Risk Level Assessment of Pipelines using a Combination of Analytical Network Process and Risk Based Inspection Methods

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Abstract

Using pipelines is the most effective and efficient way to transport oil and gas to an intended destination. However, pipelines also pose risks to humans, the environment and business interests. This research study assessed the level of pipeline risk of PT X. As such, it aimed to identify the efficacy of inspection and maintenance planning using a priority scale based on the ranking of the causes of failure. A combination of Analytical Network Process (ANP) and Risk-based Inspection (RBI) methods was used to assess the risk level of pipeline failure. The results using the ANP method showed that corrosion (44.64%) is the main factor causing failure to the pipelines. The atmospheric corrosion subfactor is one of the corrosion factors that contributed to pipeline failure (16.12%). Safety is the most significant consequence of the impact of pipeline failure (51.54%). Furthermore, by applying the RBI method, the Probability of Failure (PoF) value was calculated to be 1.2028 and the Consequence of Failure (CoF) value was 4.290, resulting in a risk level of 4 on the risk matrix order of 6 x 6. Inspection and maintenance programmes should pay special attention to the corrosion factors and the atmospheric corrosion subfactors in order to reduce the risk level associated with pipeline failure.

Keywords: *Analytical Network Process, Risk Based Inspection, Probability of Failure, Consequence of Failure*

I. INTRODUCTION

Pipelines serve to transport fluid (liquid or gas) from one location to another. Based on geographical aspects, pipelines are categorised as onshore pipelines and offshore pipelines [1]. In the oil and gas industry, a pipeline is the most economical means of transporting crude oil, natural gas and other oil product from one point to another; it is more cost-effective than railroad transportation, tank trucks or tankers [2]. Although pipelines have been designed as well as possible, there is still a risk of failure. When a leak or rupture occurs on the pipeline, it can be dangerous, and even fatal, because it may cause a fire or explosion and result in environmental pollution [3].

There have been several pipeline leaks in Indonesia. The last incident resulted in fire and environmental pollution due to the breakdown of the submarine crude oil pipeline. To reduce the risk of failure, it is important to conduct good inspections and to ensure proper maintenance. At present, many companies still rely in Time-based Inspection (TBI) methods to inspect and maintain their equipment. When the inspection and maintenance of pipelines is not done properly, it can lead to ineffective and inefficient time management as well as increased costs [2].

Some developed countries have shifted from TBI to Risk Based Inspection (RBI) to assess and maintain pipelines. RBI is a risk assessment method used to develop a planning or inspection programme based on the risk of failure and the consequences of failure of equipment [4]. With the RBI method, it is possible to effectively and efficiently determine the frequency and time interval of inspections based on potential failures in order to reduce inspection costs [5]. This approach consists of a thorough examination covering corrosion, materials, processes, plant operations and consequence analysis to identify and reduce the risks by taking corrective, proactive and preventive actions.

The RBI process is an important element of the inspection programme based on risk analysis.The result of RBI is a risk matrix that assigns a specific level of risk to equipment. In terms of risk level values, scheduling inspections and maintenance for equipment can be done based on the mechanism of damage that occurs to the equipment. Several studies have investigated the failure of pipelines. Shafiq and Silvianita [2] compiled a ranking of the causes of pipeline leakage using the AnalyticalHierarchy Process (AHP) method. Dawotola et al. [3] also used the AHP method to determine the main factor that causes pipeline failure. The AHP method can be used to determine the weight of the factors that cause a pipeline to leak.

This present study used the Analytical Network Process (ANP) method, which was developed from the AHP method, to evaluate the dependency relationship between the factors and subfactors [6]. This research study aims to identify the ranking of the factors and subfactors that cause pipeline failure as well as the consequences of that failure. It also seeks to determine the level of risk that is likely to occur in the pipeline using the RBI method. Furthermore, based on the ranking of factors and subfactors that cause pipeline failure and the resulting risk level, this paper presents some recommendations that are effective, on target and efficient ways to reduce the risk of pipeline failure.

II. RESEARCH METHODS

A. Research Object

The object studied in this research is a crude oil pipeline with a diameter of 12 inches (MKSA-STN), owned by PT X, which operates in East Kalimantan.

