Risk Forecast of Gas Transmission Pipeline Maintenance using Random Number Generation Simulation

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ABSTRACT

Risk forecast gas distribution pipeline using random generation is developed. The tool is based on a simulation software. The tool has been applied to find the dominant risk in distribution pipeline to support the activity of pipeline integrity management of the company. The main strength of this method is that it has a high probability of obtaining better solution with significantly fewer simulation runs than oher methods. Also, by changing step size, it is possible to influence the results. This method is general and can be applied to other process modelled or activities. The result of this study can be applied in maintaining the activity of asset management integrity of the gas pipeline company.

Keywords

Random number, Pipeline Integrity Management, Gas Distribution Pipeline Maintenance, Potential Hydrocarbon Release, Crystal Ball, Risk Matrix

1. INTRODUCTION

Natural gas distribution pipeline has an importance role in contributing the industrial activity in the west of Java and Jakarta Area, the capitol of Indonesia. The pipeline has to be maintained to ensure that pipeline working properly in transporting natural gas to the end-users. Preventive maintence is one of the maintenance strategy to reach the goal of the gas transmission and distribution company. For ageing pipelines, i.e. those pipelines reaching the end of or exceeding their original design life, there is an increasing requirement around the world to defer their replacement and extend their remnant life. In order to evaluate the actual pipeline condition in service, operators will implement routine condition monitoring activities; for example on-line process control and monitoring systems, product monitoring, corrosion probes, etc. for internal corrosion and external surveys such as corrosion protection and coating condition surveys to monitor external corrosion. The primary aim being to identify at a very early stage any occurrence of accelerated deterioration, i.e. deterioration faster than that accounted for in the original design plan.

It is widely accepted that in-line inspection is a key component of any pipeline integrity management programme which based on accurate and reliable data provides a sound technical basis for planning future maintenance and repair activities.

Pipeline Integrity Management System

It is a safety management system, whose field is pipeline integrity. The field does not cover occupational health. Each natural gas pipeline operator has a system to manage all its resources and activities. This management system is specific to each operator. It generally integrates all the following activities: storage, compression, transportation and delivery of natural gas (see diagram below). PIMS is based on such principles as: - adoption of high technological standards in construction; - carrying out of proactive measures for ensuring that the pipeline system is maintained fit for purpose; - working out of emergency procedures; - incidents investigation; - training of personnel; - definition of roles and responsibilities of

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personnel. It follows the basic principle plan, do, check and act (PDCA) which includes policy, planning, implementation and operation, inspection and corrective actions, and management review [**1**].

In this study, our scope of work is focusing a segment of pipeline transmission network in North Java area operated by PT PERTAMINA (Persero). The segment of 12 km pipeline is located tie-in from Walet Utara area to Cemara, Balongan area using 6 inches pipeline diameter. The pipeline is lied down under the ground and have several points swamp and river crossing. Pipeline is crossing the river it appears to land surface and become above ground because it using bridge structure to support pipeline when crossing the river. This survey inspected 9 (nine) critical points and stated as test point. Critical points are located at 12 points in under ground and 1 points above ground. The survey found that the pipeline has well insulated using anodic sacrifice protection system [**2**].

2. Risk Assesment using Random Number Generation Simulation

Random number generation as discussed in the current litarature normally refers to the generation of a sequence of independent values thar are uniformly distributed over the interval from 0 to 1 [0,1]. These values in turn form an essential part of programs incorporating uncertainty in simulations. This type computation occasionaly require the selection of a random item from a list to test the presence or absence of a particular quality of pattern. An example use of random numbers is to reflect event frequencies: any nine out ten times, a particular weighting factor may be appropriate, but the remaining time may require a different factor [**3**, **4**, **5**, **6**]. Random number generator in this study using montecarlo method simulation package developed by Crystal Ball Software. Montecarlo method are a class of computational algorithms that rely on repeated random sampling to compute their results. These methods are most suited to calculation by a computer and tend to be used when it is infeasible to compute an exact result with a deterministic algorithm [**7**, **8**, **9**].

