate corporate challenges. The author also employs the stakeholder analysis method to determine stakeholders' expectations for problem resolution. The author developed three alternative solutions: increasing the pump impeller diameter, developing an identical pump, and retrofitting the existing pump. Using subject matter experts with decision-making power in the RU-VI Balongan refinery setting, the author used the Analytic Hierarchy Process (AHP) to find the best option. The findings of this study demonstrate that the addition of a pump unit is the optimal approach, offering superior quality, reliability, and the most suitable after-sales support. Upon concluding this research, the author recommends a strategy for executing the optimal solution to resolve the capacity challenges of LGO and HGO product pumps.

Keywords: Gap operational capacity of pump, Operational of crude distillation unit, Operational pumps selection criteria, Kepner Tregoe Problem Analysis, Analytic Hierarchy Process (AHP)

1 INTRODUCTION

The crude distillation unit (CDU), the first significant processing unit in refinery production planning, heats crude oil and divides it into its various components based on their boiling points. CDU often consists of several sections, one of which is the stripping unit. The stripping unit's goal is to improve CDU separation efficiency and product quality by eliminating lighter hydrocarbons from the liquid fraction and ensuring that each product is appropriately refined and meets necessary standards. RU-VI Balongan equips the CDU with two stripper units, LGO and HGO, for efficient separation. These units collect and transport Their products from the bottom of the stripper column utilizing LGO and HGO product pumps.[1]

To meet the growing demand for petroleum products in Indonesia, PT Kilang Pertamina International RU-VI Balongan is strategically planning its expansion. In early 2022, RU-VI Balongan completed the RDMP Phase-1 project, marking the initial stage of the implementation plan. It effectively increased the CDU's capacity from 125 to 150 MMBSD.

The commissioning phase of the project revealed that the unit stripper LGO needed to simultaneously operate both the primary product pump and the standby product pump to balance the new capacity of the crude distillation unit. The same situation occurs with the unit stripper HGO; the primary HGO product pump operates in tandem with the standby HGO product pump to balance the new capacity of the CDU. Figure 1.1 below outlines the increasing operational capacity required for both LGO and HGO product pumps.

Refineries strictly design their equipment processes to ensure uninterrupted, continuous operation over time. Refineries prioritize high plant operational availability, making redundancy crucial. It is a strategy decision based on balancing safety, reliability, operational continuity, economic impact, and regulatory requirements (Calixto, 2016)[1]. Post the completion of the RDMP Phase-1 project, it can be tentatively concluded that the operational LGO and HGO product pumps of crude distillation unit RU-VI Balongan do not match the standard operating design requirement. Once one of the tandemly operated LGO and HGO pumps malfunctions, the entire crude distillation unit process must be decelerated, which may result in limited operation.

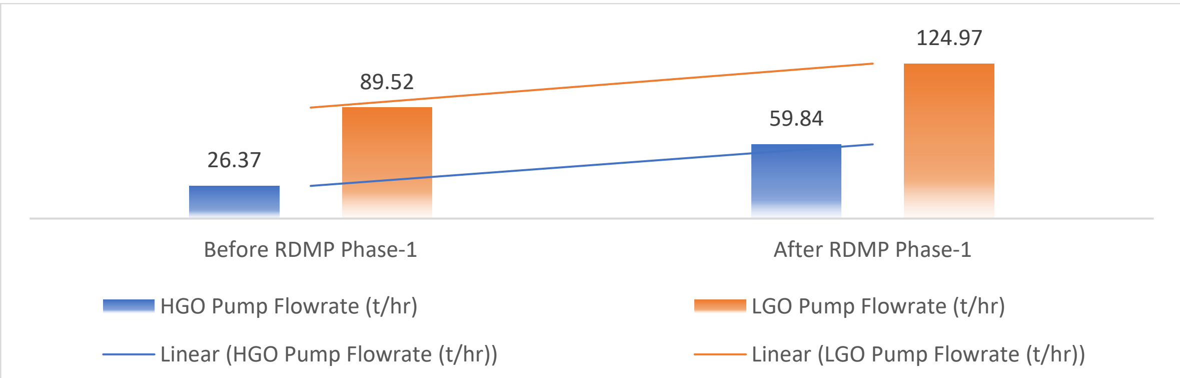

Figure 1-1 Compared flowrate of the pump before-after RDMP Phase-1

2 LITERATURE REVIEW

2.1 Kepner Tregoe Problem Analysis

This study uses the Kepner-Tregoe (KT) Problem Analysis approach to determine the root cause of low-capacity stripper product pumps 11-P-107A/B and 11-P-108A/B. Begin with finding the root cause of a problem, which includes defining it, describing it, identifying potential causes, establishing a possible cause, testing the most probable cause, and verifying the true probable cause (Tregoe, 1981)[2].

