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Risk Assessment of Onshore Pipeline in Gresik Area

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ABSTRACT

Pipeline is a transport means to distribute the fluid in the form of liquid or gas. Meanwhile, risk is defined as the combination of the likelihood of failure and the consequences of failure. In this research, the implementation of risk assessment using the index or scoring models as developed by Muhlbauer is made. Pipeline used for the analysis was located in Legundi - Cerme, Gresik Area. The pipeline has a diameter of 12 inches which distribute gas. Scoring method is based on a sum index composed of damage indices caused by a third party with a score averagely 57.71, with a score of corrosion index averagely 68, index design with a score averagely 75, and the index operation errors with a score averagely 90. Furthermore, leak impact factor calculation is made by considering leak impact factor consisting of product hazard, leak volume, and dispersion, receptors. Estimates for product hazard criteria score is 7, leak or spill volume is 0.4, the dispersion score is 0.8, and score in receptor variation value of between 10.8 up to 15.9. Relative risk score average obtained from the calculation is 9.87, which is the result of dividing the sum by the leak index impact factor. This low value indicates the pipeline to be classified in the low risk level, or has a sufficiently high safety.

Keywords: *risk assessment, gas pipeline, relative risk score*

1. INTRODUCTION

Over the years the use of oil and gas for various purposes is increasing [1]. In the oil and gas industry, the pipeline holds a very important role because it serves to transport fluid or gas which is the main product of this industry. Distribution carried out by pipeline will pass through rural, urban, jungle, even crossing the ocean. In this case the factor of safety when operating the pipeline will play an important role in order to maintain human safety and preservation of the surrounding environment.

The distribution of oil and gas through this pipeline is very diverse, among others, from the wells to the treatment plant or an offshore platform or directly ashore. Sources of natural oil and gas are available in several of the islands in Indonesia, such as Aceh, Riau Archipelago, Natuna, East Kalimantan, Java, Sulawesi and Papua [2,3,4]. To keep the distribution of oil and gas through pipeline will require early action to prevent failures in transport or distribution of oil and gas carried by pipeline. Various types of actions performed by experts to prevent and cope with various threats and problems that can make the system of the pipeline fails to operate. Sources of failure in pipeline systems also vary. Such as due to the excessive load on the pipe, third party and corrosion are the causes of most of the pipe failure. Failures that can occur in pipeline systems include stress due to the internal and external loads imposed exceeds the limit of allowable stress, pipe displacements due to thermal expansion on a pedestal, failure due to buckling, pipe failure due to dynamic loads, pipe failure due to corrosion, and others.

Risk assessment is a quantification process to determine what risks that may occur in a system. To get the concept of quality and good management of a process it requires the involving factors to be quantified. The size or the value obtained will determine the size and risk of loss that may result from a process, which will determine the course of inspections to be carried out. By conducting such inspections as an early stage of corrective maintenance, the expected damage, failure or the risk of pipeline can be reduced [5,6].

Risk can be defined as an opportunity or possibility for an occurrence or failure that can lead to a consequence (negative) in the form of loss, damage, injury and even death to the personnel, facilities, and the environment. Potential component failures are further divided into four indices. The four index values are then summed up for the total value (called the sum index) which represents the overall probability of failure. Risk segment can be measured or estimated using a formula which states that the risk is multiplication of probability of failure with the consequences of failure [5].

Probability of failure is defined as the opportunity or possibility of a failure in a component that is expressed in the time period and is calculated based on the mechanism of a damage. While the consequences of failure are consequences or effects (negative) that can be caused by a failure of a component, such as an accident or death of personnel, damage to equipment or facilities (fire, explosion, leakage), losses from the economic side, and pollution of the surrounding environment. Both of these factors are calculated separately and multiplied to obtain the value of risk that occurs in the component. The higher the index score (weighting), then the safety level is also higher [5,6].