3. Risk Assessment for Pipeline Integrity Prioritisation and Planning

Risk Based Assessment (RBA) is a systematic approach which aims to reduce the overall risk exposure by focusing on the areas of higher risk. This approach reduces the total scope of work and inspection costs in a structured and justifiable way. The underlying philosophy of risk based assessment is ensuring pipeline system integrity while maintaining risk at as low a level as is reasonably practicable (ALARP principle) [**1**, **10**, **11**]. Risk is generally described as the product of the likelihood of a given failure multiplied by the consequence of that event:

Risk = Likelihood or Probability of failure x Consequence of failure

Risk assessment strategies can be applied to pipelines at all stages of their life, from design through to decommissioning. The application of methodologies enables the operator to: Identify the primary threats to pipeline integrity, rank pipelines in terms of risk (probability of failure and consequences), optimise Inspection, Maintenance, Repair (IMR) activities, i.e. defining the appropriate maintenance need and maintenance activities, and define an appropriate frequency for conducting the maintenance activity combined with a detailed understanding of pipeline degradation mechanisms the primary steps in conducting a risk assessment include:

- Data collection
- Segmentation of pipeline into sections (e.g. High Consequence Areas).
- Consideration of threats, consequences and mitigation to pipeline sections
- Relative risk assessments
- "What if" capability for sensitivity analysis
- Generate report for the reference IMR plan.

This information can be used to optimize and plan inspection and maintenance activities and identify the need for further detailed quantitative risk assessment or fitness-for-purpose assessment [**10**, **11**]. For example such a programme aimed to limit the risk of external corrosion may involve a combination of external coating and corrosion protection (CP) surveys, internal inspection using intelligent pigs to detect and monitor corrosion. fitness-for-purpose assessment and Pipeline Integrity (IMR) Plans at the heart of any pipeline integrity management system is having an understanding of the likely condition of a pipeline and confidence in the data generated from any inspection programme conducted to validate this understanding [**1**].

Based on the data generated by the inspection programmes, an operator can go forward and make decisions related to the current and future integrity of a pipeline, remaining life assessment and appropriate preventative maintenance and inspection activities to maintain the design plan for the pipeline.

3. 1. Integrity Management based on prevention and mitigation

Only when the active threats/degradation mechanisms have been identified and the corrosion growth rates have been estimated, can appropriate preventative measures be determined which will form the basis of an appropriate, cost effective corrosion management plan.

Combined with a review of corrosion management activities, e.g. review of external corrosion protection and coating systems, internal corrosion control/monitoring, correlation with the inspection findings, the primary aim of any integrity management strategy is to diagnose the likely causes of corrosion. On this basis, appropriate preventative measures to minimise further deterioration of the pipeline can be defined. Based on determined corrosion growth rates, predictions of future repairs together with mitigation and re-inspection requirements can be determined.This approach has been applied routinely for many pipeline Operators to develop pipeline specific integrity plans [**1**, **10**, **12**, **13**].

3.2. Qualitative probability/likelihood of failure prediction

Probability factor is made from the sum of each factor that divided with equalized factor. Equalized factor is used for ensure probability factor have range from 1 (one) to 5 (five). Factors that impact qualitative probability/likelihood prediction analysis are corrosion inspection factor, operational inspection factor, third party interference inspection factor and leak history factor inspection. Every each factors that mentioned above have sub-factors that build assessment range for likelihood analysis. We will describe that following factors for details.

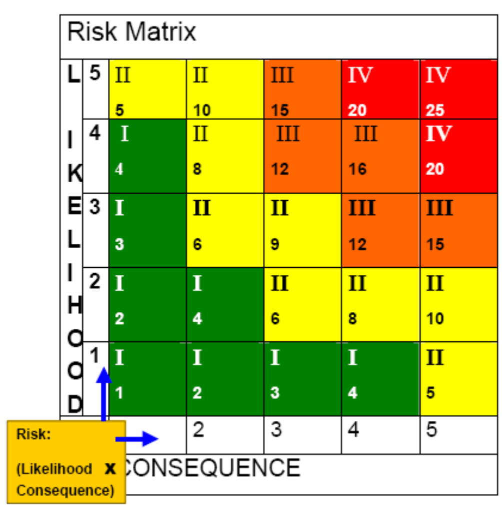

Figure 1: Risk Matrix

Scoring of assessment of the risk from every point in the pipeline is fuzzy and very relative, thus to scoring of each point was used risk based assessment model. It starts from all data records and finish with operators interview in the field. The data are checked from existing manual, such as SOP (Standard Operating Procedure), historical accident report, SHE (Safety, Health and Environment) report and incorrect operation report, and it would used for likelihood prediction. Product hazard like accident was analyzed by using cause and effect documentation and the dispersion factor like standard compliance was used for consequence prediction. From likelihood and consequence prediction, we set up risk matrix form that could used for risk classification for all available data from the field [**1**].

Risk matrix, we could use for risk classification all data from the field. Score from risk matrix indicate how much risks shall be managed and categorized (low, medium, significant and high).

3.2.1. Corrosion Inspection factor

This factor covers reports from what happened in the field based on factors lead to pipeline corrosion. Reports based on survey on September 2009 and the major factor we meet from the reports are corrosion factor from external inspection, pipeline age, cathodic protection reading, cathodic protection survey status, cathodic interference, influence of water, localized corrosion and internal inspection effectiveness. This factor each have assesment range form 1 (one) to 5 (five) as stated above.

