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Decision Analysis to Find the Best Solution to Overcome Instrumentation Problems by Using Analytic Hierarchy Process and SMART Method

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Abstract

The Laksmana offshore area is one of the oil field areas under Sumatera field. Laksmana offshore area produces 750 BOPD (Barrel Oil per Day). Instrumentation plays a vital role in the production process since it controls the Fluid Flow, level, and pressure. Based on the data collected from January 7th, 2020, to December 6th, 2020, there were 13 unplanned shutdowns caused by instrumentation system failures. This instrumentation systems failure can be grouped into three major categories: Air compressor failure, Instrumentation valve problems, and Instrument equipment malfunctions. Researchers attempted to stratify the problem using a Pareto diagram and find the root cause using a fishbone diagram and Failure Mode Effect Analysis. From the stratifying process, it was found that the company does not yet have any methods and facilities to monitor the condition of the compressor in real-time, so it is difficult to analyze and know the early signs of air compressor failure. The researcher conducted value-focused thinking with three members in a focus group discussion and generated four alternative solutions that can be used. The first alternative is installing the HMI (Human Machine Interface/SCADA) system. The second alternative is to purchase and use the S551 Data Logger. The third alternative is the assembly of own innovation tools made by the Laksmana's worker, and the last is to appoint extra personnel for daily monitoring of the compressor. This research uses the Analytic Hierarchy Process (AHP) and Simple Multi-Attribute Rating Technique (SMART) methods to determine the best alternative and found that the own innovation tool is the best alternative.

Keywords: instrumentation system, value focus thinking

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1. Introduction

Although the use of New and Renewable Energy (EBT) continues to be boosted to reduce the earth's temperature, energy derived from fossils is still the prima donna. According to OPEC World Oil Outlook 2021, Global oil demand is expected to increase by 17.6 million barrels per day (mb/d) between 2020 and 2045. Oil demand by 2026 is almost 14 mb/d higher than in 2020 but only around 4.4 mb/d higher than in 2019. As a result, oil demand is projected to reach around 108 mb/d in the long term (International Energy Forum (IEF), 2022). Facing the situation, to accelerate the growth of the company's value, Pertamina restructures its business and simultaneously demonstrates the ability to continue to prioritize Operational Excellence. One of the strategies to achieve operational excellence is to eliminate non-productive time.

After restructuration, the Sumatera field is one of the fields under Pertamina EP. Sumatera field has an onshore and offshore working area. The Offshore area, namely with Laksmana Offshore. Laksmana offshore area's strategy to eliminate non-productive time is by maintaining and improving the reliability of their equipment which is quite challenging because some of the equipment is aged and now overdue for replacement. One of the most significant issues in the reliability of surface equipment is Instrumentation systems failure. Instrumentation systems failure records in 2020 could be classified into three categories: Air compressor failure, Instrumentation valve problems, and Instrument equipment malfunction. In 2020, it was recorded that 13 hours of unplanned plant shutdown were caused by instrumentation systems failure. Therefore, as one of the production teams working in Laksmana offshore, the researcher needs to find solutions to this problem.

The research questions of this research are: What issues and problems exist in the instrumentation systems of the Laksmana Area that caused unplanned shutdown? What is the root cause factor for the instrumentation systems failure? What could be the alternative, and which one is the best alternative to be implemented?

The objectives of this research are:

- To identify and analyze issues related to the operation, maintenance, safety, and environment from the current operation of the instrumentation systems in the Laksmana Offshore area
- To identify factors that are to be the root cause
- To propose the best alternative to eliminate or reduce downtime from Instrument systems failure and create the implementation plan

The scope and limitations of this research are:

- This research is made especially for the Laksmana area condition.
- The research will focus on the instrumentation system failure contributing to lost production in Laksmana Area. Facilities other than instrumentation system failure that contribute to lost production in the Laksmana area are out of scope.
- Data limitations during this research will be determined using assumptions from other correlated data.

2. Literature Review

A Five-step problem-solving model will be used as a conceptual framework to solve the problem:

2.1 Define the problem

In this step, the researcher will determine the issues that are considered a priority to be discussed: After stratifying all the problems, the next step is to identify the risks/impacts by risk analysis method (Probability vs Severity Matrix). The risk analysis used in this project uses the Pertamina EP's Internal Organizational Work Procedures. The Procedure name is Tata Kerja Organisasi Manajemen Risiko Operasi No. B-009/A3/EP300/2017-S0 Rev.3 (Pertamina EP, 2017). This organizational work procedure is designed to ensure that operational risks in all Pertamina EP activities are evaluated, controlled, and monitored to minimize health, safety, security, environmental risks, and quality discrepancies arising from Pertamina EP's operational activities. Therefore, the researcher will prioritize the problem that generates high risk to be solved first. If there are more than one problem, it will be prioritized using relevant tools like Pareto diagrams.

2.2 Determine the root cause (s) of the problem

After the Pareto diagram appoints the most impact problem that needs to be solved, this step aims to find the root cause using a cause and effect diagram (Fishbone). The Fishbone diagram helps break down, in successive layers, root causes that potentially contribute to an effect. The condition to successfully apply the method proposed here is a correct evaluation of the probabilities, weights, and impact of the causes (Ilie and Ciocoiu, 2010). Therefore, to evaluate the impact (severity, occurrence, detection), the researcher used FMEA (Failure Mode Effect Analysis) to get the risk priority number and determine the prioritized problem using the Pareto diagram. FMEA (Failure Mode Effect Analysis) that is used in this project is Pertamina EP's Internal document NO.C-018/A3/EP0100/2018-S0. Namely, Tata Kerja Individu Penentuan Prioritas Root Cause dengan Metode Failure Mode & Effect Analysis (Pertamina EP, 2018). This method performs a risk assessment based on the identified failure modes, impacts, causes and prioritizes root causes for improvement/corrective action.

2.3 Develop alternative solutions

To develop alternative solutions, the researcher utilizes value focus thinking by discussing it with all the members (decision makers) in the focus group discussion. Focusing on the values that should be guiding the decision situation makes the search for new alternatives a creative and productive exercise. It removes the anchor on narrowly defined alternatives and allows clear progress toward "solving" the problem (Keeney, 1996).

Table 2.1 Decision maker

Members	Department	Discipline	Experience
Person A	**Offshore Production Department.**	Production	12 Years
Person B	**Reliability and Maintenance Department**	Rotating Mechanical	15 Years
Person C	**Offshore Production Department**	Production	7 Years
Person D	**Information & Technology Department**	Information Technology	10 Years

2.4 Select a solution

Decision making to select the best solution will utilize SMART (Simple Multi-Attribute Rating Technique) and Analytic Hierarchy Process (AHP). The reason for using the SMART Method is because of its simplicity (Kasie, 2013). Furthermore, the analysis involved is transparent, so this approach provides a great understanding of the problem and is acceptable to the decision maker (Siregar *et al.*, 2017). The disadvantage of SMART is that its priority and score result is not equally consistent with AHP (Kasie, 2013). Meanwhile, The Analytic Hierarchy Process (AHP) provides the objective mathematics to process the inescapably subjective and personal preferences of an individual or a group in making a decision (Saaty and Vargas, 2012). That is why AHP offers an alternative approach to SMART when a decision maker faces a problem involving multiple objectives. The researcher uses these two methods to see the results produced by these two methods. If it produces the same results, it will be more convincing to the author that this choice is the best.