PT Perusahaan Gas Negara (Persero) Tbk abbreviated as PGN is a state owned company that is engaged in transmission and distribution of natural gas. Pipeline becomes the means chosen by the company to distribute the gas to the nearest treatment facility in Legundi – Cerme, Gresik area, East Java province of Indonesia, as shown on the map in Fig. 1 and the corresponding data in Table 1.

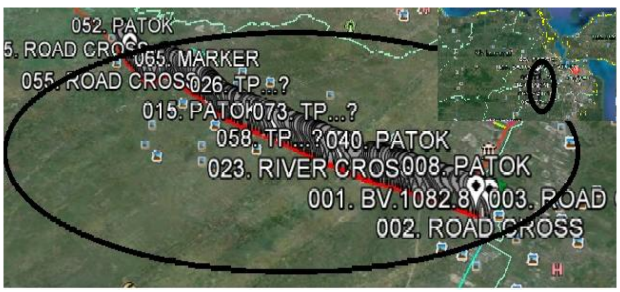

Figure 1. Map onshore gas pipeline operational location

Table 1. Data of Legundi – Cerme onshore pipeline

Pipeline Segment	Legundi – Cerme
Pipeline Length	17.755 km
Operation Pressure	22 bar
Pipeline Material	API 5L X-46
Pipeline OD	12 in

2. MATERIALS AND METHODS

In this research analysis will be done with the pipeline risk assessment method of indexing a model case study on gas pipe lines Legundi - Cerme. Pipeline risk assessment techniques of the most popular today is the index scoring model or other similar techniques. In this approach numerical value (score) assumed on conditions and activities that are importantly influence the pipeline system related to the risk picture.

2.1 Data Collection

This research requires comprehensive data and supporting literature to be used in the development of insight and analysis. These covers the aspects of:

- Pipeline data collection, especially from PGN
- Literature exploration on the study of risk assessment by indexing method

2.2 Calculation of Index Sum

Index sum is the summation of the factors related to four components, namely the third party, corrosion, design, and operational error. Each factor has a sub-sub factor and the overall amount of each factor is 100. So, considering all the four factors, the maximum amount of sum index score is 400. The smaller the score obtained from the assessment process, the greater the risk faced. The highest risk of a pipeline based on the stated sum index is when the score is 0. Whereas the lowest risk is expressed with a score of 400. In the scoring when "no" is worth 0 points and if "yes" is worth 400 points depends on the items recommended in every factor in the index sum.

2.3 Calculation of Leak Impact Factor

Leak impact factor (LIF) is a factor that takes into account the impact of a pipeline to the surrounding environment, which includes humans. The calculation of Leak Impact should take into account of four factors, namely Product Hazard, Leak Volume, Dispersion, and Receptors. Factors due to leakage generated by the multiplication result of all the factors over the pipeline area. If one factor that estimate has a score of 0, then the factor due to leakage would be 0.

2.4 Calculation of Relative Risk Score

Relative risk score is a score of initial assumption of the risk management process. Relative risk score is the ratio of the number of the overall index by the LIF. After the calculation of relative risk score is made, it will be known whether the pipe is safe to operate or not. To get the absolute risk score it should be based on the calculations which requires data of pipeline operation for several years. Relative risk score is a picture of the risk of pipelines in the area Legundi - Cerme where it can be seen how many segments that had the lowest score. So the actions that must be performed for the scaling up of pipeline security could be prepared.

2.5 Qualitative Analysis

Qualitative analysis may be considered as the elementary level of risk analysis with the simple and easy calculation. Input data needed is more in the form of qualitative data, primarily obtained from risk assessment questionnaire. Calculation of risk in this levels of analysis carried out following Muhlbauer procedure [5], which contains questions related the input data. Each question is accompanied by a few possible answers and the corresponding values associated to the answers.

Calculation of risk is composed of two parts, namely the determination of categories LIF and the sum of index categories. Each part consists of several factors that are represented by values of answers in conjunction with certain questions. The values of all factors are then summed up, giving the final result of a value that represents the risk parameters, ie. the probability and consequence of failure [5].

