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Decision Analysis to Avoid Unplanned Shutdown and Catastrophic Failure Due to Sour Crude Oil Processing in Crude Distillation Unit (CDU)

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Abstract

The Crude Distillation Unit (CDU) plays a pivotal role as the primary production unit in crude oil processing. Changes in the operational patterns of crude oil processing have unveiled potential issues that demand the refinery's capability to process Sour Crude. This type of crude oil contains relatively high impurity levels, with a Total Acid Number (TAN) of 0.3 Mg KOH/g and a sulfur content of 1.5 wt%. This has the potential to impact the remaining life and damage modes of equipment and pipes in the Preheater System due to an increase in corrosion rates. This study aims to identify the root causes and propose alternative solutions to address the possibility of damage, particularly leaks, in the Preheater system of the CDU. The focus is on preventing unplanned shutdowns and reducing the risk of catastrophic issues that may arise from the damage to the CDU's preheater system. These steps are crucial to ensuring the continuity of feed supply for secondary processes and valuable product stocks, essential for the operations of Refinery unit. The research employs Fault Tree Analysis (FTA) and Analytic Hierarchy Process (AHP) methods to evaluate several alternative solutions. The analysis results are expected to provide guidance in selecting the most effective and efficient solution, minimizing the risk of preheater system damage, and maintaining the optimal performance of the CDU.

Keywords: analytic hierarchy process, corrosion, crude oil, crude distillation unit, fault tree analysis

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1. Introduction

The Refinery unit is one of the refineries with the main business activities of processing crude oil and naphtha into fuel oil, and Petrochemical products. The RU VI refinery started operating in 1994, designed to operate at a production capacity of 125 Million Barrel Steam per Day (MBSD) with a feed composition ratio of 80% and 20% crude Duri (heavy oil) and crude Minas (light oil) (Pertamina Energy Outlook, 2021).

The crude oil distillation unit (CDU) is one of the main units and is the primary processing for processing crude oil into a valuable product and the bottom product (atmospheric residue) from the CDU into feed and processed again at the ARHDM (Atmospheric Residue Hydrodemetallization) Unit and partly more directly to the RCC (Residual catalytic Cracking) Unit. Along with the depletion of crude oil sources and world crude oil prices, PT Kilang Pertamina Internasional must make changes to its business processes by processing crude oil by adding and mixing other crude oil that has a high impurity content such as Teak Goods

Mixed Crude Oil (JMCO), Nile Blend, MUDI (Gresik), Banyu Urip, and AZERI (Malaysia), Low Sulphur Waxy Residue V (LSWRV), Banyu Urip Crude Oil (BUCO), LSL and Qarun.

Changes in Processing Business Patterns that require the ability of refineries to be able to process Sour Crude Oil. Based on the simulation approach in the worst conditions by adding other crude oil, the estimated crude acid impurities can reach a maximum Total Acid Number of 0.3 Mg KOH/g and Sulphur content of 1.5 wt% Sulphur vs Total Acid Number of 1.47 Mg KOH/g and Sulphur content of 0.37 wt% Sulphur design.

Based on API RP 581 Risk Based Inspection, the use of sour crude with a maximum Total Acid Number of 0.3 Mg KOH/g and Sulfur content of 1.5 wt% Sulfur at a temperature of ±280oC with a Carbon Steel material design will have an impact on an increase in the corrosion rate in the Preheater system to 0.89 mm per year (mmpy) due to the mechanism of High-Temperature Sulfidic and Naphthenic Acid Corrosion. So, the increase in corrosion rate has the potential to cause unplanned shutdown and catastrophic if there is a leak in the piping system in the preheater system at the Crude Distillation Unit (CDU).

Changes in the operational patterns of crude oil processing have unveiled potential issues that demand the refinery's capability to process Sour Crude. This type of crude oil contains relatively high impurity levels, with a Total Acid Number (TAN) of 0.3 Mg KOH/g and a sulfur content of 1.5 wt%. This has the potential to impact the remaining life and damage modes of equipment and pipes in the Preheater System due to an increase in corrosion rates. The research utilizes Fault Tree Analysis (FTA) as one of the frequently employed methods in decision-making and the Analytic Hierarchy Process (AHP) methods as a novel approach used to evaluate several alternative solutions. Currently, decision-making is based on the results of consensus meetings with Subject Matter Experts (SMEs).