2.5 Implementation Plan

This step creates a plan and schedule to implement the chosen alternative. To distinguish the information needed for better understanding, frame the situation, and evaluate each purpose and constraint, the researcher and team use the 5W1H method. The 5W1H is a questioning approach and a problem-solving method that aims to view ideas from various perspectives with the goal to gain an in-depth understanding of a specific situation (SafetyCulture, 2022). Detailed analysis of each fact allows the researcher and team to approach the problem in the best possible way.

2.6 Conclusion

This step explains the answer to the research question and gets the conclusions of the result of the research

3. Result and Discussion

3.1 Define the problem

Based on 2020 data (shown in Table 3.1), Instrumentation systems failure in Laksmana Offshore area could be classified into three categories: Air compressor failure, Instrumentation valve problems, and Instrument equipment malfunction.

Table 3.1 2020 Instrumentation monitoring record

INSTRUMENTATION MONITORING SHEET					
Date	Indication	Duration (Minutes)	Remarks	Unplanned Shutdown (Hours)	%
February 2nd 2020	LCV Relay Positioner malfunction	30	Replace Relay		3%
February 10th 2020	Compressor's Hose outlet leak	120	Replace Hose	2	14%
March 27th 2020	SDV Production header Stuck	120	Manual Operated	2	14%
May 11th 2020	Air Supply Line blocked by condensation water	60	Drain	1	7%
May 20th 2020	Oil Filter leakage	120	Replace seal & Bearing	2	14%
June 3rd 2020	Air Supply Line blocked by condensation water	60	Drain	1	7%
July 17th 2020	Pressure switch malfunction	45	Bypass Pressure switch		5%
August 18th 2020	Transducer malfunction	120	Replace transducer	2	14%
September 16th 2020	Pressure Controller error	15	Resetting controller		2%
September 27th 2020	Hose air end damage	120	Replace Hose	2	14%
October 20th 2020	PCV Scrubber Fuel gas Stuck open	60	Manual operated	1	7%
TOTAL		**870**		**13**	**100%**

- Air Compressor Failure

This problem comes from air pressure supply drop due to failure in the compressor. For information, the Laksmana process is air pressurize system. All instrument equipment needs air pressure to work properly. Laksmana area is equipped with compressors on each platform to supply the air pressure into instrumentation equipment. One of the operational challenges was no remote surveillance system available to monitor compressor running conditions. The monitoring process required sending the crew back and forth to the remote platform. With this limitation, accurate compressor data conditions are challenging to provide. When the parameter data is incomplete and inaccurate, the crew difficult to know the root cause of failure and arrange precise preventive maintenance. In 2020 Found, 8 hours of Unplanned shutdown due to Compressor Failure, as shown in Table 3.1. Loss production due to this compressor failure was about Rp225,317,167.

- Instrumentation valve problems

This problem comes from the valve condition itself. Most of the valve (Shut Down Valve, Pressure Control Valve, Liquid Control Valve, etc.) in the Laksmana area was aged and is overdue and needs replacement. A valve that has been in service for too long is at a high risk of leakages because of wear and tear, especially when exposed to extremely high pressures and temperatures (Apollo Valves, 2018). In 2020 There were 3 hours of Unplanned shutdown due to Instrumentation valve problems (as shown in Table 3.1). The Lost Production was Rp84,493,938

- Instrument equipment malfunctions.

This problem comes from Instrument equipment failure. According to 2020 data (shown in Table 3.1), some issues came from the pressure switch, pressure controller, and positioner malfunction. There were 2 hours of Unplanned shutdown due to this malfunction, and the lost production was Rp 56,329,292. The failure of this equipment could cause undesired process flow or, even worse, could cause process shutdown and total plant shutdown. In 2020 the problems that caused plant shutdown resulted from liquid build-up in the instrumentation line. The dryer process couldn't work properly to drop out the mass of water it condenses. All the work to reduce temperature in order to take out the moisture is invalidated. Dew point will equal the ambient temperature, and condensation will occur in the plant system (Dugan, 2022).

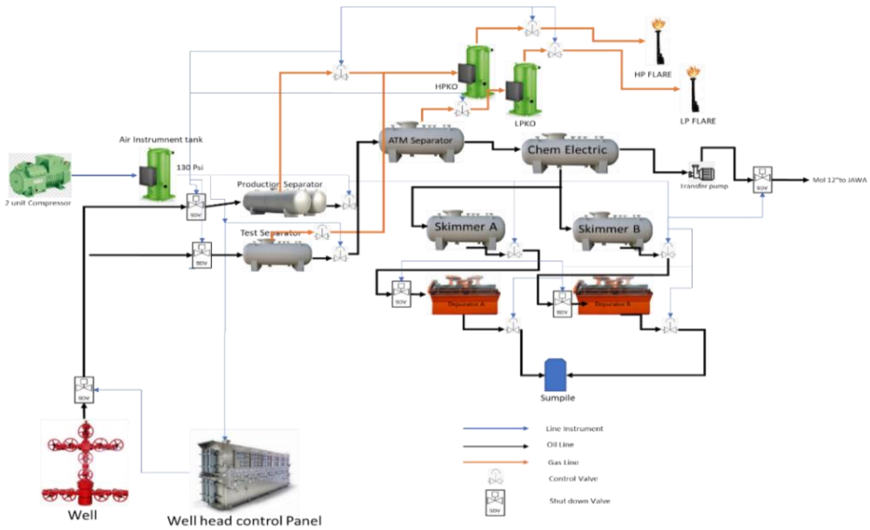


Figure 3.1 Laksmana instrumentation concept flow diagram

Table 3.2 Hazard identification and risk assessment & risk control

NO	BAGIAN/ FUNGSI	KEGIATAN/PROSES /LOKASI/ASET	N/AN/E	H/S/Sec/E /Q	POTENSI BAHAYA / ANCAMAN / OPORTUNITY				KONSEKUENSI	PERATURAN		PENGENDALIAN EKSISTING (Eliminasi/Substiitusi/Engineering/Administratif/APD)
					O	A	M	L		Y/T	No. Peraturan	
1	Operation	Air Compressor Failure	AN	Q	0	0	4	0	Emergency shut down	Y	TKO	ENGINEERING
2	Operation	Instrumentation Valve Problem	AN	Q	0	0	4	0	Emergency shut down	Y	TKO	ENGINEERING
3	Operation	Instrumentation Malfunction	AN	Q	0	0	3	0	Process shut down	Y	TKO	ENGINEERING

To know the impact of those 3 problems, Researcher tried to make risk analysis with using Tata Kerja Organisasi Manajemen Risiko Operasi N0. B-009/A3/EP300/2017-S0 Rev.3 (Pertamina EP, 2017) The risk assessment is carried out by combining the probability of occurrence with the severity (consequence) factor by considering the magnitude of the loss (severity), possibility, and exposure period. While for safety hazards, the level of vulnerability and threat must be considered. From this risk analysis, we can determine that those three problems generate high risk. These three problems must be solved due to their high impact on humans, equipment, environment, and the company's image.