2.2 Analytical Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) was founded in the 1980s by Saat and nowadays is widely used in business as a method for decision-making processes that require the consideration of multiple criteria and the integration of quantitative and qualitative factors. This study will utilize the Analytic Hierarchy Process (AHP) to further process the data and identify the most effective alternative solution. The process

[1] Calixto, D. E. (2016). *Gas and Oil Reliability Engineering Modeling and Analysis*. USA: Elsevier Inc. p. 306
[2] Tregoe, C. H. (1981). *The New Rational Manager*. USA: Princeton NJ p. 38

involves evaluating the criteria and alternative solution data by generating a structure hierarchy, generating a pairwise comparison, creating matrices for numerical judgement, normalizing these matrices, transforming the matrix into a weight sum vector, calculating the principal eigenvalue (λmax), determining the consistency index (CI), and finally calculating the consistency ratio (CR) (Wright, 2004)[3].

3 METHODOLODY

This study use framework as shown in figure 2.1 below.

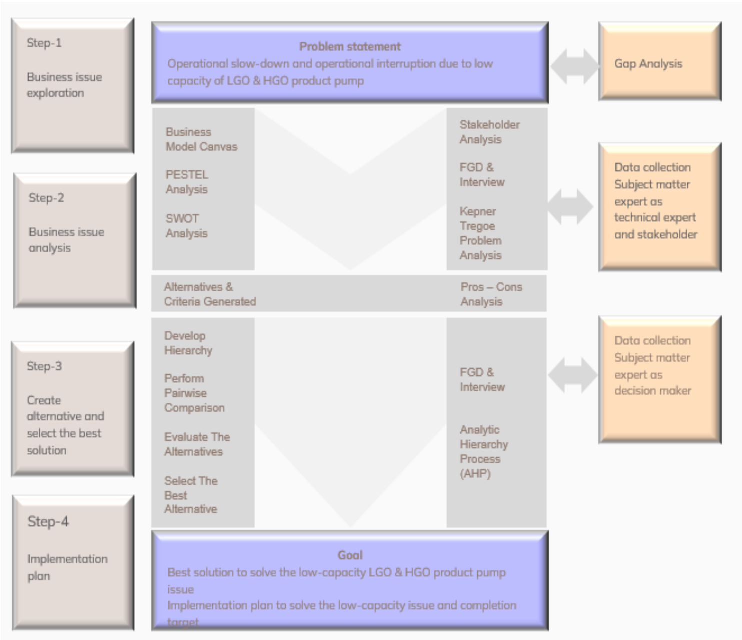

Figure 3-1 Conceptual framework

The framework illustrates the issue is examined using Kepner Tregoe problem analysis in order to identify the root cause. Through focus group discussions, by utilizing the Kepner-Tregoe problem analysis worksheet, SMEs identify potential solutions and criteria. In order to choose the best solution from the alternative solution, Analytic Hierarchy Process (AHP) approach is conducted. The study aims to ensure process availability and operational reliability of the LGO and HGO product pumps, which are utilized to support the stripper unit of the RU-VI Balongan crude distillation unit.

[3] Wright, P. G. (2004). *Decision analysis for management judgement* (3rd ed.). West Sussex, England: John willey & sons, Ltd page 414