B. Research Scope

This research study aimed to assess the risk level of the pipeline under investigation in the 5 km onshore pipeline. This research framework uses the concept of risk management by applying the RBI method to the pipeline. In terms of research variables, the probability of the cause of a pipeline failure consists of the following factors and subfactors [7]:

1. Third Party Damage Index (TPDI). This factor consists of the following subfactors:
   a. Minimum Depth of Cover (MDC)
   b. Activity Level (AL)
   c. Above Ground Facilities (AGF)
   d. Line Locating (LL)
   e. Public Education Program (PEP)
   f. Right of Way (ROW)
   g. Patrol Frequency (PF)
2. Corrosion Index (CI). This factor consists of the following subfactors:
   a. Atmospheric Corrosion (AC)
   b. Internal Corrosion (IC)
   c. Subsurface Corrosion (SC)
3. Design Index (DI). This factor consists of the following subfactors:
   a. Safety Factor (SF)
   b. Fatigue (FAT)
   c. Surge Potential (SP)
   d. Integrity Verification (IV)
   e. Land Movement (LM)
4. Incorrect Operation Index (IOI). This factor consistsof the following subfactors:
   a. Operation (OP)
   b. Maintenance (MAIN)

Moreover, according to Integrated Risk Prioritization Matrix User Guide, the consequences of the failure of a pipeline have an impact on: Safety (SFT),Healthy (HLT), Environment (ENV) and Assets (AST) [8].

C. Data Collection

This research study collected primary data and secondary data. Primary data were obtained from questionnaires resulting from interviews with experts (expert judgment) that have an understanding of pipelines. There were 29 respondents (the experts) with different professional backgrounds, including asset integrity specialist, facility engineers, operators (operation), healthy environmental and safety specialist and maintenance team. Secondary data consisted of information about the design, specifications, history of inspections and maintenance of the pipeline as well as standard procedures related to the pipeline. All of the data wereobtained from the database found in the Pipeline Integrity Management System (PIMS).

D. Risk Level Assessment

The risk assessment process consisted of three stages. In the first stage, the condition of the pipeline was assessed based on the subfactors that cause the failure and the consequences of that failure. In the second stage, the weight of each factor and subfactor that causes the pipeline failure was calculated as was the weight of each of the possible consequences of the failure. This calculation process used the ANP method. In the third stage, the Probability of Failure (PoF) and Consequence of Failure (CoF) values are determined in order to obtain the level of risk through the risk matrix.

1. Assessment of the Condition of the Pipeline

Assessment of the condition of the pipeline included an investigation of the subfactors of the cause of the pipeline failure and the CoF. The results of the average value of the assessment of the pipeline condition through the questionnaire are the risk rating value that will be used to calculate the score.

2. Calculation of ANP

The calculation of ANP consisted of the following stages:

a. Arrange the structure of the problem by creating a network model of decision that shows the relationships among the elements of the decision.
b. Create a paired comparison matrix between the factors that influence decisions by assessing the importance of an element in relation to other elements based on Saaty Fundamental Scale.

Table 1
Saaty Fundamental Scale [9]

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak	Between equal and moderate
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	Between moderate and strong
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	Between strong and very strong
7	Very strong or demonstrated importance	An activity is favored very strongly over another;
8	Very, very strong	Between very strong and extreme
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Use reciprocals for inverse comparisons		

c. If there are many respondents, there are often differences of opinion in determining interests, so that the average geometry is needed. That is obtained by using the following equation:

$$\text{Average Geometry} = \sqrt[n]{R1 \ x \ R2 \ x \ R3 \ x \ldots Rn}$$

Where:
R = value of the comparison between the value of B_i and B_j.
n = number of respondents.

d. Prioritise each criterion/factor.

e. Calculate the value of the priority vector (eigen vector) using the following formula:

$$X = \sum\left(\frac{Bij}{\sum Bj}\right)/n$$

Where:
X = eigen vector
Bij = column cell values in one row (i, j = 1, 2 ... n)
$\sum Bj$ = total number of columns
n= number of matrices being compared.

f. Check the consistency ratio (CR) with a value of no more than 10%. If the CR value is more than 10%, the assessment of the decision data must be corrected/repeated. The following steps are used to check the CR:

1. Look for the value of λ_{max} using the following equation:

$$\lambda_{max} = (\text{eigen value 1 x number of columns 1}) + (\text{eigen value 2 x number of columns 2}) + \ldots + n$$

2. Determine the Consistency Index (CI).

$$CI = (\lambda_{max} - n) / (n - 1)$$

Where:
CI = Consistency Index
λmax = the largest eigen value
n = number of matrices being compared.