Table 3.3 Hazard Identification and Risk Assessment & Risk Control

NO	BAGIAN/ FUNGSI	KEGIATAN/PROSES /LOKASI/ASET	PIC	PENILAIAN RISIKO						REVIEW PENGENDALIAN			PRIORITAS	RENCANA PENGENDALIAN (Eliminasi/Substitusi /Engineering/Administratif/APD)	PIC	RESIKO YANG TERSISA					
				KEPARAHAN (S)				P	R							KEPARAHAN				P	R
				O	A/M	L	C			A	B	C				O	A/M	L	C		
1	Operation	Air Compressor Failure	Operation	0	4	0	0	E	TINGGI	X	-	-	II	ENGINEERING	OPERATION	0	4	0	0	E	TINGGI
2	Operation	Instrumentation Valve Problem	Operation	0	4	0	0	E	TINGGI	X	-	-	II	ENGINEERING	OPERATION	0	4	0	0	E	TINGGI
3	Operation	Instrumentation Malfunction	Operation	0	3	0	0	E	TINGGI	X	-	-	II	ENGINEERING	OPERATION	0	3	0	0	E	TINGGI

According to the risk analysis, the pareto diagram exhibits Air compressor failure has the highest impact problem. The Air compressor failure contributed to almost 62% of the shutdown problems caused by Instrumentation systems failure in 2020. Therefore, the researcher decides to appoint Air Compressor failure as a priority problem in instrumentation systems that needs to be solved.

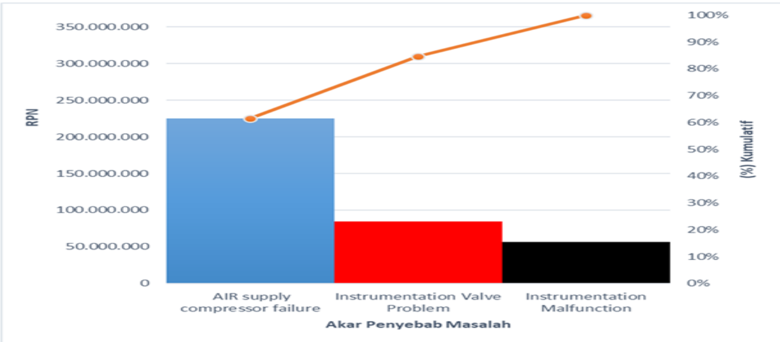


Figure 3.2 Pareto chart of instrumentation systems problems

3.2 Determine the root cause(s) of the problem

Since the Air compressor failure became the most significant contributor, the researcher focused on finding a solution to solve this. The first thing to do was find the primary root cause of this condition by using a fishbone diagram. The causal factors developed through Stratification into groupings of factors (4M+E): Man, Machines, Materials, Methods, and Environment.

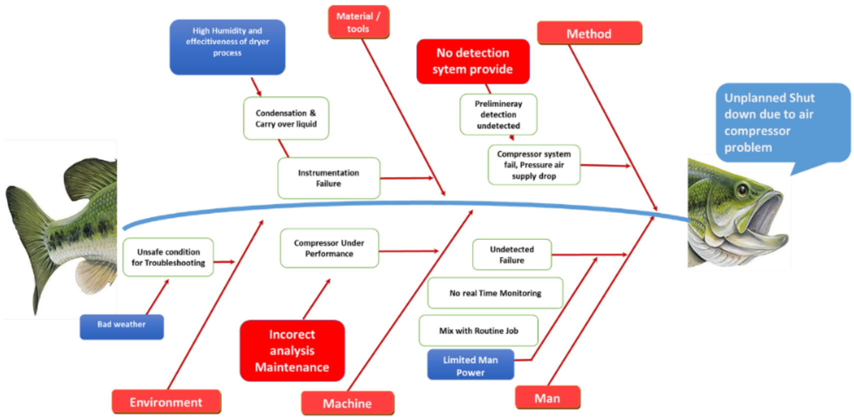


Figure 3.3 Fishbone diagram of unplanned shutdown due to air compressor failure

Method Factor: Found that no detection system is provided. Laksmana area didn't have a system to detect the anomaly condition (Preliminary detection) that will lead to failure.

Machine Factor: There was an incorrect analysis in preventive and predictive maintenance. This condition happened due to a limited source of data running parameters. Air compressor performance monitoring is only found on the compressor panel, and data was recorded manually. So, it was less accurate, limited, and not real-time recording. The cause of failure that occurred in 2020 based on maintenance data was the occurrence of high temperature and overpressure.

Material Factors: There were high humidity and ineffectiveness of the dryer process. Oil and condensation water that is carried over enter the instrument controller and make the controller malfunction. The unplanned shutdown due to this problem in 2020 was when the compressor surged.

Man Factor: The rotating maintenance team (The Reliability and Maintenance division) is responsible for the compressor reliability performance. Maintaining and monitoring compressor performance isn't their only task. The lack of human resources and also human error possibility become the man factor.

Environment factor: Due to safety reasons, the crew is inhibited from going to remote platforms during bad weather. These conditions can slow down actions to conduct preventive maintenance and troubleshooting activity.

To determine the priority factor, the researcher used FMEA (Failure Mode Effect Analysis) to perform a risk assessment and the Pareto diagram to determine the most significant factor (Pertamina EP, 2018).

Table 3.4 Failure mode effect analysis

	Cause Factor		S	O	D	RPN	% Relatif	% Komulatif
Methode & Machine	Method	No detection sytem provide	8	8	8	512	59%	59%
	Machine	Incorrect Maintenance analysis						
Material	Material	High Humidity and ineffecitiveness of dryer process	8	3	7	168	19%	79%
Man	Man	Limited Man Power	8	3	5	120	14%	93%
Environment	Environment	Bad Weather	8	2	4	64	7%	100%
						864		

S = Severity; O = Occurrence; D = Detection RPN = Risk Priority Number

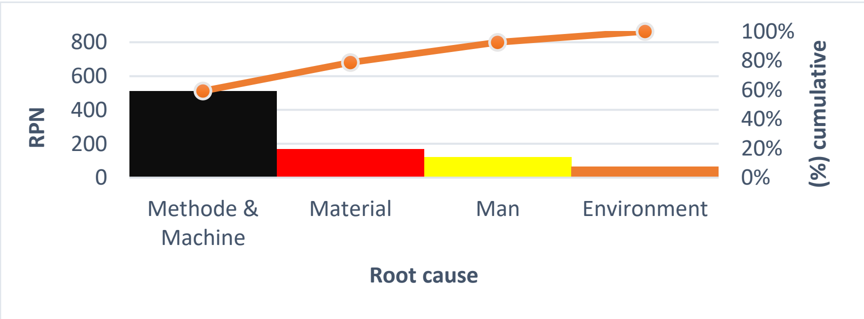


Figure 3.4 Pareto diagram of root cause analysis

Failure Mode Effect Analysis and the Pareto diagram found that the problem from Method & Machine Factor contributes 59% of the problems. It means that the researcher needs to prioritize the solutions plan to solve the issue of the no detection system in the compressor and how to solve the incorrect maintenance analysis.

3.3 Develop alternative solutions

3.3.1 Value Focus Thinking

The alternatives in this research will be generated by using the Value Focused Thinking (VFT) method. In this step, the Focus group discussion develops a value list from each decision maker, converting each value statement and then adding a directional preference to create an objective. The objective was organized to define the means-end relationships to achieve the end benefit (fundamental) objectives.