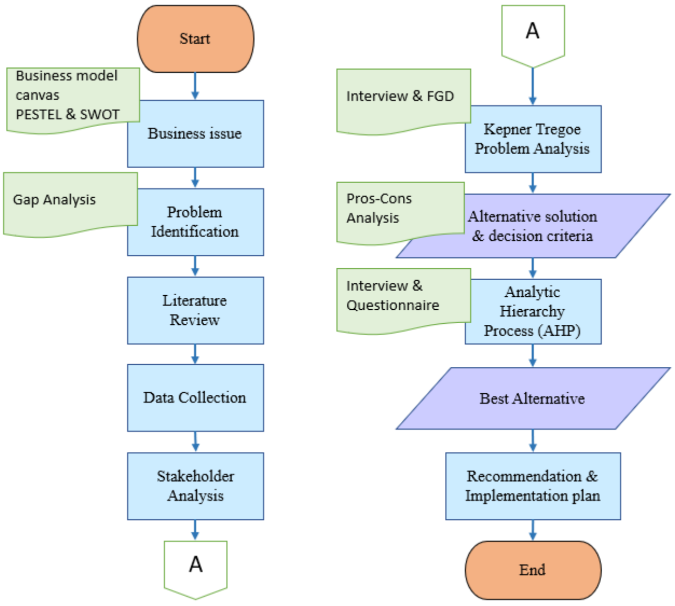

Figure 3-2 Sequence of Study

This study follows the common steps for problem solving, as illustrated in figure 3-2. These steps include identifying the issue, analysing the problem using Kepner-Tregoe problem analysis, creating, and conducting a risk assessment of the criteria, generating and evaluating an alternative solution, developing alternative solutions in multiple ways, proposing and implementing a solution using the Analytic Hierarchy Process (AHP), and finally planning for the best solution realization.

4 FINDINGS AND ARGUMENT

A focus group discussion among subject matter experts was conducted to find the root cause of the problem. The subject matter experts (SMEs) included a process engineer, an inspection engineer, an operation crew, and an execution crew, all of whom possessed competence and experience in the operational and reliability aspects of the CDU series equipment. A Kepner-Tregoe problem analysis worksheet was used on this brainstorming phase. After finishing the worksheet, an alternative solution was generated using the scamper technique. The SMEs apply best practices and risk assessment in the RU-VI Balongan business process to gather alternative solutions, and they suggest criteria for subsequent selection steps. The result of the creation and evaluation of the criteria are detailed as follows:

1. **Price:** low cost may be associated with increased expense in the long run due to maintenance as well as increased equipment failure that could lead to an impact on the overall unit of CDU efficiency.
   Mitigation: Evaluate the overall cost of ownership, which includes potential future repair costs, rather than just the initial price.
2. **Aftersales service:** insufficient aftersales service may result in prolonged periods of interrupted operation during maintenance and difficulty in purchasing spare parts. This could lead to increased downtime and affect overall production activity.
   Mitigation: Evaluate the vendor's service network, their response time, and the availability of spare parts in the marketplace.
3. **Quality and reliability:** Low quality and reliability may lead to a higher failure rate, resulting in an

unexpected shutdown due to increased maintenance activity. This could result in significant production losses and potentially trigger safety issues.
Mitigation: Evaluate the vendor's product reliability record, certification, and customer reviews to mitigate the risk.

4. **Geographic location:** If a supplier is located far away, it may result in delayed delivery and increased transportation expenses. This could extend the period of pump inactivity and increase the risk of production loss.
Mitigation: Prioritizing vendors with the same location and availability of their local agent or local authorized workshop can mitigate this risk.
5. **Ease of use:** A difficult-to-operate pump could lead to being miss operated and/or mishandled during maintenance. This could increase operational risk and potential safety hazards due to improper use or maintenance.
Mitigation: Evaluate the pump design, necessary training, and maintenance complexity to mitigate the risk.

Table 4-1 Scamper technique

Root cause	Scamper technique	Proposed solutions
The low-capacity LGO Product Pump 11-P-107A/B and HGO Product Pump 11-P-108A/B due to the difference of capacity between capacity design and operational pump capacity required after completion of RDMP Phase-1 RU-VI Balongan.	Substitute	Replace the pump with a suitable design
	Combine	Add a new identical pump and operated two identical pumps tandemly
	Adapt	Adjust pump's feed, specific gravity of the gas oil
	Modify	Increase diameter of pump impeller
	Put to another use	Use the portable pump to fill the required capacity gap.
	Eliminate	Full-operated pump, no spillback or throttling of the discharge valve
	Rearrange	Adjust the CDU capacity to match the pump capacity, but only during periodic maintenance.

After evaluating and utilizing the scamper technique, three alternative solutions were finalized.
1. Increase diameter of pump impeller through modification work.
2. Replace the pump with suitable design.
3. Add new identical pump.

4.1 Hierarchy Structure

Refers to AHP procedures, this study using following hierarchy structure to approach the gap capacity of pump problem.

