The Application of Fuzzy Inference System during Risk Assesment Process Study Case: 14" Subsea Pipeline PT. PHE-WMO

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Abstract: Potential hazard that could lead to the failure of the operations of gas pipelines 14 "PT PHE-WMO is often found in the offshore and onshore area. In order to prevent potential damage, the companies need to conduct risk assessment. This study compares the risk assessment approach between Muhlbauer and Fuzzy Inference System to get a proper risk assessment for gas pipelines 14" PT. PHE-WMO. Muhlbauer scoring system used in this approach i.e. third party damage index, corrosion index, design index, incorrect operation index, and leak impact factor. On the other hand, Fuzzy Inference System approach applied in the scoring system is Mamdani method (Max-Min) that includes the formation of fuzzy set, the implications of the application functions, composition rules, and defuzzyfication. The comparative results of both RSS approach are used as consideration to determine the next appropriate mitigation step for gas pipe 14 "PT PHE-WMO. The calculation of pipe using fuzzy approaches provides greater difference value in RRs. The greater difference value of RRS makes it easy and clear in administering the rank for each segment of data input. Thus, the fuzzy method is more accurate and precise than the Muhlbauer.

1. INTRODUCTION

Piping systems is the main transport mode in the oil and gas industry to distribute oil and gas products yet very effective and efficient, especially for distributing the product from sea to the land. There are diverse the pipeline pathways, starting from the sea, plains, and plateaus, with the potential hazards and safety risks such as fire, explosion, leakage, and environmental pollution. These problems are influenced by several factors, there are internal factors and external factors.

Hazards and risks that occur will effect the loss to the company, the people, and environmental pollution located around the pipeline. PT. Pertamina Hulu Energi in West Madura Offshore (PHE WMO), is the national operator of the Production Sharing Contract in Indonesia. This include the business of exploration and exploitation of oil and gas using the pipeline about 65 kilometers from the CPP to ORF consists of 62 km in the offshore area and 3 km over the coastal/onshore areas. So, It's very important to control and manage the risk of piping system to minimalize the hazards and

risks that will happen. By using the method of risk assessment and Fuzzy Inference System-Kent Mulhbauer, risk assessment analysis results obtained quickly and accurately, so the control can be done early to prevent the occurrence of a failure.

Due to the pipeline included in the process flow diagram of a plant oil and gas industry, ppipeline has a high level of risk, so it is needed for the examination. Risks that could impact on the environment occur around the plant or natural gas distribution lines. There are several studies that have been conducted on the risk of pipeline risk assessment of social and individual case studies of gas pipelines [1] PT. Pertamina Hulu Energi in West Madura Offshore, the risk of a gas leak due to the method of Societal risk Det Norske Veritas (DNV RPF-107). The result of this research is to determine the level of risk of pipeline leaks to environment around the pipeline using the alkaline societal risk DNV RPF–107. [6] Risk analysis and assessment studies of oil and gas pipeline with Kent Muhlbauer method and Risk Based Inspection API 581 recommendations. Sovian try to compare the assessment of risk level using the risk-based inspection Muhlbauer (RBI). The results obtained by the method Muhlbauer low risk score (low), while using the API RP 581 RBI medium risk values obtained on the risk matrix C1.[2], The new development of fuzzy logical inference for pipeline risk, try to develop a pipeline risk assessment using fuzzy inference system. The fuzzy method obtained more accurate results and faster.[4], Environmental Risk Assessment of Gas Pipeline with Mühlbauer method, conduct research using gas pipeline assessing the level of risk from the third party interference factors, corrosion of materials, design, and operation of the pipeline system.[7], Tsukamoto Fuzzy Inference Study To Determine The imposition Factor Transformer PLN, use fuzzy logical inference to maintenance, and detection of damage to the transformer.

The problem that appear is the lack of information or even the uncertainty of the data used for decision making in pipeline risk assessment, so that the engineers did not reach a definitive solution to resolve the problems faced. In this case study will be compared with the classical risk assessment approach, Muhlbauer risk approach. So expect with this comparison can provide a systematic framework to create a more confident and do not take time to do a risk assessment on the pipeline in particular 14" PT. PHE-WMO. Thus it can be immediately taken action in an effort to overcome early failures in the pipeline system.