It is obtained the process thinking to generate alternatives are as follows:

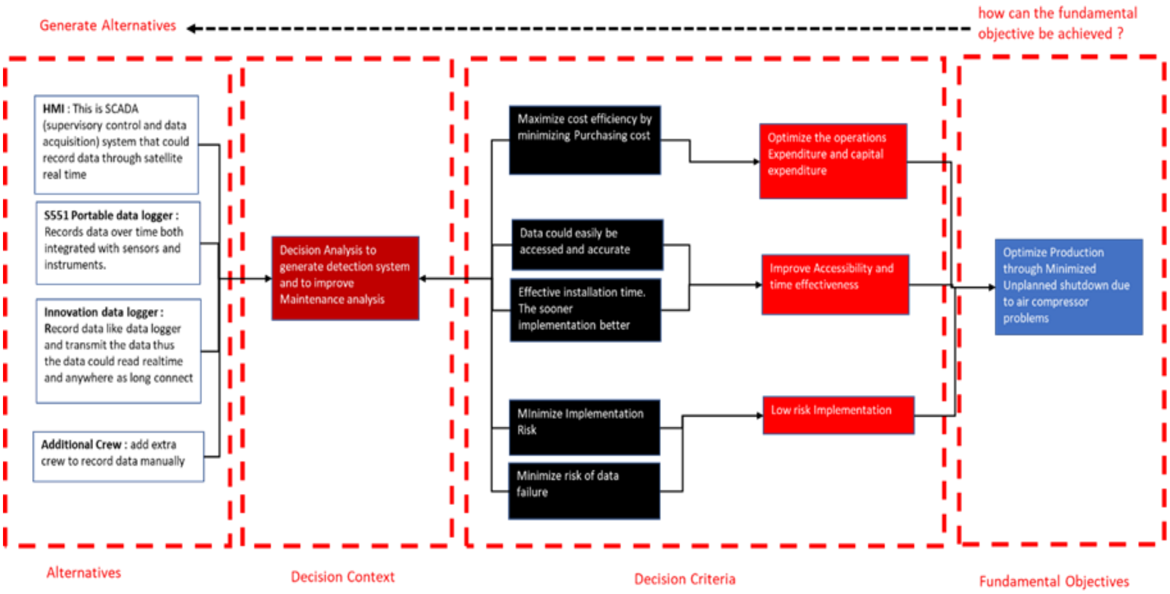


Figure 3.5 Value focus thinking

The result of the discussion constructs a hierarchy tree that consists of:

1. Goal: choose the best alternative to improve the reliability of the Air compressor to minimize unplanned shutdown.
2. Criteria:
   a. Product: This criterion was chosen to ensure that the product to be applied does not impose an excessive cost burden on the operational expenditure or capital expenditure. The company has implemented budget efficiencies in all areas to maintain its sustainability. Therefore, expensive products will be less likely to be approved by Management.
   b. Benefit: This criterion was chosen to ensure that the alternative chosen later must offer good Accessibility and could be implemented as soon as possible.
   c. Risk: This criterion was chosen to ensure that the alternative selected later has installation risk as low as possible. In addition, the alternative also must offer a low risk of human error. The more accurate the data obtained, the more precise the analysis.
3. Sub-Criteria:
   a. Sub-Criteria for product criteria are:
      i. Cost: This cost sub-Criteria refers to the expenses incurred to be able to implement the chosen alternative. Management suppressed budget spending. Submissions to purchase items with high prices will most likely be disapproved.

b. Sub-Criteria for Benefit criteria are:
   i. Accessibility: It is a sub-criterion that refers to the Accessibility of the alternative. The alternative must offer a new way of efficient and easy monitoring. It is very much needed considering the condition of the offshore work area is very high risk and highly dependent on weather conditions.
   ii. Installation Time: This sub-criterion refers to the time required to install or implement the alternative. It is important because the sooner the alternative is installed, the more benefits will impact operations.

c. Sub-Criteria for Risk criteria are:
   i. Installation Risk: This sub-criterion refers to the risks faced when installing and implementing the chosen alternative. The condition of the offshore work area that is already at high risk has made the focus group discussion concerned regarding job risks. Therefore, the work implementation for the chosen alternative is expected to have a low job risk.
   ii. Human Error: This sub-criterion refers to the error or inaccurate data possibility. Decision makers hope that the chosen alternative will provide accurate data.

Based on the Value Focus Thinking that was developed during the discussion among cross-functional members, it was generated four alternatives to solve the problem as follows:

1) Purchase & Install HMI (Human Machine Interface)/SCADA (Supervisory Control and Data)
Supervisory Control and Data Acquisition (SCADA) systems are used for controlling, monitoring, and analyzing industrial devices and processes (SCADA International, 2021). SCADA systems are critical as it helps maintain efficiency by collecting and processing real-time recording data remotely. If implemented in the Laksmana area, this SCADA system could monitor the Compressor data remotely and real-time recording.

2) Purchase S551 Portable data logger
A data logger (also known as a data recorder) is a small and relatively inexpensive electronic device that monitors and records data over time (such as voltage, temperature, or current) via an internal or external sensor. It is usually based on a digital processor (Smith, 2020). Data loggers are small, battery-powered, portable (can be carried and moved), and equipped with a microprocessor, internal memory for data storage, and sensors. By plugging the compressor into the S551 Portable data logger, users in the Laksmana area could read data from sensors that have been installed. Then, the crew needs to be deployed to the compressor location and download the data using a portable S551 data logger.

3) Assembly owns Innovation data logger
In principle, our innovation data logger created by the Laksmana team has all of the advantages that data logger has and strengthens with the ability to transmit data. Therefore, the data could be downloaded remotely without deploying any crew to the site.

The working principle: The sensors installed in the air compressor will read the compressor parameter and send it to the microcontroller. Then the data in the microcontroller will transmit to a receiver located in the Antasena Service Platform by a point-to-point system by LoRa Module. LoRa module is the physical (PHY) silicon layer or wireless modulation used to create the long range communication link (Semtech, 2022). This tool doesn't need an Internet network signal to transmit data from transmitter to receiver. As long as there is no barrier, this point-to-point data transfer could transmit data for the length of view. This point-to-point system is suitable for offshore areas with no building around the platform. Since the data is automatically transferred, the data received is real-time recording. So, the Laksmana team could use that data to arrange proper maintenance for the compressor. And also, if any anomaly occurred during the operation, it could be recognized from the data trend.

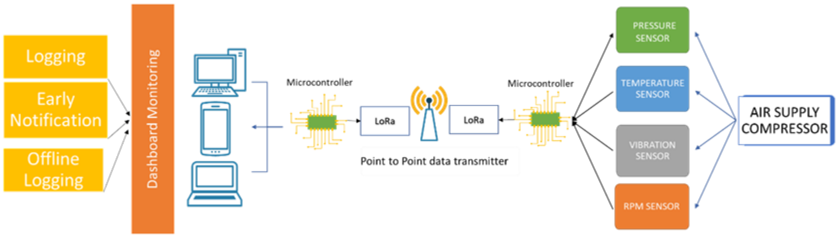


Figure 3.6 Innovation tools working system

4) Additional Crew

This alternative comes up in the focus group discussion. The reason is that no particular crew focuses on recording data from the compressor. However, they could only check the compressor once a week due to limited human resources and lots of equipment that needs to be monitored besides the compressor. Therefore, adding additional crew could hopefully be the alternative solution with a dedicated crew to record data from the compressor.