3.2.1.1. External Inspection

Table 1: External Inspection Criteria.

Criteria	Point
Directly Routine survey. Air Patrol and GVI Inspection have been done more than 1 year for all pipelines. Prediction result and corrective action needed.	1
Directly survey and GVI inspection have been done within last 2 through 5 years for all pipelines. Prediction result and corrective action needed.	2
Directly survey and GVI inspection have been done within last 2 through 5 years just part of pipeline. Prediction result and corrective action needed.	3
External survey hasn’t been done for all pipeline and done on last 5 years	4
no External survey that has been done	5

3.2.1.2. Pipeline Age

Table 2: Pipeline Age Criteria.

Criteria	Point
Pipeline has been installed to current standards within the last 2 years	1
Pipeline has been installed to current standards within the last 5 years	2
Pipeline has been operating for 50 – 85% of its design life. If design life is not known, then pipeline has been installed for less than 10 years	3
Pipeline has been operating for > 80% of its design life, if the design life is not known, then pipeline has been operating for 10 – 15 years.	4
Pipeline has exceeded its design life and has not had an engineering re-lifing. If the design life is not known, the pipeline has been operating for more than 15 years.	5

3.2.1.3. Cathodic Protection Reading

Table 3: Cathodic Protection Reading Criteria.

Criteria	Point
Cathodic Protection reading indicated protection (reading showed more negative than protection criteria)	1
Cathodic Protection reading indicated thin protection (reading showed fail for protection where protection criteria less than 25mV)	3
Cathodic Protection reading indicated no protection (reading showed fail for protection where protection criteria more than 25mV). If that is no survey cathodic protection then it is a fail point	5

3.2.1.4. Cathodic Protection Survey Status

Table 4: Cathodic Protection Survey Status Criteria.

Criteria	Point
Full survey Cathodic Protection (CIPS) that have been done in the last year	1
Full survey Cathodic Protection (CIPS) that have been done within last 2 through 5 years	2
partial survey Cathodic Protection (CIPS) that have been done within last 2 through 5 years	3
Cathodic Protection Survey have been done un-continuously > 5 years	4
No Cathodic Protection survey	5

3.2.1.5. Cathodic Interference

Table 5: Cathodic Interference Criteria.

Criteria	Point
No detected interference	1
Detected interference and had been successfully eliminated	2
Near from electricity way	3
Detected Interference	4
Detected Interference and Near from electricity way	5

3.2.1.6. Localized Corrosion

Table 6: Localized Corrosion

Criteria	Point
CO_2 > 1 Bar	2
Contents rated as sour (NACE)	2
MIC (Microbial Influenced Corrosion) detected	2
Solid in line	2
O_2 > 50 ppb	2
No increased local corrosion risk factor	1

Here, likelihood factor is summation of the item of localized corrosion, maximum value is 5.

3.2.1.7. Influence of Water

Table 7: Influence of Water.

Criteria	Point
Carbon Steel line operates dry – No Water ever present	1
Carbon Steel line operates dry – but water may be present in upset situations or effectively inhibited	2
Carbon Steel line occasionally has water, typically vapor phase	3
Carbon Steel line occasionally has water, typically vapor phase some drop out	4
Carbon Steel line occasionally has water is present in normal operation	5

3.2.1.8. Cathodic Inspection Effectiveness

Table 8: Cathodic Inspection Effectiveness.

Criteria	Point
Full intelegent pigging survey conducted within the last 2 years, no defects detected	1
Full intelegent pigging survey conducted within the last 2 years, defects have been evaluated and repaired as required	2
Intelegent pigging survey conducted within the last 5 years	3
Basic inspection have been performed, including UT – ultraviolet tests spot-checks or guided wave UT, however these have only been on fraction of the pipe length, and wall loss < CA (Corrosion Allowance)	4
No Inspection (either IP – interference potential or UT spot-checks or guided wave UT) have been performed, or inspections have been performed and wall loss > CA	5

3.2.2. Operational Inspection factor

Based on that survey report on September 2009 operational inspection factor have five sub-factors that support for assessment. That following are Pressure Cycling, Over Pressure, Operational Pigging, Design Consideration and Pipeline Construction.

3.2.2.1. Pressure Cycling

Table 9: Pressure Cycling Criteria.

Criteria	Point
Less than 10 pressure cycles of 10% MAOP per year	1
Between 10 and 100 pressure cycles of > 10% MAOP per year	2
No Data	3
More than 100 pressure cycles of 10% MAOP per year	5

3.2.2.2. Over Pressure

Table 10: Operational Pigging Criteria.