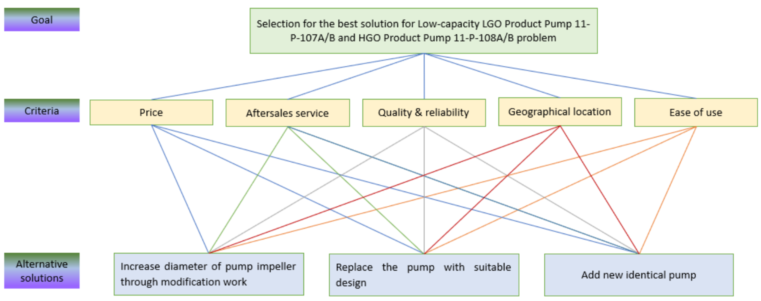

Figure 4-1 Hierarchy Structure of the Problem

4.2 Respondent profile, rule, and responsibility (SMEs)

This study conducted interviews and used Google Form questionnaires on the website to gather expert opinions for a pairwise comparison of criteria and alternative solutions. The SMEs involved are the top management of RU-VI Balongan, who have been authorized as decision-makers. The roles and profiles of the SMEs are listed below:

Table 4-2 SME profile, role, and responsibility

No	Subject Matter Expert	Role
1	General Manager	Top management leader, responsible for business process and operation
2	Senior Manager Operation & Manufacturing	Second man top management leader, responsible for business process and maintenance
3	Reliability Manager	Responsible for operation & maintenance reliability
4	Manager Planning & Support	Responsible for assessment and inspection
5	Manager Maintenance Execution	Responsible for execution maintenance activity
6	Manager Refinery Planning Optimization	Responsible for refinery operational optimization
7	Manager Production I	Responsible for sustainability operation primary area
8	Manager production II	Responsible for sustainability operation secondary area (supporting such as utility, etc)
9	Manager Engineering & Development	Responsible for refinery process operation & development

4.3 Pairwise comparison

The interview results of these SMEs were aggregated using Natural Logarithmic Least Square Methodology (LLSM). The result of the calculation is shown in the following Table 4-2

Table 4-3 Aggregate pairwise comparison of criteria and alternative solutions.

Criteria	Aggregate	Criteria	Aggregate
Price	0,178	Aftersales	5,6169
Price	0,1608	Quality &	6,2199
Price	0,2894	Geographical	3,4553
Price	2,7375	Ease of use	0,3653
Aftersales	0,3966	Quality &	2,5215
Aftersales	3,257	Geographical	0,307
Aftersales	5,7756	Ease of use	0,1731
Quality &	3,6359	Geographical	0,275
Quality &	7,5733	Ease of use	0,132
Geographical	3,4553	Ease of use	0,2894

Criteria	Alternative Solution	Aggregate	Alternative Solution	Aggregate
Price	Increase diameter of pump impeller	0,4597	Add new identical pump	2,1752
	Increase diameter of pump impeller	4,5446	Replace the pump	0,22
	Replace the pump	0,2329	Add new identical pump	4,2938
Aftersales	Increase diameter of pump impeller	0,1541	Add new identical pump	6,4898
	Increase diameter of pump impeller	0,3362	Replace the pump	2,9745
	Replace the pump	0,5478	Add new identical pump	1,8254
Quality &	Increase diameter of pump impeller	0,1481	Add new identical pump	6,7521
	Increase diameter of pump impeller	0,23	Replace the pump	4,3482
	Replace the pump	0,5369	Add new identical pump	1,8627
Geographical	Increase diameter of pump impeller	3,7646	Add new identical pump	0,2656
`	Increase diameter of pump impeller	6,8688	Replace the pump	0,1456
	Replace the pump	0,5132	Add new identical pump	1,9486
Ease of use	Increase diameter of pump impeller	0,2079	Add new identical pump	4,8099
	Increase diameter of pump impeller	1,8411	Replace the pump	0,5432
	Replace the pump	0,1242	Add new identical pump	8,049

4.4 Synthesizing the data

Table 4-4 Priority vector of criteria and alternative solutions

Criteria	Priority vector
Quality & reliability	0,4567
Price	0,0704
Aftersales service	0,2888
Ease of use	0,0427
Geographical location	0,1414