3.3.2 AHP (Analytic Hierarchy Process Method)

AHP was initially developed by Thomas Saaty (Kasie, 2013). The Ultimate scope of AHP uses pairwise comparisons between alternatives as input to produce a rating of alternatives compatibly with the theory of relative measurement (Brunelli, 2014). Pairwise comparison compares two different elements by rating the relative importance of each pair of decision alternatives and criteria. The scale from 1 to 9 will be used in AHP as a numerical rating for the prioritization process. The numerical comparison rating is shown below:
Equal Importance = 1, Weakly more important = 3, Strongly more important = 5, Very strongly more important = 7, Extremely more important = 9

AHP results are more consistent and accurate than other MAUT (Multi-attribute utility theory) methods as the matrix size is not greater than ten criteria. Its consistency deteriorates and becomes tedious and time consuming when the number of factors increases (Kasie, 2013). During the discussion, four members (including the researcher) were interviewed to judge the selection process and how many times more preferred or important one alternative to another alternative is based on specific sub-criteria. This technique is also applied for the prioritization process sub-criteria. This interview was conducted to make pairwise comparisons and receive judgments from the focus group discussion members on the importance intensity of one element compared to another. The researcher used a geometric mean to get the average value from the experts. After a pairwise comparison is made, the AHP measures the consistency of pairwise comparison judgments by computing a consistency ratio. Saaty and Vargas (2012) recommends that inconsistency should only be a concern if the index exceeds 0.1 (as a rule of thumb), in which case the comparisons should be re-examined.

The equation of Consistency Index is shown below:

$$Consistency\ Index = \frac{\lambda\,\mathrm{max} - n}{n-1}$$

Where n is the number of items being compared

Meanwhile, the equation of the Consistency Ratio is shown as follows:

$$Consistency\ Ratio = \frac{Consistency\ Index}{Random\ Index}$$

Where RI is the random index, which is the consistency index of a randomly generated pairwise comparison matrix, it can be shown that RI depends on the number of elements being compared and takes on the following values. After interviewing all the focus group discussion members, the pairwise comparison of sub-criteria and the consistency ratio calculation are shown in the table below:

Cost Sub-Criteria

Table 3.5 Cost sub-criteria

	HMI	S551 Portable data logger	Innovation	Additional Crew	Row AVG
HMI	0,05	0,03	0,07	0,03	0,048
S551 Portable data logger	0,30	0,18	0,18	0,28	0,233
Innovation	0,49	0,72	0,66	0,60	0,617
Additional Crew	0,16	0,06	0,09	0,09	0,102

n = 4, Average =4,128 Consistency Index = 0,042725, Consistency Ratio = 0,047473 (≤0,1)

Installation Risk Sub-Criteria

Table 3.6 Installation risk sub-criteria

	HMI	S551 Portable data logger	Innovation	Additional Crew	Row AVG
HMI	0,12	0,12	0,12	0,19	0,14
S551 Portable data logger	0,24	0,19	0,18	0,29	0,22
Innovation	0,6	0,65	0,61	0,45	0,58
Additional Crew	0,04	0,04	0,09	0,06	0,06

n = 4, Average =4,181, Consistency Index = 0,060375, Consistency Ratio = 0,067083 (≤0,1)

Installation Time Sub-Criteria

Table 3.7 Installation time sub-criteria

	HMI	S551 Portable data logger	Innovation	Additional Crew	Row AVG
HMI	0,06	0,02	0,08	0,04	0,051
S551 Portable data logger	0,25	0,10	0,12	0,07	0,135
Innovation	0,42	0,51	0,60	0,67	0,549
Additional Crew	0,28	0,36	0,20	0,22	0,265

n = 4, Average =4,255, Consistency Index = 0,085181, Consistency Ratio = 0,094645 (≤0,1)

Human Error Sub-Criteria

Table 3.8 Human error sub-criteria

	HMI	S551 Portable data logger	Innovation	Additional Crew	Row AVG
HMI	0,37	0,40	0,37	0,33	0,37
S551 Portable data logger	0,19	0,16	0,19	0,23	0,19
Innovation	0,37	0,40	0,37	0,37	0,38
Additional Crew	0,07	0,05	0,07	0,07	0,06

n = 4, Average =4,157, Consistency Index = 0,052436, Consistency Ratio = 0,058262 (≤0,1)

Accessibility Sub-Criteria

Table 3.9 Accessibility sub-criteria

	HMI	S551 Portable data logger	Innovation	Additional Crew	Row AVG
HMI	0,44	0,46	0,50	0,38	0,44
S551 Portable data logger	0,12	0,11	0,10	0,25	0,15
Innovation	0,37	0,40	0,33	0,31	0,35
Additional Crew	0,08	0,03	0,07	0,06	0,06

n = 4, Average =4,233, Consistency Index = 0,0779, Consistency Ratio = 0,086556 (≤0,1)

After calculating the weight of each alternative in each sub-criteria, the researcher calculates the priority ranking of the sub-criteria to have an AHP ranking of the decision alternatives. the pairwise comparison and the consistency ratio are shown in the table below:

Table 3.10 Priority ranking of sub-criteria

	Cost	Risk	Installation time	Human error	Accessibility	ROW AVERAGE
Cost	0,37	0,30	0,29	0,45	0,37	0,36
Risk	0,12	0,10	0,21	0,15	0,10	0,14
Installation time	0,05	0,02	0,04	0,03	0,05	0,04
Human error	0,07	0,17	0,13	0,09	0,12	0,12
Accessibility	0,37	0,41	0,33	0,27	0,37	0,35

n = 5, Average =5,42, Consistency Index = 0,11, Consistency Ratio = 0,0944 (≤0,1)

Based on the calculation, we could see that all the consistency ratio results are less than 0,1. It means that the pairwise comparison judgments are consistent. The pairwise comparison shows that the Cost sub-criteria have the highest weight with a score of 0,36. The second place goes to Accessibility, with a score is 0,35. Being in the first rank considers the Cost aspect essential for the correspondent in choosing the best execution alternative. The reconstructed hierarchy trees are shown in the following figures.

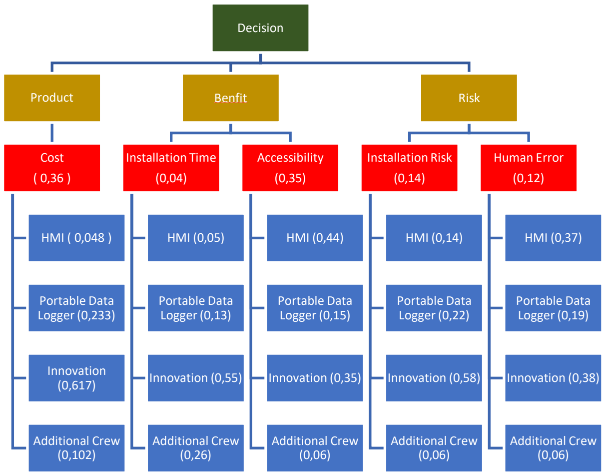


Figure 3.7 Hierarchy tree

The subsequent step is to calculate the weights of each alternative on the priority ranking of sub-criteria to know the alternative that has the highest score to the lowest score.