Criteria	Point
Impossible to overpressurise pipeline. Eg. Design pressure greater than compressor pressure	1
Over pressure possible but pipeline protected by multiple overpressure protection systems (i.e. HIPPS and relief valve)	2
Over pressure possible but pipeline protected by single overpressure protection systems	3
Over pressure possible but pipeline not protected by an overpressure protection systems	5

3.2.2.3. Operational Pigging

Table 11: Operational Pigging Criteria.

Criteria	Point
Pipeline regularly was been pigging with basic recommendation frequency based pigging needed on that line (analysis from production scale)	1
Pipeline was been pigging less than basic recommendation frequency based pigging needed on that line (analysis from production scale)	2
Pipeline seldom was been pigging but there was no recommendation for pigging	3
pipeline never was been pigging	5

3.2.2.4. Design Consideration

Table 12: Design Consideration Criteria.

Criteria	Point
Design documented and for code to recognized, Pipeline operated base on original design parameter	1
Design documented and for code to recognized, Pipeline operated base on original design parameter. Pipeline end connection with threaded	2
Design documented and for code to recognized, Pipeline operated base on original design parameter. But pipeline is over the lifetime.	3
Design documented and for code to recognized, Pipeline operated out of original design parameter.	4
Design hasn't been known	5

3.2.2.5. Pipeline Construction

Table 13: Pipeline Construction Criteria.

Criteria	Point
Pipeline construction fit to design consideration (as built drawing) and have fully consistency supervising	1
Pipeline construction fit to design consideration (as built drawing) and have un-fully consistency supervising (80%)	2
Pipeline construction fit to design consideration (as built drawing) and have weakly consistency supervising (40%)	3
Pipeline construction fit to design consideration (as built drawing) and un-supervising	4
Pipeline construction un-fit to design consideration (as built drawing)	5

3.2.3. Third Party Interference Inspection factor

Pipeline lay down cannot neglect interference from outside caused by external load that can come from live load like man activity and vehicles, agricultural activity and natural effect that called third party interference. For assessment this factor should be support by sub-factor like pipeline cover, third party damage, Right of Way (ROW) and land stability.

3.2.3.1. Pipeline Cover

Table 14: Pipeline Cover Criteria.

Criteria	Point
Buried with more than 1 m with warning sign and additional physical protection	1
Buried with more than 1 m with warning sign or additional physical protection	2
Buried with more than 1 m	3
not buried	4
Buried less than 1 m	5

3.2.3.2. Third Party Damage

Table 15: Third Party Damage Criteria.

Criteria	Point
pipeline going across forest, mountain, ocean or agriculture area with less than 10 buildings on a distance 1.6 Km, 0.4 Km wide and crossing with pipe (MIGAS 300.K Class 1)	1
pipeline going across agriculture area with 10 through 46 buildings on a distance 1.6 Km, 0.4 Km wide and crossing with pipe (MIGAS 300.K Class 2)	2
pipeline going across village, market and small city with more than 46 buildings on a distance 1.6 Km, 0.4 Km wide and crossing with pipe (MIGAS 300.K Class 3)	3
pipeline going across more densely populated or big city with more than 46 buildings and high rise building on a distance 1.6 Km, 0.4 Km wide and crossing with pipe (MIGAS 300.K Class 2)	5

3.2.3.3. Right of Way (ROW)

Table 16: Right of Way (ROW) Criteria.

Criteria	Point
Thicket and trees far from pipeline. Pipeline sign can be seen from all direction and with or directly through it	1
most condition of ROW are Thicket and trees far from pipeline. Pipeline sign can be seen from all direction and with or directly through it	2
Little condition of ROW are Thicket and trees far from pipeline. Pipeline sign can be seen from all direction and with or directly through it	3
not in ROW Condition	5

3.2.3.4. Land Stability

Table 17: Land Stability Criteria.

Criteria	Point
land slide is not happened through or under ROW	1
land slide is happened through or under ROW	3
land slide is happened through or under the pipeline	5

3.2.3.5. External Inspection

Table 18: External Inspection Criteria.

Criteria	Point
Directly Routine survey. Air Patrol and GVI Inspection have been done more than 1 year for all pipelines. Prediction result and corrective action needed.	1
Directly survey and GVI inspection have been done within last 2 through 5 years for all pipelines. Prediction result and corrective action needed.	2
Directly survey and GVI inspection have been done within last 2 through 5 years just part of pipeline. Prediction result and corrective action needed.	3
External survey hasn't been done for all pipeline and done on last 5 years	4
no External survey that has been done	5

3.2.3.6. Sabotage

Table 19: Sabotage Criteria.