The analysis results are expected to provide guidance in selecting the most effective and efficient solution, minimizing the risk of preheater system damage, and maintaining the optimal performance of the CDU. This study aims to identify the root causes and propose alternative solutions to address the possibility of damage, particularly leaks, in the Preheater system of the CDU. The focus is on preventing unplanned shutdowns and reducing the risk of catastrophic issues that may arise from the damage to the CDU's preheater system. These steps are crucial to ensuring the continuity of feed supply for secondary processes and valuable product stocks, essential for the operations of Refinery unit.

The research employs Fault Tree Analysis (FTA) and Analytic Hierarchy Process (AHP) methods to evaluate several alternative solutions. The analysis results are expected to provide guidance in selecting the most effective and efficient solution, minimizing the risk of preheater system damage, and maintaining the optimal performance of the CDU.

2. Literature Review

2.1 Fault Tree Analysis

Fault-Tree Analysis or Cause and Effect Tree Analysis is a method of analyzing system reliability and safety (Henley and Kumamoto, 1996). This method starts with a known event (the top event) and describes possible combinations of events and conditions that can lead to this event. The top event in the Fault Tree Analysis (FTA) can be the loss event under investigation or a specific event that is involved in the incident. The Fault Tree Analysis (FTA) describes the state of the system components (basic events) and the relationship between basic events and top events. Graphic symbols used to represent relationships are called logic gates. The output of a logic gate is determined by the events that enter the gate. Creating a fault tree by using Boolean symbols and standardization of these symbols is necessary for the communication and consistency of the fault tree.

Fault tree analysis is a method that details the deductive analysis that is usually needed to determine problems related to a system. The output of the FTA is the important possibilities that occur in a system and produce the root cause of the problem. This root cause will be used to prioritize correction action or improvement in solving a problem in the system. The steps in making a fault tree analysis is as follows:

a. Identify the most important events/ events in the system (top-level events).
b. Creating a fault tree.
c. Fault Tree Analysis, to obtain clear information from a system and what improvements should be made to the system.

2.2 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is designed to cope with both rational and intuitive to select the best from several alternatives evaluated with respect to several criteria (Saaty, 2012). The AHP is a basic approach to decision-making and a popular method for multi-criteria decision making. AHP objective is to develop a hierarchy of decision criteria and define the alternative courses of actions. The AHP method was first introduced by Thomas L. Saaty and Luis G. Vargas in 1970 (Saaty, 1988). AHP uses qualitative and quantitative criteria for evaluation. Both qualitative and quantitative information can be compared using appropriate judgments to obtain weights and priorities. The AHP method basically consists of two steps:

a. Determine the relative weight of the decision criteria.
b. Determine the relative rank (priority) of alternative solutions.

The following is the sequence of decision-making steps in AHP:

a. Construct structure a hierarchy
   Define the problem, determine the decision criteria, and identify the alternatives.
b. Create pairwise comparisons
   Assess the relative importance between each pair of decision alternatives and criteria.
c. Synthesizing Procedure
   Synthesize the results to determine the best alternative solution. The results and the output of AHP are the set of alternative priorities. The procedure of synthesizing for a pairwise comparison matrix as follows:
   - Step 1: Sum the values in each column
   - Step 2: Divide each element of the matrix by its column total. All columns in the normalized pairwise comparison matrix now have a sum of 1 (one).
   - Step 3: Average the elements in each row (priority vector/ eigenvector)
d. Consistency measurement
   The AHP provides a measure of the consistency of pairwise comparison judgments by computing a consistency ratio. The AHP provides a method for measuring the degree of consistency among the pairwise judgments provided by the decision maker to answer the consistency question. The rules of consistency degree in AHP as follows:
   - The decision process can continue if the degree of consistency is acceptable.
   - The decision maker should reconsider and revise the pairwise comparison judgments before proceeding with the analysis if the degree of consistency is unacceptable.
e. Development of Priority Ranking
   The procedure of priority ranking calculation as follows:
   - Priority ranking is obtained by calculating the priority vector (Eigen Vector) of alternative solutions for each criteria matrix.
   - Criteria ranking is obtained by calculating the priority vector (Eigen Vector) for the criteria matrix.
   - Alternative ranking calculation is obtained by multiplying the Priority vector of alternative solutions for each criteria matrix (priority matrix), with the priority vector of the criteria matrix (criteria weights).