Table 3.11 Weight of each alternative

	Sub-Criteria									
	Consistency Ratio	Weight	HMI	Weight x subcriteria	Data Logger	Weight x subcriteria	Innovation	Weight x subcriteria	Additional crew	Weight x subcriteria
Cost	0,094	0,36	0,05	0,02	0,23	0,08	0,62	0,22	0,10	0,04
Risk		0,14	0,14	0,02	0,22	0,03	0,58	0,08	0,06	0,01
Installation Time		0,04	0,05	0,00	0,13	0,01	0,55	0,02	0,26	0,01
Human Error		0,12	0,37	0,04	0,19	0,02	0,38	0,04	0,06	0,01
Accessibility		0,35	0,44	0,16	0,15	0,05	0,35	0,12	0,06	0,02
				0,24		0,19		**0,49**		0,08

From the calculation, we can conclude that the chosen alternative using the AHP method is Innovation (0.49) due to having the highest score. The second position is HMI (0.24), the third position is Portable data logger (0.19), and the last position is the additional crew (0.08). Therefore, we can conclude that Innovation is the best alternative we have to AHP Method.

3.3.3 SMART Method

SMART (Simple Multi Attribute Rating) is a linear additive model to predict the value of each option. SMART can also structure a system and environment into components that interact with each other and then unite them to measure and regulate the effects of a system error (Risawandi and Rahim, 2016). SMART proposed the theory that each alternative consists of some criteria with values and weights that describe how important compared to other criteria. This weighting is used to assess each alternative to obtain the best choice (Siregar *et al.*, 2017). The hierarchy tree is still the same as the AHP. Three criteria (Product, Benefit, and risk) and five sub-criteria (Cost, Installation Risk, Human Error, Installation Time, and Accessibility) will be the consideration to choose the best alternatives. The first step to do is to measure how well the alternatives perform in each sub-criterion.

Accessibility

To measure Accessibility, the group discussion team agreed to the direct rating value as shown in the table below:

Table 3.12 Direct rating of accessibility

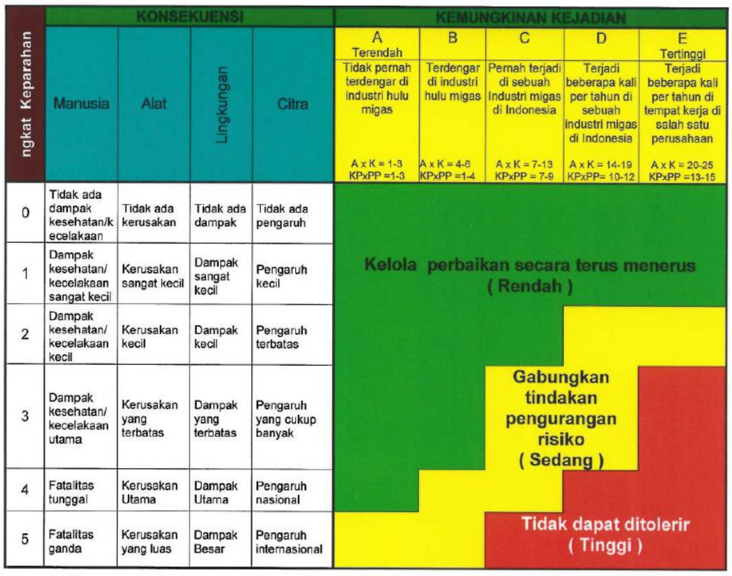
Accessibility	Automatic Minutes recording data and remotely access	100
	Automatic Minutes recording data	50
	Manual recording	0

The Group discussion found that HMI and innovation tools get 100 (maximum scores because both devices could record data as desired, and the data can be accessed everywhere. Meanwhile, the S551 portable data logger gets 50 because it could record data as expected, but it has weaknesses because it still needs to deploy crew to obtain data. Meanwhile, the additional crew gets 0 because of manual data recording.

Installation Risk

To evaluate the installation risk, the researcher used the Internal Organizational Work Procedures at Pertamina EP (B-009/A3/EP0300/2017-SO) as a guideline for the group discussion team to analyze the risk in each alternative (Pertamina EP, 2017).

Table 3.13 Risk matrix (B-009/A3/EP0300/2017-SO)



ngkat Keparahan	KONSEKUENSI				KEMUNGKINAN KEJADIAN				
	Manusia	Alat	Lingkungan	Citra	A Terendah Tidak pernah terdengar di industri hulu migas A x K = 1-3 KPxPP =1-3	B Terdengar di industri hulu migas A x K = 4-6 KPxPP =1-4	C Pernah terjadi di sebuah Industri migas di Indonesia A x K = 7-13 KPxPP = 7-9	D Terjadi beberapa kali per tahun di sebuah industri migas di Indonesia A x K = 14-19 KPxPP= 10-12	E Tertinggi Terjadi beberapa kali per tahun di tempat kerja di salah satu perusahaan A x K = 20-25 KPxPP =13-15
0	Tidak ada dampak kesehatan/kecelakaan	Tidak ada kerusakan	Tidak ada dampak	Tidak ada pengaruh					
1	Dampak kesehatan/ kecelakaan sangat kecil	Kerusakan sangat kecil	Dampak sangat kecil	Pengaruh kecil			Kelola perbaikan secara terus menerus (Rendah)		
2	Dampak kesehatan/ kecelakaan kecil	Kerusakan kecil	Dampak kecil	Pengaruh terbatas					
3	Dampak kesehatan/ kecelakaan utama	Kerusakan yang terbatas	Dampak yang terbatas	Pengaruh yang cukup banyak			Gabungkan tindakan pengurangan risiko (Sedang)		
4	Fatalitas tunggal	Kerusakan Utama	Dampak Utama	Pengaruh nasional					
5	Fatalitas ganda	Kerusakan yang luas	Dampak Besar	Pengaruh internasional				Tidak dapat ditolerir (Tinggi)	

The discussion found that HMI and additional crew are generated high risk. Meanwhile, a Portable data logger and Innovation have moderate risk. Therefore, the high-risk value gets 0, moderate risk 50 points, and Low risk 100 points.

Cost

In Cost Sub-Criteria, the focus group discussion uses the value function to determine the value of each alternative. The cost of HMI obtains from the quotation from the supplier company. They offer IDR 546.8000.000 for HMI installation. The cost of the S551 Portable data logger gets from the marketplace price, the price is IDR.81.000.000. The Innovation tool's cost is obtained from the cost spent to buy material. The researcher spent IDR.4.630.000 to assemble this tool. Meanwhile, the cost of an additional crew is IDR.156.000.000. This cost obtains from the existing worker's payment accumulating over one year.

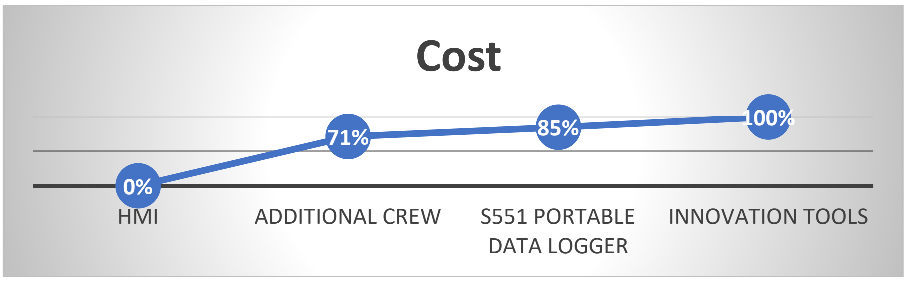


Figure 3.8 Value function of cost sub-criteria

Installation Time

This sub-criterion will measure the value for each alternative according to installation and implementation duration. The shorter time needed will get a higher value (observation time excluded). The researcher used direct rating for measurement value.