2.6 Risk Mitigation

After the overall calculations has been made it can further be determined how many segments in the pipeline that had the high score of risk. This will then give the direction into what kind of action that must be done to improve the safety of the pipeline. To a certain degree it could also come to a decision on which segment of the pipeline section which need a repair to be performed.

In final stage of research the necessary analysis of the processed data will be performed. The results of which are then arranged to generate suggestions useful as improving corporate performance and as a reference in subsequent studies. Risk mitigation is done after level of risk is indicated. In general, to reduce a risk is better accomplished by reducing the probability of a failure rather than reducing the consequences. Mitigation or reduction of the consequences are usually more complicated because it may demand certain changes to some governing aspects.

3. RESULTS AND DISCUSSION

3.1 Pipeline Planning Rules

A special code or standard must be used as a reference in establishing the design, and further the construction, of gas pipeline. There are various codes or standards are available from acknowledged institutions and societies. For the current research the standard code ASME B3.18 applied for piping systems gas transmission and distribution [7] is selected for the reference.

3.2 Class Location

Class location is required to determine the value of design factor to be implemented in the calculation and analysis. Division of class locations according to ASME B3.18 is determined depending on the population density in a certain area where the pipeline extends. To describe the state of the location of the pipeline one need to know the location of the class. Most of the class locations used in describing the state of the location of the pipeline in this research is regarded as class 4 locations.

3.3 Design Data

The design data is essential in completing the calculation and analysis. Before the work is started the initial data of the pipeline should be known in advance, covering the length of pipeline, pipeline diameter, and the resulting product. Cerme – Legundi pipeline length is 17.755 km with a diameter of 12 in a gas distribution pipelines with the product being transported is natural gas (methane).

Data available in the form of satellite images of pipeline that will describe the condition of the environment surrounding the pipeline, as well as type of pipe used. From these data it can then be calculated indices of damage due to the effects of third party, design, corrosion, and operational errors.

3.4 Segmentation

Segmentation is based on satellite data that already exists. From these data it is further illustrated the picture of the condition of the path through which the pipeline location and class. Overview of pipeline refers to the density of population in the area around the pipeline, soil conditions and the state of the pipeline protective coating. In this respect the pipeline is divided into 7 segments, as listed in Table 2, including also the description of each segment condition.

Table 2. The segment description of the gas pipeline Legundi-Cerme

Segment	Route	Direction	Location	Description
1	Perempatan Legundi	7°23'4.20"S - 112°34'34.53"E	Gresik	*Road cross, River cross,* class location 4
2	Jl.Karang Andong	7°21'29.13"S - 112°34'16.64"E		*Road cross,* Village offices, police station, class location 4
3	Jl.Kedamean	7°19'29.81"S - 112°33'58.15"E		*Road cross, River cross,* Village offices, class location 4
4	Jl.Raya Putat Lor	7°15'35.03"S - 112°34'2.77"E		Village offices, class location 4
5	Jl.Domas Raya	7°15'3.81"S - 112°34'6.18"E		*Elbow, Road cross, river cross,* class location 4
6	Jl.Ker Ker Geger	7°14'35.70"S - 112°33'44.77"E		Village offices, *river cross,* class location 4
7	Jl.Raya Cerme Kidul	7°14'11.02"S - 112°33'51.78"E		*Road cross,* Hospitol, School ,*Rail cross* class location 4

3.5 Index Sum Assessment Result

Index is a measure of the level of pipeline operational safety. The parameters used in this evaluation are the third-party damage, corrosion, design, and operational errors. Index calculation can be done by assessing each pipeline segment based on Pipeline Risk Management Manual, as shown by Muhlbauer [5]. Assumptions are made in the overall index number when estimating risks in the pipeline, where estimates is determined based on existing data.

Third-party Damage Index. Third-party damage is derived based on some accidental failures in the pipeline as a result of the activities of personnel who are not related to the pipeline system [8]. For the current study result of recapitulation of the third party damage index for the Cerme – Legundi pipeline of segments 1 up to 7 is as presented in

Table 3.