Criteria	Point
Situation stable. No history of sabotage in the region	1
Situation stable, sabotage has occurred in the region in the past	3
Civil / Military unrest in the region	5

3.2.4. Leak History Inspection factor

Form report we have based on survey there was historical notes the leak of the pipeline. This factor is one of main factor and will have big effect to assessment.

Table 20: Leak History Inspection Criteria.

Criteria	Point
No leaks	1
one leak caused by third party	3
one leak caused by corrosion or more than one leak caused by mechanical	5

Form all tables above we should choose event that similarly or most approaching event compared with actual condition on the field. Thus, from all the result use distribution data type that most suitable for that condition, like isosceles triangle, right triangle and uniform [**9**].

3.3. Qualitative consequence prediction

Determination for consequence use the same method that using for likelihood prediction. It using sum of individual factor divided by normalized factor. Normalized factor is to ensure that all consequence factor have point range within 1 (one) through 5 (five). There four main factor is used to make assesment, there are safety, environment, financial and reputation of company [**1**]. But in this case financial is excluded because no supporting data for assessment.

3.3.1. Safety

Safety data base on survey report from PERTAMINA consist of operating pressure, release quantity, flammability/toxicity and population density. Pipeline operating pressure refers to daily operational pressure of transmission gas in working pipeline, greater operating pressure mean greater consequence.

Release quantity refers to nominal pipe size of pipeline, greater nominal pipe size mean greater consequence. Nominal pipe size break down from low consequence with point scale 1 is pipeline under 6 inches diameter. Point scale 2 for diameter 6 through 12 inches. Point scale 3 for diameter 12 through 24 inches. And point scale 5 for diameter 24 inches above.

Flammabilty/ toxicity is refers to service fluid of pipeline that consist fluid potential produce flame or toxic. Population density use same parameter like on table 8.

3.3.2. Environment

Existence of pipeline may affect the environment, this factor should be assessed to know how much risk that effected from pipeline. This make consequences and consider based on release quantity, type of fluid and location factor. For release quantity and location factor we can use same data from safety that have same parameter with this. But for type of fluid have different assessment even though have a same data for type of fluid.

3.3.3. Financial

Damage of pipeline directly made to financial problem related to accidental event could be happen, this factor should be assessed to know how much risk that effected from damaged pipeline. This make consequences and consider based on financial effect that related to cost bleeding of damaged pipeline repairing and financial loss that related to potential loss of gas distribution fee during damaged pipeline repairing has been doing. For both of financial effect and financial loss, value of each point scale was depend to company size and decided by finance policy of company,

3.3.4. Reputation of Company

The operator company that take control of pipeline operation is one of consideration for consequences of pipeline. The popularity and scale of company use to determine point of assessment.

4. LIKELIHOOD AND CONSEQUENCE ANALYSIS

Using Crystal Ball software for analyzing each assumption of every factor. Every point on each factor refer to criteria that mentioned above. We need likelihood and consequences that will produce risk forecast for this case using crystal ball simulation. This following table below will give description based survey data of 12.7 km reconditioning trunkline of PERTAMINA EP Java (Figure 2) and determine distribution data type use in crystal ball [**2**, **9**].