- Ranking these priority values from the alternative ranking calculation, so we will have AHP ranking of the decision alternatives. From the results of the alternative ranking calculations, an alternative ranking matrix is obtained, where the highest score from the matrix indicates the best solution.

3. Result and Discussion

This chapter will explain the analysis and alternative solutions to business problems faced in to avoid unplanned shutdown and catastrophic due to sour crude oil processing in Crude Distillation Unit (CDU) Refinery unit by using two methods, Fault Tree Analysis (FTA) and the Analytic Hierarchy Process (AHP). Fault Tree Analysis is a technique used to identify the risks that contribute to the occurrence of failure. This method is carried out with a top-down approach, which begins by assuming failure or loss from the event peak (top event) and then details the causes of a top event to a basic failure (root cause) (Blanchard, 2004) and as one of the frequently employed methods in descision-making. On the other hand, the Analytic Hierarchy Process (AHP) is a method that, theoretically, (Saaty, 2008) has not been previously utilized in decision-making (Somonggal and Novani, 2022). AHP was initially developed by Thomas Saaty (Kasie, 2013) and the Analytic Hierarchy Process (AHP) methods as a novel approach used to evaluate several alternative solutions. Currently, decision-making is based on the results of consensus meetings with Subject Matter Experts (SMEs).

Therefore, this study is expected to serve as one of the guidelines for all employees and management of the company in decision-making processes. The primary purpose of the Analytic Hierarchy Process (AHP) involves conducting pairwise comparisons among alternatives to generate ratings that align with the theory of relative measurement, (Brunelli, 2014).

3.1 Analysis of Business Situation

More comprehensive information from various effectiveness is needed to solve problems with the best solution to avoid the unplanned shutdown and catastrophic due to sour crude oil processing in Crude Distillation Unit (CDU) Refinery unit.

3.1.1 Fault Tree Analysis

Fault Tree Analysis serves as an analytical tool that visually represents combinations of errors leading to system failure. This method proves valuable in describing and assessing events within the system (Foster, 2004). This study uses fault tree analysis to verify the true cause which can cause damage (leakage) that can cause an unplanned shutdown and catastrophic due to increased corrosion rate in the piping system of the preheat system caused by high impurities of feed (sour crude oil) Crude Distillation Unit (CDU) Refinery unit.

In this study, the brainstorming method was used to determine recommendations and alternative solutions which were determined together with Subject Matter Experts (SMEs) who have technical experts and have competence and authorization in making decisions at Refinery unit. The Subject Matter Experts (SMEs) of Refinery unit can be seen in the Table 1 below. The SMEs jointly compile the FTA according to the results of the FTA in Figure 1. It can be stated that the root causes of problems are divided into two categories, namely immediate causes, and basic causes. These results are used as the basis for determining an action plan or recommendation as a corrective action against the problem (immediate or basic cause) and can be seen in Table 1. The root causes of Unplanned Shutdown and Catastrophic due to processing sour crude oil as follows:

Table 1. Subject matter expert's refinery unit

No	SME	Division	Job Description
1	Mechanical Engineer	Inspection	Responsible for quality, especially related to mechanical integrity (Mechanical Engineer)
2	Process Engineer	Engineering	Responsible for quality Process Control (Chemical Engineering)
3	Reliability Engineer	Reliability	Reliability is a high-level planning function that is responsible for equipment reliability, maintenance strategy and improvement
4	Crude Distillation Unit Supervisor	Production	Responsible for supervising the operation of the Crude Distillation Unit
5	Maintenance Supervisor	Maintenance	Responsible for carrying out supervision of maintenance activities

a. The immediate cause
Unplanned Shutdown and Catastrophic due to Damage in Preheater System CDU due to processing sour crude caused by mechanical failure and operation failures such as low performance of desalter, piping system leak, and sour crude processing (high impurities content; TAN and Sulphur). In the crude oil processing business at Refinery unit, the terms "mechanical failure" and "operation failure" are frequently used, with the main distinction lying in their sources of failure. Mechanical failures, generally, result from failures occurring in mechanical equipment and piping. On the other hand, operation failures stem from shortcomings in effectively executing the crude oil processing procedures.

b. The basic cause: 1) Inadequate scheduling of maintenance work; 2) Inadequate assessment of repair needs; 3) Inadequate product specification.