Table 3.14 Direct rating of the installation time value

Installation time	One month	100
	2 Month	75
	3 Month	50
	>3 Month	0

HMI and Portable data logger obtain 0 scores because besides the installation takes time, these items need to be ordered by procurement tender (Take three months minimum). The price is above the direct charge limit. On the other hand, innovation tools received a score of 75 because the device could be bought by direct charge (price less than IDR.50.000.000). Direct charge's approval takes approximately one week. The fabrication and installation time need time, not over two months. Meanwhile, the additional crew gets 50 because it needs around three months to rearrange the human resources in Sumatera Field to allocate in Laksmana area.

Human Error

The researcher and group discussion members measure the value of each alternative according to the human error sub-criteria. The less occurrence tendency gets a bigger value. The focus group discussion determines the direct rating parameter shown in Table 3.15 below.

Table 3.15 Direct rating of failure likelihood

Likelihood of Failure	Criteria: Occurrence of Cause -PFMEA (Incidents per Items)	Value
Very High	≥100 per thousand ≥1 in 10	10
High	50 per thousand 1 in 20	20
	20 per thousand 1 in 50	30

Table 3.16 Direct rating of failure likelihood (continued)

Likelihood of Failure	Criteria: Occurrence of Cause -PFMEA (Incidents per Items)	Value
High	10 per thousand 1 in 100	40
Moderate	2 per thousand 1 in 500	50
	0.5 per thousand 1 in 2000	60
	0.1 per thousand 1 in 10.000	70
Low	0.01 per thousand 1 in 100.000	80
	≤ 0.01 per thousand 1 in 1.000.000	90
Very low	Failure is eliminated through preventive control	100

In the discussion session, each decision makers put their subjective value on each alternative and calculated the average value. Based on average calculation results, the team agreed that HMI got a score of 90, S551 Portable data logger got 85, Innovation got 90, and additional crew got 40. After measuring all the alternative values. It can conclude in the table below.

Table 3.17 Alternative performance in each sub-criterion

	Risk		Benefit		Product
	Installation Risk	Human Error tendency	Installation time	Accessibility	Cost
HMI	0	90	0	100	0
S551 Portable data logger	50	85	0	50	85
Innovation	50	90	75	100	100
Additional crew	0	40	50	0	71

The subsequent step is determining the sub-criteria's weight and calculating the aggregate of weighted value. The researcher asked the group discussion member to rank the best to least preferred level of sub-criteria and calculate the normalized weight. The result could see in the table below:

Table 3.18 Weight of sub-criteria

Determining Weight of Sub-Criteria			
Criteria	Attributes / Sub-Criteria	Original Weights	Normalized Weight
Product	Cost	100	0,32
Benefit	Accesibility	90	0,29
Risk	Installation Risk	60	0,19
Risk	Human Error Tendency	40	0,13
Benefit	Installation Time	20	0,06
		310	

After obtaining the weight of sub-criteria, calculate the value from each alternative to get an aggregate weighted value, as shown in the table below.

Table 3.19 HMI aggregate of weighted value

	The aggregate of Weighted Value		
	HMI		
	Value	Normalized Weight	Result
Cost	0	0,32	0,00
Risk	0	0,19	0,00
Human Error tendency	90	0,13	11,61
Installation time	0	0,06	0,00
Accessibility	100	0,29	29,03
			40,65

Table 3.20 Portable data logger aggregate of weighted value

	The aggregate of Weighted Value		
	S551 Portable data logger		
	Value	Normalized Weight	Result
Cost	85	0,32	27,42
Risk	50	0,19	9,68
Human Error tendency	85	0,13	10,97
Installation time	0	0,06	0,00
Accessibility	50	0,29	14,52
			62,58

Table 3.21 Innovation aggregate of weighted value

	The aggregate of Weighted Value		
	Innovation		
	Value	Normalized Weight	Result
Cost	100	0,32	32,26
Risk	50	0,19	9,68
Human Error tendency	90	0,13	11,61
Installation time	75	0,06	4,84
Accessibility	100	0,29	29,03
			87,42

Table 3.22 Additional crew aggregate of weighted value

	The aggregate of Weighted Value		
	Additional Crew		
	Value	Normalized Weight	Result
Cost	71	0,32	22,90
Risk	0	0,19	0,00
Human Error tendency	40	0,13	5,16
Installation time	50	0,06	3,23
Accessibility	0	0,29	0,00
			31,29

The aggregate of weighted value can conclude that Innovation is the best alternative (87,42). The second position goes to the Portable data logger (62,58). HMI becomes the third (40,65); the last choice is the additional crew (31.29).

The next step is trading weight with cost, as shown below.

Table 3.23 Weight vs Cost

	Weight	Cost
Innovation	87,42	4.630.300
S551 Portable data logger	62,58	81.000.000
Additional Crew	31,29	156.000.000
HMI	40,65	546.800.000

We can conclude from the Figure below that Innovation generates the highest weight and most affordable cost on that graph. It makes Innovation become the best alternative according to the SMART method.

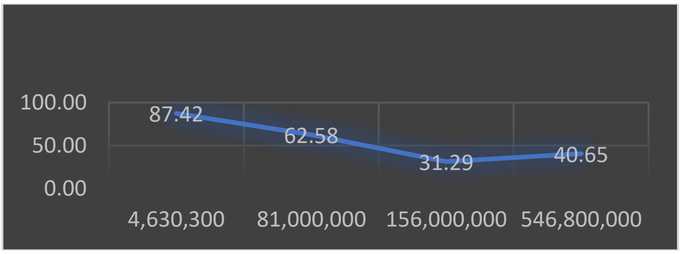


Figure 3.9 Weight vs cost

The last step of the SMART method is making sensitivity analysis. Sensitivity analysis is used to examine how robust the choice of an alternative is to changes (Goodwin and Wright, 2014).The sensitivity analysis is made by changing the weight of the same criteria to become 0 (zero) and then adding the value to other criteria. We do this to all criteria in the decision-making. The result of this step is shown in the table below.

Table 3.24 Value risk = 0

	Risk = 0					agregat weighted value
	Cost	Installation Risk	Installation time	Human error tendency	Accessibilty	
	0,48	-	0,10	-	0,43	
HMI	0,0	-	-	-	42,86	42,86
Portable logger S551	40	-	-	-	21,43	61,90
Inovasi	48	-	7,14	-	42,86	97,62
Additional Crew	34	-	4,76	-	-	38,57

Table 3.25 Value benefit = 0

	Benefit = 0					agregat weighted value
	Cost	Installation Risk	Installation time	Human error tendency	Accessibilty	
	0,5	0,30	-	0,20	-	
HMI	0,0	-	0	18,00	0	18,00
Portable logger S551	43	15,00	0	17,00	0	74,50
Inovasi	50	15,00	0	18,00	0	83,00
Additional Crew	36	-	0	8,00	0	43,50

Table 3.26 Value cost = 0

	Product = 0					agregat weighted value
	Cost	Installation Risk	Installation time	Human error tendency	Accessibility	
	0	0,29	0,10	0,19	0,43	
HMI	0	-	-	17,14	42,86	60
Portable logger S551	0	14,29	-	16,19	21,43	52
Inovasi	0	14,29	7,14	17,14	42,86	81
Additional Crew	0	-	4,76	7,62	-	12

The graph from the sensitivity analysis calculation is shown in the graph below.