Figure 2: Observation Survey Record of 12.7 km Walet Utara – Balongan Trunkline

Table 21: Qualitative Assessment of Likelihood

A	QUALITATIVE ASSESSMENT OF LIKELIHOOD	Probability		
	Type	Point	Description	Distribution Type
1	**Corrosion Inspection Factor**			
1.1	External Inspection	1	routine survey every 1 year and several point was inspected more than 1 every year	Right Triangle 1 -2
1.2	Pipeline Age	3	Pipeline has been operating more than 10 years	Uniform 3 - 4
1.3	Cathodic Protection Reading	1	CP Reading indicated protection but some point indicate marginal protection	Right Triangle 1 - 3
1.4	Cathodic Protection Survey Status	-	Cause of protection using by anode sacrifice method it is not necessary to know CP survey status	-
1.5	Cathodic Interference	1	No known interference	Uniform
1.6	Localized Corrosion	3	Pipeline fluid source from BP West Java, potential content small amount of CO_2	Right Triangle 1 - 3
1.7	Influence of Water	2	Pipeline fluid content still small amount of water cause it source from BP West Java	Normal
1.8	Internal Inspection Effectiveness	1	Pipeline will been planning every 2 years and after pipeline reconditioning was found No Leaks	Normal
2	**Operation Inspection Factor**			
2.1	Pressure cycling	1	Less than 10 pressure cycles of 10% MAOP per year	Normal
2.2	Over Pressure	1	Impossible to over pressure pipeline cause of design pressure greater than compressor maximum pressure (MAOP was 123.3 Bar and Operational pressure 14.5 – 16.4 Bar)	Normal
2.3	Operational Pigging	1	Pipeline will been planning every 2 years and after pipeline reconditioning was found No Leaks	Normal
2.4	Design Consideration	1	Design documented and for code to recognized, But pipeline is over the lifetime.	Normal
2.5	Pipeline Construction	1	Pipeline constructed fit within design consideration (as built drawing) but several section was moved	Right Triangle 1 -2
3	**Third Party Interference Inspection Factor**			
3.1	Pipeline Cover	1	Pipeline buried more 2 m, some point 1.2 – 1.5 m with warning tape and river crossing pipeline not buried with additional physical protection	Right Triangle 1-3
3.2	Third Party Damage	1	Generally pipeline crossing un population area but several point located near river with more populated area	Right Triangle 1 – 4
3.3	Right of Way (ROW)	1	Generally pipeline crossing un population area but several point located near river with more populated area all of section have warning tape and physical protection	Right Triangle 1 - 3
3.4	Land Stability	1	no potential to land slide	Normal
3.5	External Inspection	1	routine survey every 1 year and several point was inspected more than 1 every year	Right Triangle 1 -2
3.6	Sabotage	1	Situation stable and no history of sabotage in the region	Normal
4	**Leak History Inspection Factor**	1	No Leak on Trunkline WLU – Balongan	Normal

Table 22: Qualitative Assessment of Consequences

B	QUALITATIVE ASSESSMENT OF CONSEQUENCES	Probability		
	Type	Point	Description	Distribution Type
1	**Safety**			
1.1	Pressure Factor	2	Pipeline operation Pressure 14.5 – 16.4 Bar	Discrete
1.2	Release Quantity	1	Pipeline Diameter 6 inches	Discrete
1.3	Flammability Toxicity	4	Sweet Natural Gas	Continuous
1.4	Population density	1 - 4	Generally pipeline crossing un population area but several point located near river with more populated area	Continuous
2	**Environment**			
2.1	Release Quantity	3	Pipeline Diameter 6 inches	Discrete
2.2	Fluid Type	2	Sweet Natural Gas	Discrete
2.3	Location Factor	1 - 4	Generally pipeline crossing un population area but several point located near river with more populated area	Continuous
3	**Financial**			
3.1	Financial Effect	3 - 4	Pipeline repairing cost was in medium - high costs criteria	Continuous
3.2	Financial Loss	3 - 4	Potential loss was in medium – high losses criteria	Continuous
4	**Reputation of Company**	4	Pipeline owned by PERTAMINA	Continuous

Calculation of risk of existence reconditioning trunkline from Walet Utara to Balongan with several parameters that was shown in Table 21 and 22 as above using simulator crystal ball, it could be forecasting using simple prediction as before and shown again in below equation.

Risk = Likelihood of failure x Consequence of failure

Furthermore, above equation was could be translated in mathematically expression as more complicated equation as consequence of a lot of parameter that is expresses in Table 21 and 22 and it shown as following equation.

$$R = \frac{\sum_{i=1}^{q} d_i \times \left(\frac{\sum_{i=1}^{p} c_i \times \left(\frac{\sum_{i=1}^{n} a_i f_i}{\sum_{i=1}^{n} a_i} \times \frac{\sum_{i=1}^{m} b_i C_i}{\sum_{i=1}^{m} b_i} \right)}{\sum_{i=1}^{p} c_i} \right)}{\sum_{i=1}^{q} d_i}$$

Here, notation **C** expresses consequence factor value, **f** expresses likelihood factor value, and constant **a**, **b,** **c**, **d** is weighting value of each parameter of **C** and **f**. Both of values were decided by deeply discussion between all of pipeline stake holders. Furthermore, notation *i* is using for identification each parameter of C and f.(*i* equal to 1,2,3, …,m, is identification of each consequence type parameters that were related to B1.1, B1.2, B1.3, …, B3.2 type of consequence); *i* equal to 1,2,3, …,n, is of each likelihood type parameters that were related to A1.1, A1.2, A1.3, …, A3,6 type of likelihood; *i* equal to 1,2,3, …,p is identification of each consequence parameters (B1, B2, B3, B4 type of consequence) ; *i* equal to 1,2,3, …,q is identification of each likelihood parameters (A1, A2, A3 type of likelihood). All of parameters $a_{1.1}$, $a_{1.2}$, $a_{1.3}$, ….d_1, d_2, d_3 was decided by gathering agreement between all of pipeline stakeholder that was also done in previous deeply discussion session.