After knowing the root cause of the problem, SMEs then determine recommendations and alternative solutions to solve the problem according to Table 2 based on experience and standards.

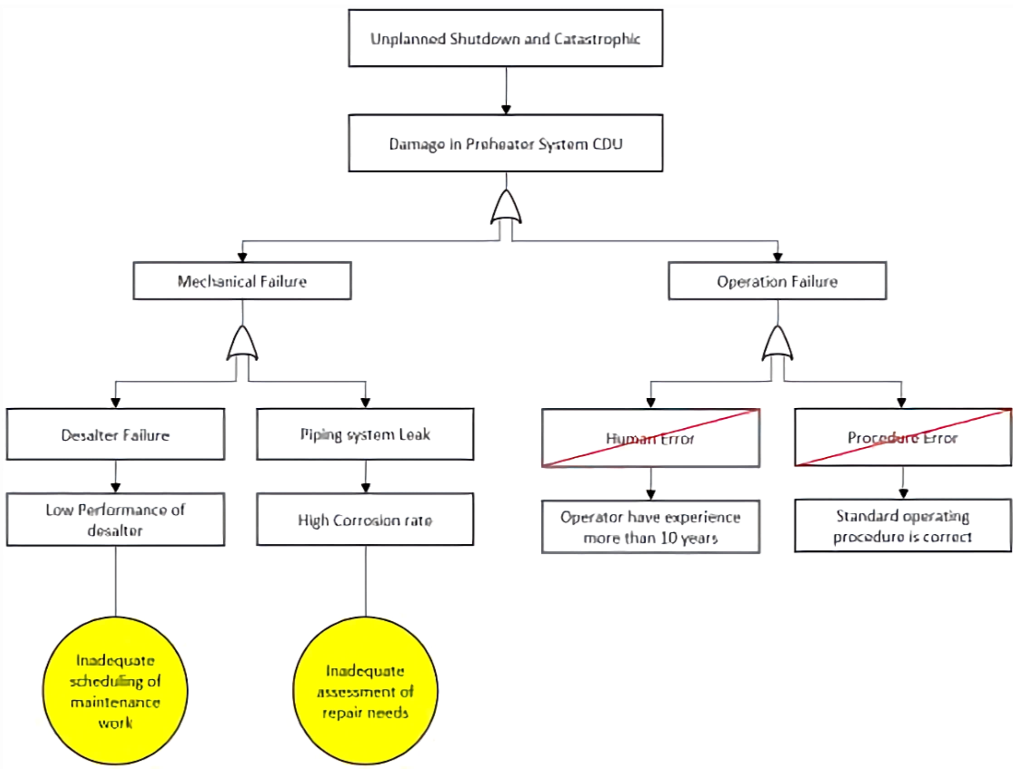


Figure 1. Fault Tree Diagram

Table 2. Recommendation for root cause of problems

Root Cause of Problem	Recommendation
Immediate Cause: Unplanned Shutdown and Catastrophic due to Damage in Preheater System CDU due to processing sour crude caused by mechanical failure and operation failure as follows: 1. Low performance of desalter, 2. Piping system leak	1. Addition new desalter Unit. 2. Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 3. Replace piping system with upgrade material from carbon steel to ASTM A335 P5
Basic Cause: 1. Inadequate scheduling of maintenance work 2. Inadequate assessment of repair needs Inadequate product specification	1. Prepare maintenance schedule based on preventive maintenance schedule with time-based standard. 2. Prepare inspection and assessment plan. Prepare crude acceptance matrix limitation

3.1.2 Alternative Solution of Business Problem

After knowing the root cause of the problem, SMEs then determine recommendations and alternative solutions to solve the problem according to Table 3 below. The recommendation for the basic cause is not included as an alternative solution, considering that the recommendation represents a routine task and is only required to be carried out continuously. When considering the above recommendations, it can be conveyed that this recommendation is directed towards tasks that need continuous preparation.