3. Determine the CR value:

$$CR = CI/RI$$

Where:
CR = Consistency Ratio
CI = Consistency Index
RI = Random Index

Table 2
Random Index Value [9]

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

g. Create a super matrix by entering all the priority vector values (eigen vector) obtained from the pairwise comparison matrix between elements.
h. Take the final value of the criterion/factor or alternative and arrange the ranking.

To facilitate the analysis process all these steps are carried out using Super Decision software developed by William J. Adams from Embry Riddle Aeronautical University, Florida in collaboration with Rozan W. Saaty [10].

3. Calculation of the Risk Level Values

In order to obtain a PoF value, the value of the global weight of each subfactor that causes the pipeline failure must be calculated. Then, the score of each ofthese subfactors is calculated. The total score results in a PoF value for the factor causing the failure, and it creates a CoF value associated with the consequences of the occurrence of failure.

III. RESULTS AND DISCUSSION

A. Condition of the Pipeline

The first questionnaire was about assessing the conditions of the pipeline in terms of the subfactors that cause the failure using a Linkert scale ranging from 1 to 6, as follows: strongly unsatisfactory (1), unsatisfactory (2), less than satisfactory (3), quite satisfactory (4), satisfactory (5) and strongly satisfactory (6). Based on the results of the questionnaire, the respondents generally gave answers with an average Linkert scale value of 4 (quite satisfactory). The second questionnaire was about assessing the pipeline against the CoF using a Linkert scale ranging from 1 to 6, as follows: catastrophic (1), severe (2), major (3), moderate (4), minor (5) and incidental (6). Based on the results of the questionnaire, the respondents generally gave answers with an average Linkert scale value of 4 (moderate). The results of these two questionnaires become the rating parameter used to calculate the score.

B. Determination of the Dependency Relationships among the Subfactors

The third questionnaire was used to determine the dependency relationship between the subfactors in one factor (inner dependency) and between the subfactors in different factors (outer dependency). The results of the questionnaire recapitulating the dependency relationships between the subfactors are shown in Table 3.

Determination of the dependency relationships was based on previous research. If the number of respondents who choose B_{ij} is $\geq$to half of N, ($B_{ij} \geq N/2$), where N is the total number of the respondents, it is concluded that there is a relationship of interdependence between the subfactors [11]. For example, in the Minimum Depth of Cover (MDC) level cells, the number of respondents is 29 and the B_{ij} value = 24; thus, it is concluded that there is a relationship of interdependence between MDC and Activity Level (AL).

Table 3
Recapitulation of the Dependency Relationships between the Subfactors

FACTORS AND SUBFACTORS		Third Party Damage Index							Corrosion Index			Design Index					Incorrect Operation Index	
		Minimum Depth of Cover	Activity Level	Above Ground Facilities	Line Locating	Public Education	ROW Condition	Patrol Frequency	Atmospheric	Internal Corrosion	Subsurface corrosion	Safety Factor	Fatigue	Surge Potential	Integrity Verification	Land Movement	Operation	Maintenance
Third Party Damage Index	Minimum Depth of Cover		24	14	11	7	9	4	17	0	16	15	21	0	18	17	0	8
	Activity Level	13		16	16	16	16	12	11	0	1	11	4	2	14	11	1	7
	Above Ground Facilities	12	12		15	7	13	12	6	0	0	13	1	1	17	13	4	15
	Line Locating	7	12	13		8	16	14	6	0	0	6	1	0	11	9	0	7
	Public Education Program	10	17	9	11		13	20	0	0	0	3	0	0	2	4	1	2
	ROW Condition	8	17	14	15	10		24	5	0	0	5	0	0	12	15	0	8
	Patrol Frequency	15	12	11	13	16	24		4	0	0	0	0	0	7	6	0	5
Corrosion Index	Atmospheric	0	8	8	2	0	5	4		0	29	29	21	0	28	5	28	13
	Internal Corrosion	0	0	0	0	0	0	0	0		0	29	29	7	29	0	29	14
	Subsurface Corrosion	10	0	0	0	0	0	0	28	0		29	28	0	29	0	29	11
Design Index	Safety Factor	7	10	3	4	1	4	0	12	16	14		21	10	18	10	18	9
	Fatigue	0	4	2	1	0	0	0	4	5	3	22		12	14	2	15	6
	Surge Potential	10	1	1	0	0	1	0	1	19	0	14	17		10	1	13	5
	Integrity Verification	10	13	11	6	1	8	3	14	19	13	15	14	10		18	12	17
	Land Movement	16	10	13	12	5	10	3	9	0	1	7	4	1	21		5	12
Incorrect Operation Index	Operation	2	4	3	2	0	0	1	26	27	29	16	13	16	12	2		25
	Maintenance	9	5	16	8	0	6	4	29	29	28	7	8	7	19	11	25	