5. SIMULATION RESULTS

These results of simulations will present the point of risk, the probability level, and the risk category with the chart of sensitivity level.

Result forecast corroson inspection factor related to safety and financial consequence are necessary cause this trunkline was reconditioning and information around corrosion inspection factor is mandatory to make sure this trunkline is absolutely safe for operation as a section of gas transmission pipeline.

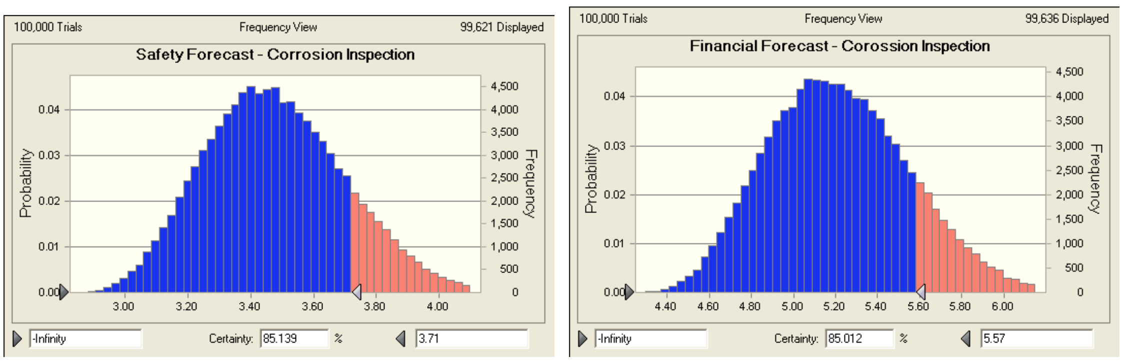

Figure 3: Safety and Financial Forecast of Corrosion Inspection

Both of result shown that safety forecast of corrosion inspection is low risk as shown risk value 3.71, but in case of its financial forecast, it categorized **medium risk** referred to risk matrx, a little bit near to low risk criteria. It could be understood cause of trunkline age was 10 years operated as a section of high pressure North Java gas pipeline for supporting energy consumption of industrial activity in Cikarang and Pulogadung district.

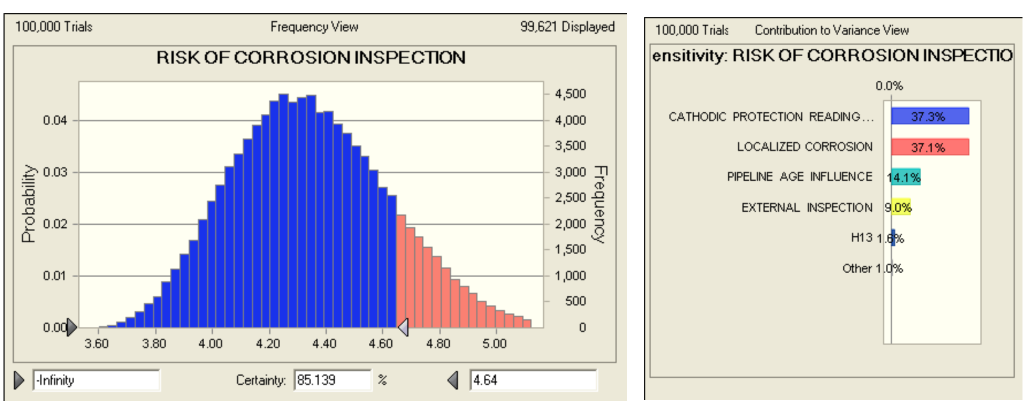

Figure 4: Forecast Corrosion Inspection and Sensitivity

Forecast Corrosion Inspection have risk value 4.64 with probability level 85.1% with that result it will categorized low risk **near medium risk** referred to risk matrx with sensitivity highest on cathodic protection Reading and localized corrosion.

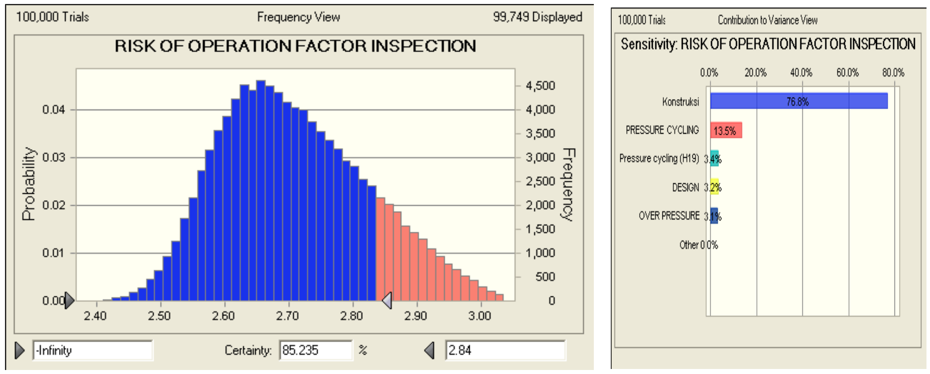

Figure 5: Forecast Operational Inspection and Sensitivity

Forecast Operational Inspection have risk value 2.84 with probability level 85.2% with that result it will categorized **low risk** referred to risk matrx with sensitivity highest on pipeline construction and pressure cycling.