PRICE	Priority vector	QUALITY & RELIABILITY	Priority vector	EASE OF USE	Priority vector
Increase diameter of pump impeller	0,3427	Increase diameter of pump impeller	0,0816	Increase diameter of pump impeller	0,1609
Replace the pump	0,1014	Replace the pump	0,3338	Replace the pump	0,0902
Add new identical pump	0,5559	Add new identical pump	0,5846	Add new identical pump	0,7489

AFTERSALES SERVICE	Priority vector	GEOGRAPHY LOCATION	Priority vector
Increase diameter of pump impeller	0,0975	Increase diameter of pump impeller	0,7071
Replace the pump	0,3075	Replace the pump	0,1008
Add new identical pump	0,595	Add new identical pump	0,1921

4.5 Develop Priority Ranking

The hierarchy structure of the low-capacity LGO and HGO product pumps provides the following description of the synthesizing result:

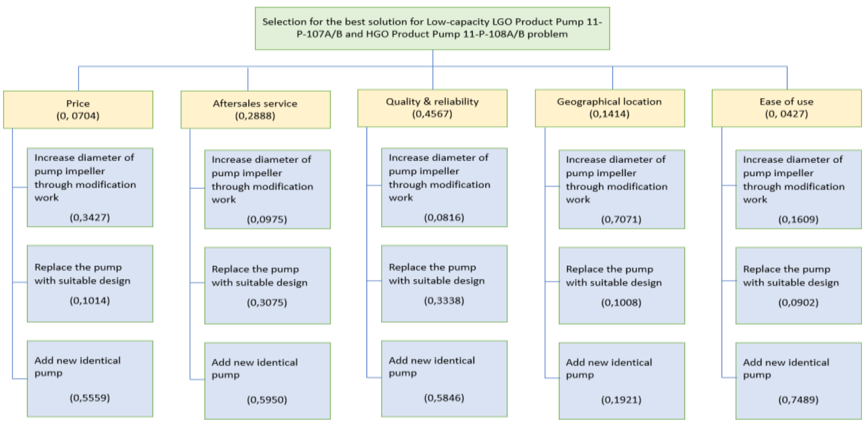

Figure 4-2 Priority ranking of criteria and alternative solution.

The priority ranking of alternative solutions is calculated using the following matrix multiplication method:

$$\begin{aligned} &Ranking\ of\ alternative\ solution \\ &= \begin{bmatrix} increase\ diameter\ of\ impeller \\ replace\ the\ pump \\ add\ new\ adentical\ pump \end{bmatrix} [combined\ eigen\ value] x [eigen\ vector] \\ &= \begin{bmatrix} 0{,}3427 & 0{,}0975 & 0{,}0816 & 0{,}7071 & 0{,}1609 \\ 0{,}1014 & 0{,}3075 & 0{,}3338 & 0{,}1008 & 0{,}0902 \\ 0{,}5559 & 0{,}5950 & 0{,}5846 & 0{,}1921 & 0{,}7489 \end{bmatrix} x \begin{bmatrix} 0{,}0704 \\ 0{,}2888 \\ 0{,}4567 \\ 0{,}1414 \\ 0{,}0427 \end{bmatrix} = \begin{bmatrix} 0{,}1967 \\ 0{,}2665 \\ 0{,}5371 \end{bmatrix} \end{aligned}$$

The results show that "add new identical pump" gets the highest score (53.71%). Referring to criteria ranking, the best alternative "add new identical pump" gained the majority score on criteria quality and reliability (45.67%), followed by after-sales service (28.88%) and geographical location (14.14%).

4.6 Consistency Ratio

The consistency ratio is used to verify the random judgments made by subject matter experts (SMEs) during pairwise comparison are logically sound or consistent.