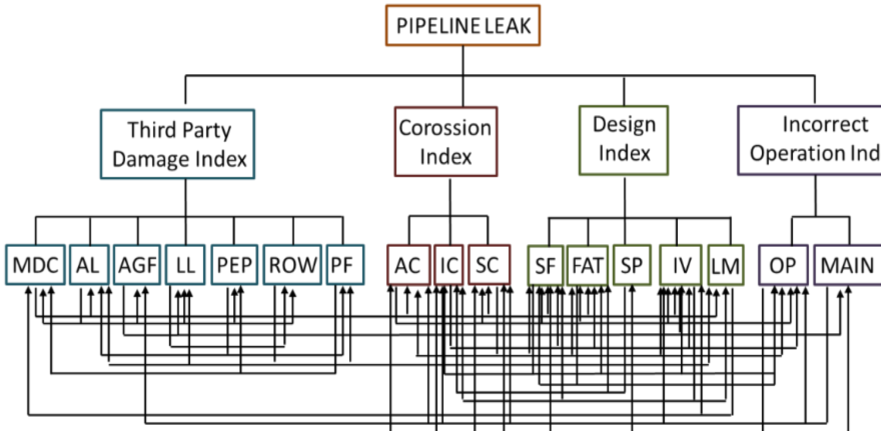

Figure 1: Network structure of the subfactors that cause the pipeline failure

C. Pairwise Comparison Between the Factors and Subfactors

The fourth questionnaire was about the pairwise comparisons between the factors and subfactors that cause a pipeline failure based on the information presented in Figure1, using a scale ranging from 1 to 9. The fifth questionnaire was about the pairwise comparisons between the consequences of the impact of the pipeline failure using a scale ranging from 1 to 9.

D. Data Testing

The validity test uses Correlation Item-Total Correlation and Bivariate Pearson (Product Moment Pearson) correlation techniques [11]. If the r count is ≥ the r table with a significance level of 0.05, then the instrument is said to be valid. The r table value with the number of respondent N = 29 having a confidence level of 95% (α = 5%) is 0.3610.

The validity test results showed an r count value >0.3610 for all data, so the questionnaire data is said to be valid. Next, a reliability test was conducted using the Cronbach Alpha method [12]. From the calculation results, it is concluded that the Cronbach Alpha coefficient value is >0.6, so the data are said to be reliable. Experts agree that the Cronbach Alpha coefficient value is> 0.7 for a scale that is already established and is considered stable. But the coefficient value of 0.6 is considered sufficient for the scale that is still under development [13].

E. Calculation of the Weight Value of the Factors and Subfactors

At this stage, the weight value of the fourth questionnaire results were calculated. This consisted of the pairwise comparisons among the factors and among the subfactors that cause the pipeline failure. The questionnaire results of the pairwise comparison are shown in Table 4. As seen, the TPDI factor is 0.1429-times more important than the CI factor, or the CI factor is 7-times more important than the TPDI factor.

Table 4
Pairwise Comparison Matrix

Factors	TPDI	CI	DI	IOI
TPDI	1	0.1429	5	0.5
CI	7	1	7	7
DI	0.2	0.1429	1	0.5
IOI	2	0.1429	2	1

Figure2 shows a network diagram of the factors that cause the pipeline failure.The CR value of the calculation result is 0.0695. This value is <0.1, so the results of the opinion questionnaire about the factors that cause the pipeline failure is consistent. The CI factor has the highest weight value, which is 0.4464, followed by TPDI with a weight of 0.2641, DI with a weight of 0.1841, and IOI with a weight of 0.1054.