2. METHODOLOGY

Risk assessment can defined as the level of probability from an event which has the potential to cause harm and serious loss. If the risk increased, the probability also increases. Risks can be systematically formulated according to the following equation [5].

$$\text{Risk} = (\text{event likelihood}) \times (\text{event consequence})$$

Risk is not a static quantity. With the changes, the risks also change.

2.1. Methode of Approach Muhlbauer

Muhlbauer approach is a method of semi-quantitative approach risk rating, developed by Muhlbauer. According to this model, pipeline risk influenced by probability and consequence factors. Factors affecting the probability of damage is a third party such as corrosion, design, and operation errors damage. While the consequences, including the dangers of the product, the volume of leakage, scattering factors and receptors.

The determination of the likelihood of pipe failure that occurred Probability of failure (Sum Index) is calculated by taking into account the parameters of a broken pipe weights each hazard that occurs or index scoring system used was based on the method of risk Muhlbauer[5].

Basically, the concept of Relative Risk Score (RRS) is (index sum) divided by LIF (leak impact factor).

$$RRS = \frac{IS}{LIS} \quad (1)$$

$$RSS = \frac{Score\ of\ IS}{Score\ of\ LIS} \quad (2)$$

$$IS = TPD + C + D + IO \quad (3)$$

$$LIS = PH\ x\ LV\ x\ DI\ x\ RE \quad (4)$$

Where:

RSS = Relative Risk Score
TDP = Third Party Damage
C = Corrosion
D = Design
IO = Incorrect Operation
PH = Product Hazard
LV = Leak Volume
Di = Dispersion
Re = Receptor
IS = Index Sum
LIF = Leak Impact Factor

2.2. Method of Fuzzy Inference System

Fuzzy logic means rule-based decision-making process that aims to solve the problem, where the system is difficult to model or there is a lot of ambiguity and uncertainty. Fuzzy logic is determined by the logic equations instead of differential equations derived from the complex and is expected to identify and take the advantage of greyness between the two extremes. This system consists of a fuzzy logic fuzzy sets and fuzzy rules[2].

The fuzzy method that applied in this research consists of three phases: IS (Index Sum) assessment, evaluation LIF (Leak Impact Factor), and risk analysis. The first two stages is conducted based on the idea of fuzzy logic. Fuzzy logic is applied to resolve the uncertainty involved during modelling process. Proposed model become an integrated model with addition of pipeline risk assessment on both qualitative and quantitative.

Fuzzy calculate the probability and frequency factor-emerging risk factors that cause the use of fuzzy logical inference systems with Mamdani method. To get the output method Mamdani required 4 stages as follows:

a. Formation of Fuzzy Association
b. Formation of Basic Rules
c. Fuzzy Inference System
d. The assertion (defuzzyfication)

3. RESULT AND DISCUSSIONS

3.1. Results of Analysis of Muhlbauer Methods

After calculating probability damage from the third party, corrosion, as well as incorrect design operation. On the other hand, the leak impact includes product hazard, dispersion, leak volume, and receptor would be associated with a relative risk scoring formula.

Relative risk scoring index = sum / leak impact factor

From the results of calculations by the method of Muhlbauer 10 pipe segment can be determined sum index value, leak impact factor, and RRS in each segment. The results of the relative risk scoring on all risk rating to all segments can be seen in Table 4.1 below.

Table 1: Relative Risk Score (RRS)

Segment	Muhlbauer		
	IS	LIF	RRS
14-CPP-ORF-01	226.8	84	2.7
14-CPP-ORF-02	239.8	84	2.855
14-CPP-ORF-03	235.8	84	2.807
14-CPP-ORF-04	243.8	98	2.488
14-CPP-ORF-05	242.8	98	2.478
14-CPP-ORF-06	243	108.5	2.24
14-CPP-ORF-07	251	105	2.39
14-CPP-ORF-08	243	116.9	2.079
14-CPP-ORF-09	244	95.2	2.563
14-CPP-ORF-10	253	91	2.78