Based on Table 3, the SMEs decide to select 3 (three) alternatives as a long-term solution to avoid unplanned shutdown and catastrophic failure due to sour crude oil processing in Crude Distillation Unit (CDU) as follows: 1) Addition new desalter Unit; 2) Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316; 3) Replace piping system with upgrade material from carbon steel to ASTM A335 P5. The costs incurred for the 3 (three) alternative solutions above refer to references and approaches based on the Owner's Estimate (OE) and benchmarking from other Refinery Units, which can be seen in Table 4 below.

Table 3. The alternative solution

Root Cause of Problem	Alternative Solution
To avoid unplanned shutdown and catastrophic failure due to sour crude oil processing in Crude Distillation Unit (CDU)	1. Addition new desalter Unit 2. Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 3. Replace piping system with upgrade material from carbon steel to ASTM A335 P5

Table 4. Project cost

Alternative Solution	Cost Estimation	Reference	Remarks
Addition new desalter Unit	Rp. 20 billion	Refinery Unit III Procurement	Cost of Building a New Desalter without Tie in
Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316	Rp. 25 billion	Cost estimation from Planning Department	based on estimated calculation results in 2020
Replace piping system with upgrade material from carbon steel to ASTM A335 P5	Rp. 24 billion	Cost estimation from Planning Department	based on estimated calculation results in 2020

The 2020 estimate data can be used as a reference for estimating the next project considering that there is no data from the closest year after the 2020 estimate data. Pro-cons analysis of alternative solutions made by SMEs is an additional reference in determining the best alternative solution to avoid the unplanned shutdown and catastrophic failure due to sour crude oil processing in Crude Distillation Unit (CDU) as shown in Table 5. The references used are indeed related to the job and follow-up actions resulting from the failures that occur.

Table 5. Pro-cons analysis

No	Alternative Solution	Pro	Cons
1	Addition new desalter unit	- Reduce crude oil impurities	- Need Prepare new location for tie in - Need additional maintenance cost, maintenance strategy and new procedure - Need feasibility and engineering study
2	Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316	- No need Insulation installation - Have a good corrosion resistant - Easy to installation and repair	- Requires good treatment in installation
3	Replace piping system with upgrade material from carbon steel to ASTM A335 P5	- Have a good corrosion resistant	- Need Post Weld Heat Treatment (PWHT) after Welding

3.1.3 Analytic Hierarchy Process (AHP)

In this study, The SMEs carried out a brainstorming method and Group Discussion forum in compiling FTA's which were used to provide alternative long-term solutions to solve Unplanned Shutdown and Catastrophic due to Damage in the CDU Preheater System due to processing sour crude as follows: 1) Addition new desalter Unit; 2) Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 ASTM; 3) Replace piping system with upgrade material from carbon steel to A335 P5.

In the decision making, the most important and relevant criteria which influence the decision analysis must be selected for determining the best solution. in this case it was decided to use 4 (four) criteria in choosing the best solution based on some experience and references including (1) Construct Ability (2) Cost (3) Reliability and Quality (4) Operability and Maintainability. In supporting the mechanical integrity of the Crude Distillation Unit (CDU), the reliability and quality of equipment and piping system is an important requirement.
The criteria description that is used in Analytic Hierarchy Process (AHP) for selection process, can be found in Table 6.

Table 6 Criteria for decision making

Criteria	Description
Cost	Costs required for implementation of the selected solution such as project cost, maintenance cost, operational costs, and procurement cost.
Construct Ability	Explain how the level of difficulty of the work, the effect on the schedule, how much manpower and tools are involved in the work.
Reliability and Quality	Reliability and Quality consists of how the quality of work affects the long-term mechanical integrity after repairs or replacements are carried out
Operability and Maintainability	Determine how the results of either repair or replacement work affect the ease and flexibility to operate and maintain equipment

By using super decision software, all criteria and alternative solutions are simulated so that the best alternative solution is produced to solve unplanned shutdown and catastrophic due to sour crude oil processing in Crude Distillation Unit (CDU) Refinery unit. Based on the survey that has been conducted by Super Decision Result in Figure 2 to obtained pairwise comparisons of the criteria and alternative solutions and the reliability and quality is the most important with the value 0.409.