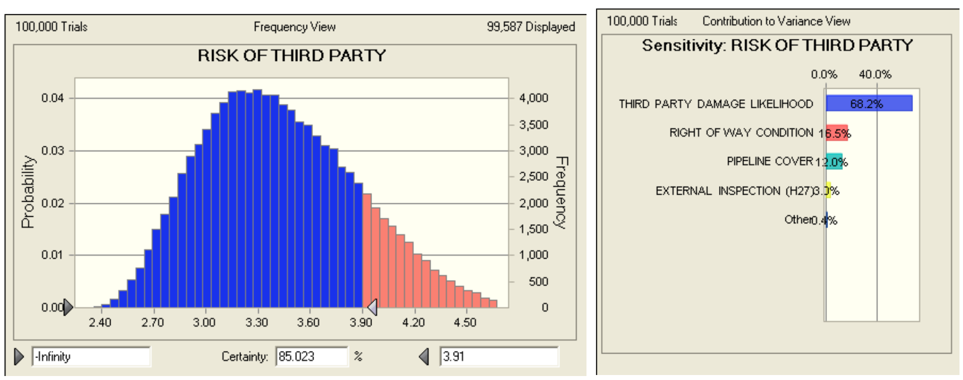

Figure 6: Forecast Third Party Interference Inspection and Sensitivity

Forecast Third Party Interference Inspection have risk value 3.91 with probability level 85.0% with that result it will categorized **low risk** referred to risk matrx with sensitivity highest on third party damage.

6. CONCLUSION

The simulation using by random number generation apply to forecast the risk on gas transmission pipeline is developed. Furthermore, simulation has been sucessfully applied to asses the risk for every point in the reconditioning trunkline Walet Utara - Balongan. Based on that simulation results, the risk value of the pipeline is 3.3 with probability level 85.2%. With that result, we can conclude that using risk matrix, the risk of the pipeline will be categorized at **low risk** referred to risk matrx. The highest sensitivity of forecast parameters are on pipeline construction with sensitivity presentage 22.9 %, followed by third party damage sensitivity with presentage at 18.4% and localized corrosion and cathodic protection reading with sensitivity presentage 15.7 %.

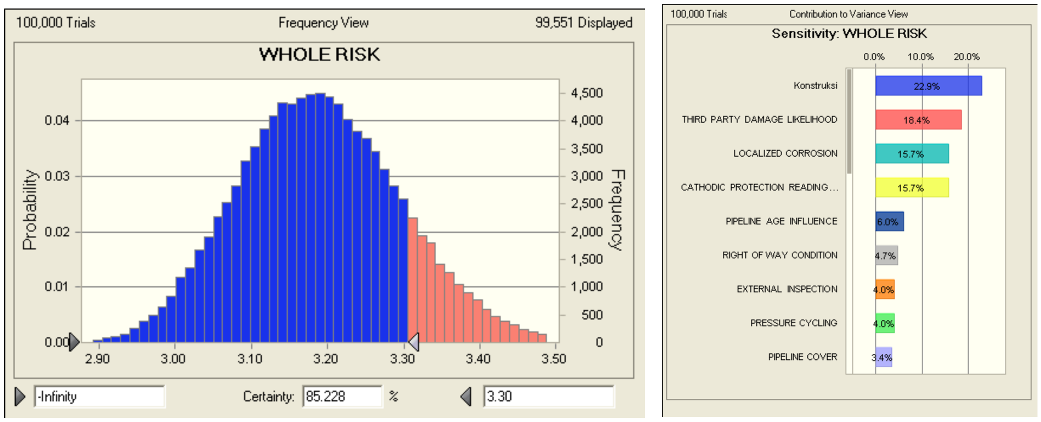

Figure 7: Total Forecast

As a conclusion by this developed risk forecasting using crystal ball, it was understood that trunkline Walet Utara – Balongan could be safely operating as a section of high pressure North Java gas pipeline for supporting energy consumption of industrial activity in Cikarang and Pulogadung districts. Our future research based on risk inspection will focus on developing more efficient computation or hybrid methods to solve more real complex problem.

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