Table 3. Recapitulation of third-party damage index of segment 1 up to 7

Segment	A	B	C	D	E	F	G	H=A+B+C+D+E+F+G
1	20	0	10	15	7	1	4	57
2	20	0	10	15	7	2	4	58
3	20	0	10	15	7	2	4	58
4	20	0	10	15	7	1	4	57
5	20	0	10	15	7	2	4	58
6	20	0	10	15	7	1	4	57
7	20	0	10	15	7	3	4	59
							Σ	404

Corrosion Index. Corrosion indexes have considerable influence on the smoothness performance of the distribution pipeline. Corrosion can be caused by the atmosphere, the products which are transported or the surrounding soil. In Table 4 below can be seen recapitulation assumption of the corrosion index in all segments in the Legundi-Cerme pipeline.

Table 4. Recapitulation of corrosion index of segments 1 up to 7

Segment	A	B	C	H=A+B+C
1	7	20	41	68
2	7	20	41	68
3	7	20	41	68
4	7	20	41	68
5	7	20	41	68
6	7	20	41	68
7	7	20	41	68
			Σ	408

Design Index. This index does not only accounts for the possibility of mechanical failure related to the design process, but also include the ability of the pipeline to withstand other mechanical failures. Again, the maximum score is 100. The design for the index design is used as one of the indices here, for the most pipeline part, though not all. The risk variable is usually directed at the basic structure of the system design. That is what should be done unitary structure that overcomes all internal loads and external loads in a random period of time. Therefore, this index as a guide in evaluating the pipeline to critical design parameters. In Table 5 it can be seen the recapitulation assumptions index design in all segments in the pipeline of Legundi-Cerme.

Table 5. Recapitulation of design index of segment 1 up to 7

Segmen	A	B	C	D	E	H=A+B+C+D+E
1	35	15	10	10	5	75
2	35	15	10	10	5	75
3	35	15	10	10	5	75
4	35	15	10	10	5	75
5	35	15	10	10	5	75
6	35	15	10	10	5	75
7	35	15	10	10	5	75
					Σ	450

Incorrect Operation Index. This index assesses the potential for pipeline failure caused by errors (mistakes) committed personnel in the pipeline design, build, operate or maintenance. The maximum score on the index of operational errors is 100. There are four main areas that should be expected in the index determination operational errors, namely the design, construction, operation and maintenance. In Table 6 it can be seen recapitulation index assuming operational errors on all segments of Legundi-Cerme.

Table 6. Recapitulation of incorrect operation index of segment 1 up to 7

Segmen	A	B	C	D	H=A+B+C+D
1	28	12	35	15	90
2	28	12	35	15	90
3	28	12	35	15	90
4	28	12	35	15	90
5	28	12	35	15	90
6	28	12	35	15	90
7	28	12	35	15	90
				Σ	540

Index Sum Result. After the index scores obtained from the accumulation of four parameters where the results are already known, namely of the third-party damage, corrosion, design, and operational errors, then the index sum is established. In this scoring system it needs to be underlined that the score is directly proportional to the level of safety.

The higher the score means an increase in safety is attained. The index sum obtained for this evaluation is presented in Table 7.

Table 7. Index sum of segment 1 up to 7

Segment	Third-Party Damage Index	Corrosion Index	Design Index	Incorrect Operations Index	Index Sum
1	57	68	75	90	290
2	58	68	75	90	291
3	58	68	75	90	291
4	57	68	75	90	290
5	58	68	75	90	291
6	57	68	75	90	290
7	59	68	75	90	292
				Σ	2035

3.6 Leak Impact Factor

Leak Impact Factor (LIF) is used to adjust the index score to illustrate the consequences of failure. The higher the points score for LIF shows the higher consequences, and therefore the higher risk.