Figure 2. Result of pairwise comparison for criteria importance survey

After conducting a Pairwise comparison assessment to determine which criteria are the most important, the next step is to compare the alternatives with each other.

Figure 3. Result of pairwise comparison for alternatives cost

Based on Result of Pairwise Comparison for Alternatives Cost above, in line with the cheaper price (procurement cost) of ASTM A312 TP316 pipe material on the market so that it gets the highest rank with 0.493 value.

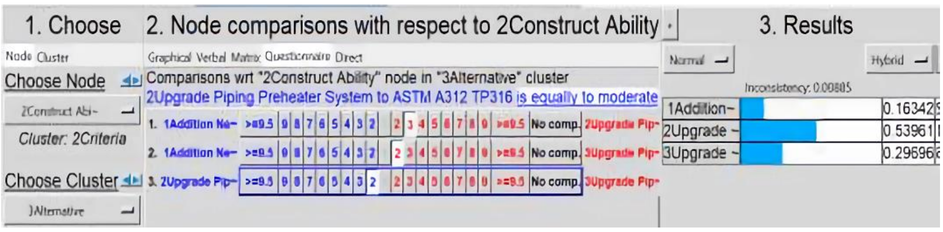


Figure 4. Result of pairwise comparison for alternatives construct ability

Based on Result of Pairwise Comparison for Alternatives Construct Ability, replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 has high rank with 0.539 value. It refers to level of difficulty of the work, the effect on the schedule, how much manpower and tools are involved in the work.

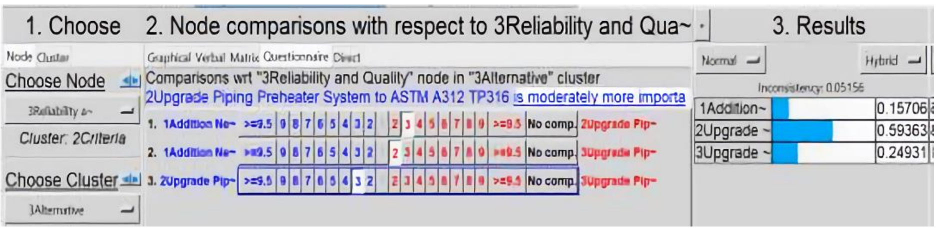


Figure 5. Result of pairwise comparison for alternatives reliability and quality

Based on Result of Pairwise Comparison for Reliability and Quality, replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 has high rank with 0.593 value. It refers to the remaining life estimation which is calculated using the corrosion rate calculation based on API 581 Risk based Inspection.

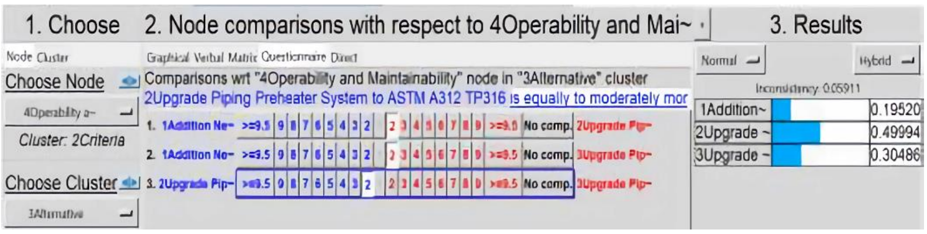
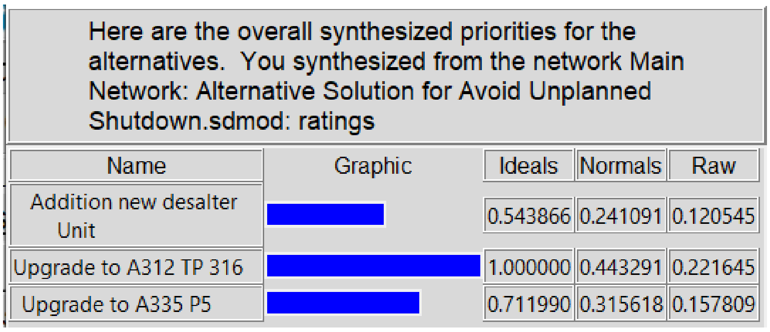


Figure 6. Result of pairwise comparison for alternatives operability and maintainability

The last criteria are Pairwise Comparison for Reliability and Quality, replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 has high rank with 0.499 value. This is based on the consideration that by replacing the pipe with ASTM A312 TP316 there is no need to add insulation and create a new Standard Operation Procedure.