3.2.Results of Analysis of Muhlbauer Methods

3.2.1. Fuzzyfication

Fuzzyfication is the first phase of which is the conversion value of the fuzzy calculations firmly into fuzzy values. Fuzzyfication process is written as follows:

$$x = \text{fuzzifier}\,(x0) \qquad (5)$$

With x0 is a vector of firm value of an input variable, x is the vector of fuzzy sets are defined as variables and fuzzyfication. Fuzzifier is an operator that converts the value to a fuzzy set firmly. FIS is the first part in the process of transferring fuzzification where pure value into the If-Then fuzzy rule is applied through membership value for fuzzy linguistic variables. It means the input vector (raw value) can be divided into some linguistic terms i.e. very high, high, medium, low, and very low. The help of the membership function (MF) is required to satisfy this process. Then there are two different types of function: linear and non-linear.

The MF highly relies on the problem which modeled, knowledge from the expert, and its context.

3.2.2. Fuzzy Inference System

The fuzzy unit inference utilizes If-Then Fuzzy rules to create a map for fuzzy input which sets into fuzzy output rule, all of this based on fuzzy composition. This process is the main stage of the fuzzy expert system which separate the facts from the fuzzification process base rule from previous modeling process. There are several FIS that applied widely in science and engineering field. Mamdani Fuzzy models is the example of the most popular functions. The other method od fuzzy inference system depicted below:

Table 2: Example of Fuzzy Formation Of Association [2]

Type of factors	Linguistic classification	Fuzzy level	Discourse universe
TDP	Very High (VH)	65 < TDP ≤ 100	X TDP € (25)
	High (H)	40 ≤ TDP < 100	
	Medium (M)	15 ≤ TDP ≤ 85	
	Low (L)	0 ≤ TDP ≤ 55	
	Very Low (VL)	0 ≤ TDP < 35	
C	Very High (VH)	65 < TDP ≤ 100	X C € (25)
	High (H)	40 ≤ TDP < 100	
	Medium (M)	15 ≤ TDP ≤ 85	
	Low (L)	0 ≤ TDP ≤ 55	
	Very Low (VL)	0 ≤ TDP < 35	

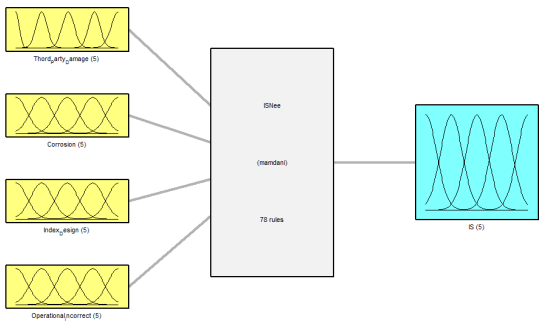
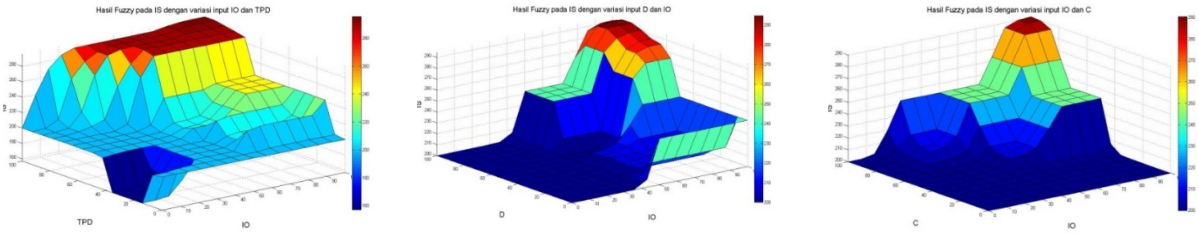


Figure 1: Example of a fuzzy model structure IS

Rule of fuzzy model:

- If (TDP is VL) and (C is VL) and (D is VL) and (IO is VL) then (IS is VL) (1)
- If (TDP is L) and (C is L) and (D is L) and (IO is L) then (IS is L) (1)
- If (TDP is M) and (C is M) and (D is M) and (IO is M) then (IS is M) (1)
- If (TDP is H) and (C is H) and (D is H) and (IO is H) then (IS is H) (1)
- If (TDP is VH) and (C is VH) and (D is VH) and (IO is VH) then (IS is VH) (1)
- If (TPD is L) and (C is M) and (D is M) and (IO is M) then (IS is M) (1)
- If (TPD is VH) and (C is H) and (D is H) and (IO is H) then (IS is H) (1)
- If (TPD is VL) and (C is L) and (D is M) and (IO is H) then (IS is M) (1)
- If (TPD is L) and (C is VL) and (D is M) and (IO is H) then (IS is M) (1)
- If (TPD is M) and (C is VL) and (D is L) and (IO is H) then (IS is M) (1)
- If (TPD is H) and (C is VL) and (D is M) and (IO is L) then (IS is M) (1)
- If (TPD is VH) and (C is VH) and (D is VH) and (IO is H) then (IS is VH) (1)



(i) (ii) (iii)

Figure 2: Surface control from IS (i) TDP as well as IO,(ii) D and IO, (iii) C and IO

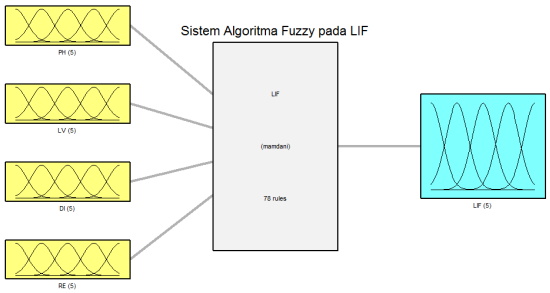
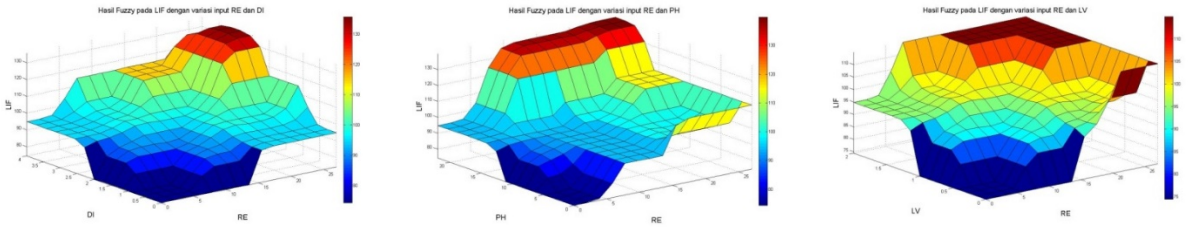


Figure 3: System LIF: 4 input, 1 output, 78 rule



(i) (ii) (iii)

Figure 4: Surface control from IS (i) RE, DI,(ii) RE, as well as PH, (iii) RE and LV

3.2.3. Defuzzyfication

Defuzzification is the process of translating the fuzzy sets to become a real value. Centroid of Area (COA) is the popular one for defuzzification process. COA method transfer the following equation applies Fuzzy scheme becomes crisp value [3].

$$Z^*_{COA} = \frac{\int_z \mu A(z) z dz}{\int_z \mu A(z) dz} \quad (5)$$

where

Z*COA is crisp value for "z" and the results of mA (z) of the membership function

3.2.4. Comparison of Risk Muhlbuaer and Fuzzy Approaches

Fuzzy method for risk analysis that used in this research contains three phases i.e. IS assessment, LIF evaluation, and risk analysis itself. The two stages in the early process are formed based on the idea of fuzzy logic. Fuzzy logic then applied to control the uncertainty level during the process of modeling. A specific model is an integrated pipeline risk assessment model that use both qualitative and quantitative techniques.