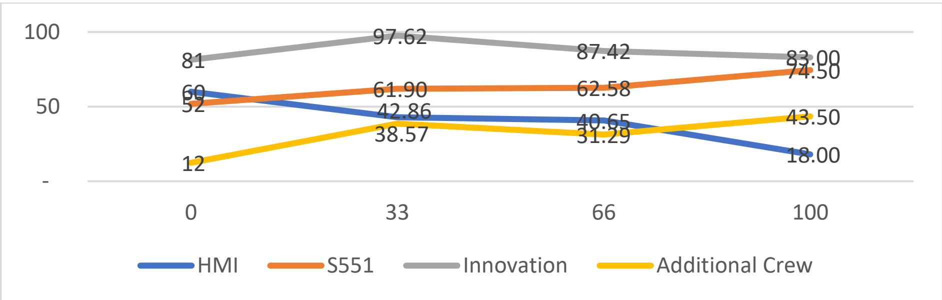


Figure 3.10 SMART sensitivity analysis

Based on the graph, it can conclude that the innovation tool is clearly the most attractive alternative.

3.3.4 Implementation Plan

The implementation plan strategy ensures inlining with all resources and the timeline. The first step of the planning was to analyze what input parameters need to be known for compressor conditions. The second step is to design an electrically safe device that could be installed in the hazardous area.

Table 3.27 5W1H

Why	How	What	When	Who	Where	Target
No detection system of air compressore failure and also incorrect maintenance analysis	Survey Field data collection and team discussion	record and analyze necessary data. Site surveys to suit tools according to field conditions and hazardous areas	Nov - Dec 2021	Person A, Person B,Person C	Antasena Service Platform	The data logger is able to present data on air compressor operating parameters accurately, real-time data and can provide early notification when high/low parameters occur
	Design and engineering drawings	Design a tool that can function as a real time data logger plus the ability to transmit the data without using the internet network	Dec-21	Person A, Person C,Person D	Antasena Service Platform	
	Material Preparation	Purchase of required components and modules according to the design	Dec-21	Person A, Person C,Person D	Antasena Service Platform	
	Fabricate hardware and interface software	Assembling and programming using Arduino IDE software, Creating an easily accessible local server and a user friendly dashboard display	Dec 2021 - Jan 2022	Person C,Person D	Antasena Service Platform	
	Data collection testing	Sensor testing and calibration	Feb-22	Person C,Person D	ASP,APC,BPP,DP, MP	
	Standard operating Procedure arrangement	Develop SOP as standard and tool operation	Feb-22	Person A,Person B	Antasena Service Platform	

The subsequent step is fabricating the tools and installing them in the setup position. If this step is completed, devices must be tested for data transmission and durability. At the same time, the MOC (The short of Management of change) and SOP (standard operating procedure) need to be created when the testing is conducted. This Management of Change (MOC) procedure ensures that changes are appropriately reviewed and recorded and that hazards introduced by the change are identified and controlled before the change is implemented and during the crucial transition period. After the MOC and SOP were approved and the testing passed. The final phase is to monitor the tool's performance.

Table 3.28 Timeline plan

Planning	Bobot	Timeline & S-curve Plan															
		Nov-21				Dec-21				Jan-22				Feb-22			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Collecting Data	2%	0,4%	0,4%	0,4%	0,4%	0,4%											
Calculation Process	2%						0,7%	0,7%	0,7%								
Tools Design and Material Selection	10%							5%	5%								
Tools Fabrication	30%								10%	10%	10%						
Installation	29%											14,5%	14,5%				
Testing and commisioning	21%													7%	7%	7%	
Create MOC (Management of Change)	1%														1%		
Evaluation and monitoring	5%														0,2%	0,2%	0,2%
TOTAL	100%																
Cumm		0,4%	0,8%	1,2%	1,6%	2,0%	2,7%	8,3%	24,0%	34,0%	44,0%	58,5%	73,0%	80,0%	88,2%	95,4%	95,7%

Table 3.29 Timeline plan

Planning	Bobot	Timeline & S-curve Plan																			
		Mar-22				Apr-22				May-22				Jun-22				Jul-22			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Collecting Data	2%																				
Calculation Process	2%																				
Tools Design and Material Selection	10%																				
Tools Fabrication	30%																				
Installation	29%																				
Testing and commisioning	21%																				
Create MOC (Management of Change)	1%																				
Evaluation and monitoring	5%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%	0,2%
TOTAL	100%																				
Cumm		95,9%	96,1%	96,3%	96,5%	96,7%	97,0%	97,2%	97,4%	97,6%	97,8%	98,0%	98,3%	98,5%	98,7%	98,9%	99,1%	99,3%	99,6%	99,8%	100,0%

4. Conclusion

Based on 2020 data, the problems in the Instrumentation system of the Laksmana Area that caused the unplanned shutdown could be classified into three categories: Air compressor

Failure, Instrumentation valve problem, and instrument equipment malfunction. The Pareto diagram exhibit that the air compressor failure had the most significant impact, contributing to almost 62% of the unplanned shutdown caused by the Instrumentation system in 2020. Therefore, finding solutions to overcome air compressor failure is the focus of this research. To help find the root cause of the compressor failure, the researcher uses Fishbone Diagram, FMEA (Failure Mode Effect Analysis), and Pareto diagram. From Man, Machines, Materials, Methods, and Environment factors, the decision makers agreed that method and machine factors are the main contributors to compressor failure. Laksmana area didn't have a system to detect the anomaly condition (Preliminary detection) that will lead to failure. It also found incorrect analysis in conducting preventive and predictive maintenance. This condition happened due to a limited source of data.

To find a suitable alternative to solve this problem, the researcher and decision makers utilize value focus thinking. The discussion constructs a hierarchy tree that consists of Goal, Criteria, and Sub-Criteria. In both the SMART and AHP methods, the sub-criteria will be ranked based on priority. This research found that even with different values, both methods generate the same priority rank. The rank of most attractive to the less attractive sub-criteria starts with Cost, Accessibility, Installation Risk, Human Error Tendency, and installation time.

For the alternatives chosen, both AHP and SMART have the same result. The best alternative goes to Own Innovation Tools. Own Innovation tools become the best alternative because it offers the lowest cost and most accessible tools compared to other alternatives. The 2nd place in the SMART method is the S551 portable data logger, the 3rd is HMI, and the last is Additional crew. Meanwhile, in AHP, the 2nd place is HMI, the 3rd place is Portable data logger, and the last alternative is the additional crew. The rank in both methods is different because of the way to obtain the value. In the SMART method, the value is obtained by direct rating and value function. Meanwhile, in AHP, the value is obtained by pairwise comparison. In the direct rating or value function, if a gap value between 2 alternatives is twice bigger, it doesn't mean it is twice as preferable as the other one. The value describes the subjective desirability of the corresponding Sub-Criteria level. Meanwhile, pairwise comparison compares two different elements by giving a rate of the relative importance between each pair of decision alternatives and criteria.

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