The next step of the AHP method is to calculate the ranking of alternative solutions to select the best alternative solution with synthesize priorities for the alternatives, which is shown in Figure 7.


Here are the overall synthesized priorities for the alternatives. You synthesized from the network Main Network: Alternative Solution for Avoid Unplanned Shutdown.sdmod: ratings

Name	Graphic	Ideals	Normals	Raw
Addition new desalter Unit		0.543866	0.241091	0.120545
Upgrade to A312 TP 316		1.000000	0.443291	0.221645
Upgrade to A335 P5		0.711990	0.315618	0.157809

Figure **7**. Result of synthesize priorities for the alternatives

From the results of the overall synthesize priorities for the alternatives above, an alternative ranking matrix is obtained, where the highest score from the matrix indicates the best alternative solution. Table 6 shows the selection of the best alternative solution from the result of alternative ranking.

Table 6 The selection of the best alternatives

No	Alternatives Solution	Final Score	Alternative Ranking
1	Addition new desalter Unit	24%	Third
2	Replace piping system with upgrade material from carbon steel to ASTM A312 TP316	44%	**First**
3	Replace piping system with upgrade material from carbon steel to ASTM A335 P5	32%	Second

From the super decision software simulation of the consistency ratio above, the consistency ratio value is obtained for pairwise comparison of criteria and alternative solutions. The calculation results show the inconsistency ratio value is less than 0.1 in Figure 2-6 (Saaty and Özdemir, 2014), which means that the pairwise comparisons are consistent judgement (Acceptable) and can be seen in the table of result of pairwise comparison for alternatives table above. Consistency index analysis is used to determine possible errors during expert judgment (Belton and Stewart, 2002).

To ensure consistency in subjective perception and accuracy in comparing weights, it is necessary to be acquainted with two indices, the Consistency Index (CI), and the Consistency Ratio (CR). The equation for CI is expressed as follows:

$$CI = (\lambda max - n)/(n - 1) \quad (1)$$

Where λmax is the largest eigenvalue, and n represents the number of attributes. As for CR., the equation is as follows:

$$CR = CI/ RI \quad (2)$$

However, in determining CR in this research, it is already available in the Super Decision software, where if the inconsistency ratio is above 0.1, it is considered unacceptable.

3.2 Conclusion of Business Analysis

Based on the Root Cause Analysis that has been carried out above, it can be conveyed that the processing of crude with high impurities with TAN content of 0.3 Mg KOH/g and Sulphur 1.5 wt% has the potential to cause unplanned shutdown and catastrophic in the Crude Distillation Unit (CDU) Refinery unit due to damage (leakage) in the preheater piping system. This study focuses on decision-making analysis to select the best solution to solve unplanned shutdown and catastrophic due to sour crude oil processing in Crude Distillation Unit (CDU) Refinery unit using the Analytic Hierarchy Process (AHP) method. The alternatives solutions from the Analytic Hierarchy Process (AHP) method gives the result described in a weighted hierarchy tree, which is shown in Figure 2. Based on overall synthesize priorities in figure 2 show that priority ranking of criteria as follow:

1. Cost with final score 10.4%
2. Construct Ability with final score 16.5%
3. Reliability and Quality with final score 40.9%
4. Operability and Maintainability with final score 32.2%

Reliability & Quality get highest score in priority ranking of criteria because mechanical integrity is first requirement for acceptance criteria to continuity of secondary feed supply and valuable product stock supply can be achieved to support the business continuity at refinery unit. Based on hierarchy tree for proposed alternative solution in Figure 7 show that priority ranking of alternative solution as follow:

1. Addition New Desalter Unit with final score 24%
2. Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 with final score 44%
3. Replace piping system with upgrade material from carbon steel to ASTM A335 P5 with final score 32%

From the result of alternative priority ranking, “Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 with final score 44%” get highest final score and become the best solution for the Select the Best Solution to Avoid Unplanned Shutdown and Catastrophic Due to Sour Crude Oil Processing in Crude Distillation Unit (CDU).