Table 4-5 Consistency ratio of criteria

CRITERIA	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Quality & reliability	0,4567	2,4601	5,3866	5,254	0,0635	0,0567	ACCEPTABLE
Price	0,0704	0,353	5,0156				
Aftersales service	0,2888	1,5724	5,4447				
Ease of use	0,0427	0,2196	5,1457				
Geographical location	0,1414	0,7464	5,2774				
ALTERNATIVE SOLUTION Price	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Increase diameter of pump	0,3427	1,0589	3,0899	3,0783	0,0392	0,0675	ACCEPTABLE
Replace the pump	0,1013	0,3062	3,0216				
Add new identical pump	0,556	1,7365	3,1235				
ALTERNATIVE SOLUTION Aftersales service	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Increase diameter of pump	0,0975	0,2925	3,001	3,004	0,002	0,003	ACCEPTABLE
Replace the pump	0,3075	0,9234	3,003				
Add new identical pump	0,595	1,7889	3,006				
ALTERNATIVE SOLUTION Quality & reliability	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Increase diameter of pump	0,0816	0,245	3,001	3,004	0,002	0,003	ACCEPTABLE
Replace the pump	0,3338	1,0026	3,004				
Add new identical pump	0,5846	1,7575	3,006				
ALTERNATIVE SOLUTION Geography location	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Increase diameter of pump	0,1608	0,4826	3,0005	3,001	0,0005	0,0009	ACCEPTABLE
Replace the pump	0,0902	0,2706	3,0003				
Add new identical pump	0,749	2,2486	3,0023				
ALTERNATIVE SOLUTION Ease of use	Average	STEP-1 Sum	STEP-2	STEP-3 λmax	STEP-4 CI	STEP-5 CR	REMARKS
Increase diameter of pump	0,1608	0,4826	3,0005	3,001	0,0005	0,0009	ACCEPTABLE
Replace the pump	0,0902	0,2706	3,0003				
Add new identical pump	0,749	2,2486	3,0023				

The calculation result from Table 4-5 above shows that SMEs' numerical judgments for the criteria and alternative solutions are consistent.

5 CONCLUSION AND IMPLEMENTATION PLAN

Using five criteria: quality and reliability, aftersales service, geographical location, price, and ease of use, the best solution to close the gap capacity of LGO and HGO product pumps is to add a new identical pump to each of the existing LGO and HGO product pumps, 11-P-107C and 11-P-108C. After the best solution is implemented, each LGO product pump and HGO product pump will operate in tandem, with an approximate flowrate of 201.45 tons/hr for the LGO product pump and 89.06 tons/hr for the HGO product pump.

The final hierarchy tree for the problem is shown below:

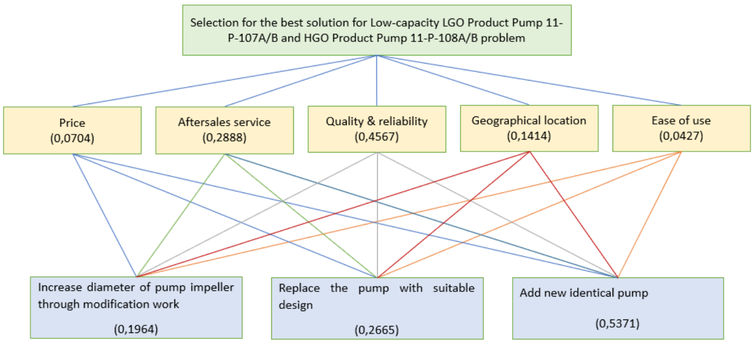

Figure 5-1 Hierarchy tree of proposed solution

To address the capacity differences between the stripper pump product capacity and crude distillation unit capacity of RU-VI Balongan, it is advisable to install a new identical pump, 11-P-107 C, to support the LGO product pump and 11-P-108 C to support the HGO product pump. RU-VI Balongan should carefully evaluate the suggested implementation plan presented below.

1. Project taskforce

According to RU-VI best practices, the taskforce team should be arranged to consist of multiple elements, such as the general manager as project owner, manager MPS, manager procurement and manager production as project manager, vendor as a stakeholder for the supplier and execution team, and planning and scheduling as the project controller.

2. Process

a. Detailed engineering design

To achieve the gap capacity, a feasibility study should be conducted to review existing equipment and propose the new installation, such as a new piping system, a new cable power arrangement, a new space for the pump foundation, and an electric motor driver.

b. Procurement

Create a comprehensive task list that encompasses the specifications of a new, identical pump, electric motor driver, and the necessary materials for the installation and maintenance of the site. Vendor selection that possesses related capability should be carefully selected to ensure quality and approval and estimate the total required budget. And carefully scheduling the delivery of the required material.

c. Execution plan

Site work preparation, quality plan and control, safety execution plan and control, and stakeholder communication network.

3. Tools

The project needs to be monitored and controlled to achieve the settled target. Several tools, including risk management, quality assurance, and resource management, are necessary for controlling the project.

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