The output of the CI value for the subfactors that cause the pipeline failure is 0.0439. This value is <0.1, so the factors and subfactors that cause the pipeline failure are consistent. The output for the weight value of the subfactors that cause the pipeline failure shows that the AC subfactor has a weight value of 0.1612 followed by SC, with a weight value of 0.1312. The MDC subfactor has a weight value of 10.54%; the SF,MAIN and OP subfactors have weight values of 9.17%, 8.28% and 7.43%, respectively. The PF subfactor had the smallest weight value (0.0058).

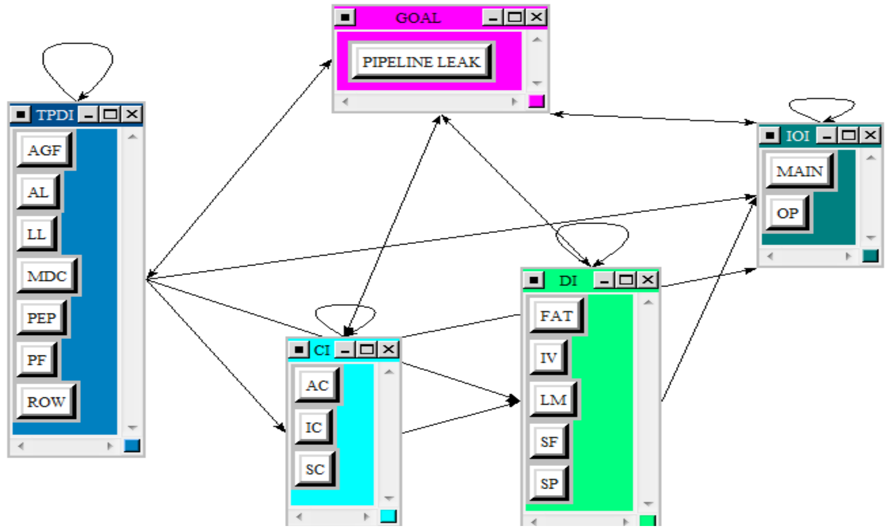

Figure 2: ANP network diagram of the factors that cause the pipeline failure

F. Calculation of the Weight Value of the Consequence Factors

The calculation of the weight of the consequence factors on the impact of the pipeline failure also used the data from the fifth questionnaire, which contains pairwise comparisons between the CoF of the pipeline using a scale ranging from 1 to 9. The information presented in Table 5 shows that the SFT factor is 5-times more important than the HLT factor, or the HLT factor is 0.2-times more important than the SFT factor. This holds true for the other factors (ENV and AST).

Table 5
Pairwise Comparison Matrix of the Consequence Factors against the Pipeline Failure

Factors	SFT	HLT	ENV	AST
SFT	1	5	3	6
HLT	0.2	1	0.3333	3
ENV	0.3333	3	1	5
AST	0.1667	0.3333	0.2	1

The result of the CR calculation for the CoF of the pipeline is 0.0952. This value is <0.1, so that the consequences factor for the impact of the pipeline failure is consistent. The SFT factor had the highest weight value of 0.5154, followed by ENV, with a weight value of 0.2248, HLT, with a weight value of 0.1885 and AST, with a weight value of 0.0713.

G. Risk Level Assessment Using the Risk Matrix

The sum of the score values for all the subfactors that cause the pipeline failure is obtained from the PoF value. The results of the risk level calculations are as shown in Table 6.

Table 6
Probability of Failure (PoF) Results

Factors	Factor Weight	Sub Factor	Weight of Subfactor	Global Wight	Rating	Score	PoF
TPDI	0.2641	**MDC**	0.1054	0.0278	4.4138	0.1227	
		AL	0.0503	0.0133	4.3103	0.0573	
		AGF	0.0319	0.0084	4.4483	0.0374	
		LL	0.0180	0.0048	4.3448	0.0209	
		PEP	0.0091	0.0024	3.9310	0.0094	
		ROW	0.0143	0.0038	3.9655	0.0150	
		PF	0.0058	0.0015	3.7931	0.0057	