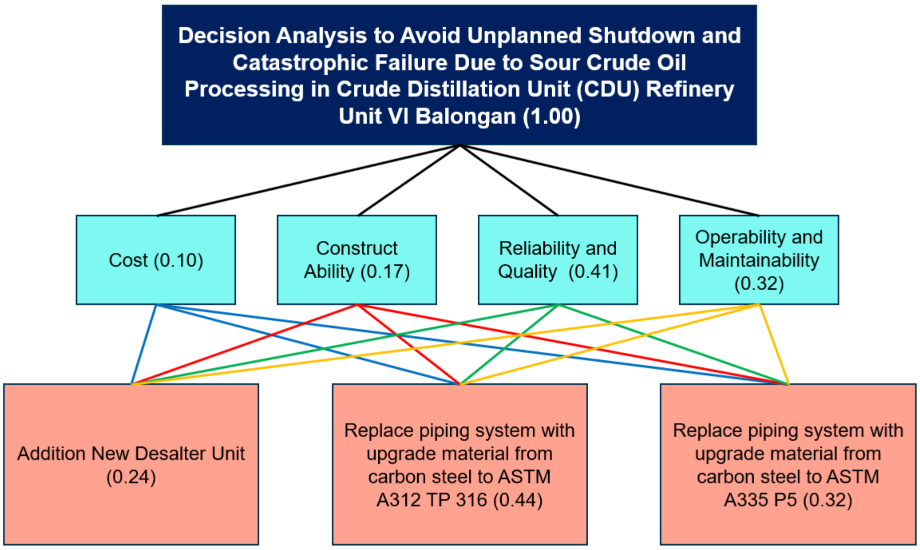


Figure 9. Hierarchy Tree

4. Conclusion

After conducting an exploration of the business problem and the proposed business solution, the following research conclusions are given to answer the research questions. Using Fault Tree Analysis (FTA), the root cause is as follows. The immediate cause was Unplanned Shutdown and Catastrophic due to Damage in Preheater System CDU due to processing sour crude caused by mechanical failure and operation failure such as low performance of desalter, piping system leak, and sour crude processing (high impurities content; TAN and Sulphur). The basic causes were inadequate scheduling of maintenance work, inadequate assessment of repair needs, and inadequate product specification. There are 3 (three) long-term alternative solutions, which are add new Desalter Unit**,** replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 ASTM**,** and replace piping system with upgrade material from carbon steel to A335 P5

Using the Analytic Hierarchy Process (AHP) method with super decision software, the best solution to solve the problem of possible damage (leakage) in preheater system Crude Distillation Unit (CDU) that could result in an unplanned shutdown and catastrophic Refinery unit is "Replace piping system with upgrade material from carbon steel to ASTM A312 TP 316 ASTM". The revamp Crude Distillation Unit (CDU) with upgrade material piping system from carbon steel to ASTM A312 TP 316 ASTM can extend remaining life above the design life based on API 570 Piping Inspection Code and this solution is one of the works included in the Job List Turn Around (TA) Refinery unit in 2021.

5. Recommendation

In this study, many things are an important part of decision-making, but of the many recommendations, the following are the most important things that need attention. First, PT. KPI Refinery unit can use this method to find the best solution to solve the problem of possible damage (leakage) in preheater system Crude Distillation Unit (CDU) that could result in an unplanned shutdown and Fatality and for the others business problems. This study can be used as input in formulating strategies and planning in carrying out follow-up actions from the best solution to solve problems appropriately (time, cost, quality, safety) covering all aspects of the process, people, tools, and costs. Second, SMEs that have been appointed by the Company must contribute and be responsible for all their respective duties and responsibilities. Third, when making decisions, use the right method and use references that are appropriate to the problem being faced.

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