Table 3: Comparison of Risk Muhlbauaer and Fuzzy Approaches

Segment	Muhlbauer			Fuzzy Model		
	IS	LIF	RRS	IS	LIF	RRS
14-CPP-ORF-01	226.8	84	2.7	235	88	2.67
14-CPP-ORF-02	239.8	84	2.855	250	88	2.841
14-CPP-ORF-03	235.8	84	2.807	253	88	2.875
14-CPP-ORF-04	243.8	98	2.488	286	97.7	2.927
14-CPP-ORF-05	242.8	98	2.478	277	97.7	2.835
14-CPP-ORF-06	243	108.5	2.24	267	102.2	2.613
14-CPP-ORF-07	251	105	2.39	280	101.3	2.764
14-CPP-ORF-08	243	116.9	2.079	267	103	2.592
14-CPP-ORF-09	244	95.2	2.563	271	95.3	2.844
14-CPP-ORF-10	253	91	2.78	282	91.6	3.079

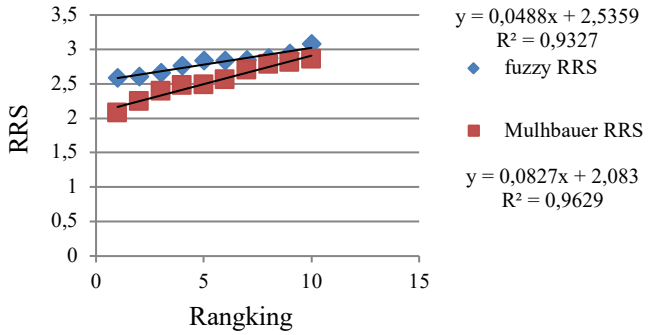


Figure 5: Graph of Range Value RRS Muhlbauer with Fuzzy

Calculation results can be obtained from the delta value of IS, LIF, and RRS. Each of them has a delta value of 2.38 for IS Mühlbauer Fuzzy 4.77. Muhlbauer LIF delta value of 2.99 to 1.36 Fuzzy. While the delta value of 0.07 for the RRS Muhlbauer Fuzzy delta value of 0.045. Thus it can be seen the comparison between Muhlbauer risk approach with fuzzy models, among others:

a. From the above approach to risk Muhlbauer IS value is smaller than the value of LIF. This result causes Relative Risk Score (RRS) of the Mühlbauer will have a small range of values. While the fuzzy risk approach IS value greater than the value of LIF. With a small range of values of Relative Risk Score (RRS) Muhlbauer generated would be similar even so the result will be the same, it would be contrary to the implications of risk which is basically the same no risk index value. Unlike the Relative Risk Score (RRS) which has a fuzzy value greater range would have an index value of different risks, so by using a model of fuzzy risk approach facilitates in making decisions.
b. The most negative feedback of the Relative Risk Score (RRS) Muhlbauer is the input variable from Third Party Damage, Corrosion, Design and Operation, Incorrect Product Hazard, Leak Volume, and Dispersion. Different receptors may result in the similar value from Index Sum (IS) and Leak Impact Factor (LIF). As a result, the value of relative Risk Score (RRS) will be the same. While the Relative Risk Score (RRS) Fuzzy models with the same case would have a different value of Sum Index (IS) and Leak Impact Factor (LIF). Therefore, the value of Leak Impact Factor (LIF) will not be the same.
c. The main limitation is from the Relative Risk Score (RRS) Muhlbauer which cannot weigh in relative importance of the input. While using the fuzzy model it should calculate the relative

importance of the input variables. The relationship of input and output information in the system is recognized as fuzzy linguistic variables. This offers more flexibility and more realistic in reflecting the real conditions. Therefore, the output Relative Risk Score (RRS) from the proposed fuzzy model. Therefore, the pipeline risk assessment is more confident, precise, as well as accurately depict the result.

4. CONCLUSIONS

From the calculation and risk analysis results, on the plumbing pipes 14 " offshore and onshore PT. PHE WMO with a total length of 65 km, divided into 10 segments of pipe, it can be concluded as follows : The average value of additions scores range Fuzzy IS greater than the average value of the IS range Muhlbauer. While the average value addition of LIF Fuzzy scores are smaller than the average value of the range LIF Muhlbauer. Thus the results of the approach is the calculation of the IS and fuzzy LIF in accordance with the formula RRS = IS / LIF.

The results of the analysis and calculation of pipe 14 " PT . PHE WMO CPP - ORF obtained average yield additional value IS a greater range of 4.77 and average value of rat LIF smaller range of 1.36 is by using Fuzzy Inference System. Thus the value of the difference RRS greater ease and reinforce the administration of each rank in each segment of data input. So the fuzzy method is more accurate and precise than the Muhlbauer.

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