Table 8. Result of LIF calculation

No	ITEM	SEGMENT						
		1	2	3	4	5	6	7
1	*Product Hazard (PH)*	7.0	7.0	7.0	7.0	7.0	7.0	7.0
2	*Leak Volume Factor (LV)*	0.4	0.4	0.4	0.4	0.4	0.4	0.4
3	*Dispersion Factor (D)*	0.8	0.8	0.8	0.8	0.8	0.8	0.8
4	*Receptors (R)*							
	General Population Category	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	Special Population Category	5.0	0.0	5.0	0.0	5.0	5.0	0.0
	Population Density Score	15.0	10.0	15.0	10.0	15.0	15.0	10.0
	Environmental sensitivity an/or high value area	0.9	0.8	0.9	0.5	0.9	0.9	0.8
	Receptors score	15.9	10.8	15.9	10.5	15.9	15.9	10.8
	Leak Impact Factor (LIF)	35.6	24.1	35.6	23.5	35.6	35.6	24.1

3.7 Relative Risk Score

Relative risk score is a picture of the pipeline risk at the Legundi – Cerme area. This score is obtained as the index sum divided by the LIF. The final results will indicate how many and which segments that have the lowest score, so the actions that must be performed for enhancing the pipeline safety can be known as well. Results of the relative risk score for all the 7 segments are listed in Table 9.

Table 9. Relative risk score of segments 1 up to 7

Segment	Index Sum	Leak Impact Factor	Relative Risk Score
1	290	35.6	8.14
2	291	24.1	12.02
3	291	35.6	8.17
4	290	23.5	12.32
5	291	35.6	8.17
6	290	35.6	8.14
7	293	24.1	12.11
Average	290.85	30.58	9.87

The results of calculation on relative risk score for gas pipeline in the area Legundi - Cerme give an average of 9.87. This low value of relative risk score means that the corresponding pipeline could be classified as very low risk. In other words the pipeline has a sufficiently high safety for operation.

3.7 Risk Mitigation

As the calculation and analysis conducted on the pipeline of the Legundi – Cerme area indicate the low level of risk, then no extensive mitigation need to be planned. Mitigation is suggested only to performed in conjunction with the factor which has lower index, namely the possibility of damage due to the third party [9]. Some scenarios of mitigation recommended in this respect are as follows:

1. Increase the frequency of checks by patroling the pipeline area. If this can be carried out routinely then it will be very effective to reduce third-party interference damage.
2. Adding right-of-way (ROW) inspection schedule and appropriate marks on pipeline. Operator should assure the ROW is clean, free of obstacles and track marks can be clearly seen from any side in the vicinity the ROW or from the air.
3. Increase inter-institutional education program, especially organize annual meetings between the company and public officials (local government officers) regarding the location and pipeline facilities. Regular public education program to local residents regarding the location and pipeline facilities, and contact door to door on people who live nearby the pipeline.

4. CONCLUSIONS

The conclusions that can be drawn from results of the analysis conducted on the local gas distribution pipelines at Legundi – Cerme, Gresik area, are as put forwards in the followings:

1. The average index sum resulted from the calculation is 290.85. This represents the overall probability of failure in the pipeline, derived as the sum of component indices of:
   a. Third party damage index with an average score of 57.71,
   b. Corrosion index with an average score 68,
   c. Design index with an average score of 75,
   d. Operational error index with an average score of 90.
2. Among the four indices, the third party index is found to be the lowest, meaning that the risk is higher. Therefore the effect of third party requires intense attention because it indicates the low level of safety.
3. The LIF calculation yields the values between 23.5 up to 35.6 for the 7 pipeline segments. These are resulted from the contribution of components:
   a. Product Hazard with a score of 7.0,
   b. Leak / Spill Volume with a score of 0.4,
   c. Dispersion with a score of 0.8,
   d. Receptors with scores between 10.5 up to 15.9.
4. By correlating the index sum and the LIF average relative risk score is found to be 9.87. This value suggest the pipeline could be classified as low risk.
5. Although the pipeline proves to be in the low risk level, none the less mitigation measures still need to be taken. This could be done by increasing the frequency of inspection, examination schedule ROW and attachment of track marks in the pipeline ROW, and improving public education program.

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