IC	0.4464	**AC**	0.1612	0.0719	4.3448	0.3123	1.2028
		IC	0.0734	0.0328	3.7931	0.1244	
		SC	0.1312	0.0586	3.7931	0.2223	
DI	0.1841	**SF**	0.0917	0.0169	4.7241	0.0798	
		FAT	0.0285	0.0053	4.3793	0.0232	
		SP	0.0361	0.0067	4.4483	0.0298	
		IV	0.0546	0.0101	4.3103	0.0435	
		LM	0.0314	0.0058	4.1379	0.0240	
IOI	0.1054	**OP**	0.0743	0.0078	4.5862	0.0358	
		MAIN	0.0828	0.0087	4.5172	0.0393	

The PoF score was calculated by multiplying the weight of the factor with the rating, while the CoF value was obtained from the sum of the scores. The results of the CoF calculation are shown in Table 7.

Table 7
The Consequence of Failure (CoF) Results

Factors	Factor Weight	Rating	Score	CoF
SFT	0.5154	4.4483	2.2927	4.3171
HLT	0.1885	4.4828	0.8450	
ENV	0.2248	4.0000	0.8992	
AST	0.0713	3.9310	0.2802	

Based on the calculations, the PoF value was 1.2028 and the CoF value was 4.3171. Furthermore, the level of risk that might occur was determined through the risk matrix. The PoF value is rounded to 1 and the CoF value is rounded to 4, then they are adjusted to the matrix, as seen in Figure 3. In that figure, the encounter of the value of 1 (likely) and the value of 4 (moderate) creates the value of 4.

This study used the Integrated Risk Prioritization Matrix compiled by PT X [8]. The Y axis represents the likelihood of risk, or the PoF value, and the X axis represents the CI value or the CoF. According to the risk criteria in the Integrated Risk Prioritization Matrix, the result with a value of 4 in the risk matrix shows that the pipeline is at high risk of failure, and it has high consequences for the company's SFT, HLT, ENV and AST in the event of a pipeline failure or leak.

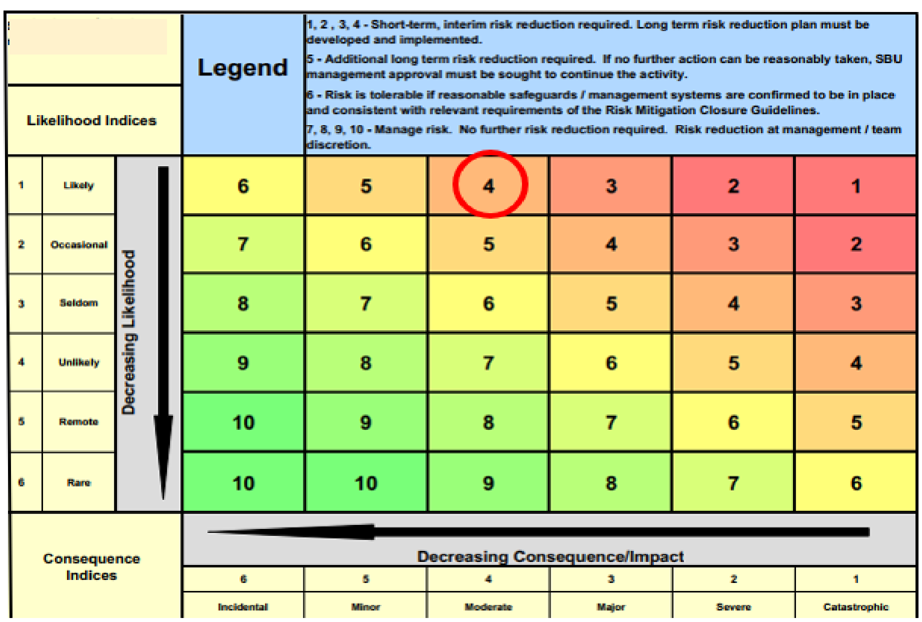

Figure 3: Risk matrix results from the data analysis

H. Inspection and Maintenance Strategy

Based on the results of the risk assessment, the inspection interval of the recommended pipeline is 6 months for the online pipeline and one year for the offline pipeline [8]. If it is not possible to implement these recommendations, other efforts are needed, such as developing plans and strategies for maintenance checks that are effective, targeted and efficient by involving competent engineers to carry out more detailed research on the pipeline.

The corrosion factor had the highest risk level value, so it is likely to occur in the pipeline. This is because the AC subfactor that is part of the corrosion factor also had a high weight value of 16.12%. In general, AC occurs in parts of the splash zone, ground/air interface, part of the pipeline that crosses trenches or small rivers, and it is interrupted between the support and conduit pipes. The mechanism of corrosion is due to mechanical damage that affects the paint coating. The type of corrosion that occurs generally is uniform corrosion, pitting corrosion, and crevice corrosion on the outside of the pipeline. Uniform corrosion rarely results in fatal damage, but it can cause other dangerous types of corrosion such as stress corrosion cracking. Corrosion causes thinning of the thickness of the pipeline, and it will eventually cause leakage. A visual inspection of the pipeline is done to assess the level of AC. The condition of the outer surface of the pipeline is inspected and the thickness of the pipeline is measured using an Ultrasonic Test tool. This measurement is conducted every 6 months at regular intervals, as recommended above, to monitor the corrosion rate to the allowable extent. To inhibit the AC rate, the pipeline's paint coating should be repaired in accordance with applicable standards so that good quality is maintained and the pipeline is protected from corrosion.

Subsurface corrosion occurs on the outside of a pipeline embedded in the soil. In general, the types of corrosion that occur are uniform corrosion and pitting corrosion. Guided Wave Ultrasonic Testing (GWUT) equipment is used to effectively inspect a pipeline for subsurface corrosion [14]. If an anomaly is found, excavation will be carried out, and the remaining thickness of the pipeline is measured manually using the Ultrasonic Test. Moreover, it is important to determine if the pipeline is still protected by a cathodic protection system; that is done by conducting a Cathodic Protection Survey or by measuring the Direct Current Voltage Gradient (DCVG) on the channel pipe. To inhibit the AC rate, the paint coating must be repaired. If needed, optimising the cathodic system is also a good way to ensure that it works well so that the pipeline is protected from corrosion.

IC is the occurrence of corrosion on the inside of the pipeline. Generally, it is caused by impurities that dissolve and are carried away by the crude oil as it flows through the pipeline. The impurities include sea water, sulphide acid (H_2S), carbon dioxide (CO_2), oxygen (O_2), chloride ions, micro-organisms, in the form of an-aerobic bacteria, and sand. Through the electrochemical process these substances can cause corrosion on the inner walls of the pipeline. The sand carried by crude oil can cause erosion on the inner walls of the pipeline when the oil flows through it. To inspect for IC, a corrosion coupon should be installed and monitored regularly. In addition, samples of crude oil at the end of the delivery and crude oil samples from the recipients should be taken for laboratory analysis to determine the content of the impurities. To prevent IC, chemicals, such as corrosion inhibitors, scale inhibitors or biocides, are injected into the pipeline depending on the cause of the corrosion. The dose of the injected chemicals depends on the results of the laboratory analysis, and the chemicals are periodically injected. To clean the inner walls of the distribution pipes to remove such things as sand and other objects, a pigging is regularly launched into the pipeline using either a rubber foam pig or a brush pig.

In addition to the above-mentioned efforts that businesses use to reduce the level of risk of pipeline leakage or failure, a long-term plan is also needed to conduct a thorough evaluation using an In-Line Inspection (ILI) method by launching the Intelligent Pig inspection tool into the pipeline. The Intelligent Pig inspection results will provide comprehensive data about the actual conditions of the pipeline, thereby enabling an analysis of the Fit for Service (FFS) of the pipeline [14].

IV. CONCLUSION

The risk analysis in this research used a combination of ANP and RBI methods to evaluate a crude oil pipeline with a diameter of 12 inches stretching from the coastline to the location of the refining process (onshore pipeline). A risk level value of 4 on the risk matrix was found, and the pipeline was in the high-risk level category.

The CI was the factor with the highest risk of pipeline failure (44.64%). In terms of the CoF of the pipeline, the SFT factor was ranked first at 51.54%. The corrosion subfactors that contribute to the high risk of pipeline failure are AC (16.12%), SC (13.12%), MDC (10.54%), SFT (9.17%), MAIN (8.28%), OP (7.43%) and IC (7.34%).

Serious consideration must be given to the corrosion factor and its subfactors to effectively and efficient inspect and maintain pipelines at key time intervals in order to reduce the level of risk of failure.

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