Risk Assessment

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Risk Assessment : Version 0209
Summary

Risk-assessments support your decisions to prioritise limited resources amongst your assets; they help you to control risk by selecting & scheduling response actions.

We deliver effective risk-assessment by identifying the conditions that threaten the integrity of your system & measure the probability that these conditions will lead to failure. Then we determine the consequence of such a failure. The results help you to prioritise response actions, develop plans & execute strategies based on validated risk rankings. We perform these tasks dynamically – adding precision to completed works & allowing greater robustness with each subsequent iteration of the integrity management cycle.

If you are starting out with limited data, we can determine an initial risk-assessment for you by exploiting the breadth of experience & depth of knowledge from the subject matter experts (SME’s) that we assemble on your behalf. If historical data is available, we reinforce this SME approach with an extrapolated relative risk model.

For more comprehensive risk-assessments, we complete scenario-based models by examining detailed consequences - factoring-in failure probabilities using event, decision & failure tree processes. For full probabilistic models, we utilise specialist risk-assessment software to support us. According to your needs, we can gather, input & validate data, configuring appropriate risk-algorithms to suit. We work with a number of software packages, including but not limited to Piramid, IAP and IMP, so can recommend applications or work with your incumbent system to suit.

All of our approaches can be configured to both pipelines & facilities – even some of today’s risk-assessment software can be extended beyond pipelines to ensure that the necessary criticality analysis (CA) is performed upon your facilities. Your entire transport system can therefore be assessed in a balanced & comparable manner.

Risk-assessments are crucial in shaping your integrity management decisions; results must therefore be validated. We deploy multidisciplinary validation teams to perform data & result reviews. This team also crosschecks segments to ensure consistency with established engineering practice. With PIMS of London, you can be sure that risk-assessment results are applicable, both from the perspective of our experience and industry expectation.
Introduction

The Risk Assessment component provides the output from all preceding steps and serves to quantify what may cause integrity management goals to be missed and prioritise segments that require actions to mitigate such failure – “what pipeline segments are in most danger and why?” The goal of the risk assessment is to evaluate the current and historical pipeline integrity data and failure consequences in order to quantify threats to integrity, prioritise and plan subsequent Integrity assessments together with other mitigation actions – be they corrective, preventative or reactive.

The information gathered during the previous steps, together with the correct implementation of this step, should maximize risk assessment accuracy and effectiveness. Such accuracy and effectiveness enables the identification and prioritisation of risks in the system. This establishes how, where and when to implement risk mitigation techniques in order to improve pipeline integrity.

A comprehensive pipeline Risk Assessment programme is central to the Integrity Management process for both subsequent actions and iterations because it enables:

- a) The planning and justification of effective resources allocation.
- b) Comparison of Risk between different pipeline segments – for example, to prioritise risk segment by segment throughout a Subsidiary.
- c) The scheduling of integrity assessments and mitigation actions according to priority.
- d) The comparative analysis to determine what impact or benefit mitigation actions have had upon calculated risk.
- e) The comparative illustration of the most effective mitigation measures.

Risk Assessment Methods

To perform a robust Risk assessment experts in the subject and people familiar with the Risk assessment programs must be used to either implement the process or at least regularly check input data, assumptions and findings.

Regarding methodology, four Risk Assessment techniques are consistent with the integrity management programme. These need not be used in isolation from one another - in other words, more than one model can be applied to achieve the final Risk Prioritisation and Validation. It is advisable that the strength and
weaknesses of each Risk Assessment method is documented as a basis for the choice of method or methods to be used.

All four methods share the following five characteristics:

1. They serve to identify potential threats or conditions threatening system integrity.
2. They enable the quantification of threat likelihood (Probability of Failure) and effect (Consequence of Failure).
3. They enable segments to be prioritised according to risk and components that drive that risk.
4. They form the basis for an informed planning and execution strategy regarding integrity assessment and mitigation measures.
5. They are dynamic – both in terms of their ability to assimilate new information and more refined configuration.

The simplest approach involves the gathering of input from Subject Matter Experts. To do this requires an understanding of the fields of expertise required to complete a comprehensive Risk Assessment together with the identification of those individuals who have such expertise. A forum must be arranged for these experts. Facilities must exist for their expertise to be supplemented with available technical literature and information. In examining each pipeline segment from a perspective of Failure Probability and Consequence, on a threat-by-threat and segment-by-segment basis, these experts will be asked to assign a numerical relative value for both Probability and Consequence. The minimum number of relative values must allow for at least a high, medium and low ranking for each potential threat and consequence scenario. Subject Matter Expertise based Risk assessments are normally considered appropriate for those segments where historical data is unavailable. It is often considered as the “Engineering Logic” approach to Risk assessment.

Provided that the information is available, a Relative Assessment may be permitted. This method develops risk models oriented at identifying the greatest and more relevant threats and consequences that have historically affected pipeline operation. It is considered a relative risk model because results are compared to values obtained from the same model – often, it is referred to as an “Extrapolated” approach to Risk assessment. This method, though based in specific data, is best applied in conjunction with other methods (even if they are more simple) in order to validate perspective.

By undertaking an exercise that theorises from route cause through to final effect, a more sophisticated Risk Assessment technique is the Scenario-based Model. This involves exercises to model an event or series of events that lead to failure and determining the consequence. With consequence determined, the Probability of such an event occurring is assessed via a Process Map involving event trees, decision trees and failure trees.
This *Modelling* approach can still be conducted in isolation from Risk Assessment tools though software greatly assists the documentation of the process.

Specialist software and tools are normally required to conduct the most complex of the four Risk Assessment methods – that of *Probabilistic Modelling*. Such modelling involves configuration and the input of algorithms into a software package that serves to mathematically combine the frequencies of events or series of events to determine an event probability.

**Determining Probability of Failure**

The events or series of events that threaten each pipeline segment will have been identified during a prior component of the process. Additionally, data will have been gathered to support the determination of relative probability that those threats may actually cause failure. Probability of failure can be expressed in terms of frequency as a number of events taking place within a specific period over a specified distance or as a relative high, medium or low likelihood. Best practice indicates that the number of events taking place within a specific period should be considered as a sub-set of the high, medium or low ranking in order to support consistency across all threats. In this way it can be seen that probability of failure can be estimated in qualitative terms, quantitative terms or both and can be conducted at different detail and complexity levels, including the following techniques:

a) **Subject Matter Expertise** - based on knowledge, where experts opinion is used to estimate events frequency based on the experience of operators, inspectors, etc. It is here where pipeline qualities are examined to determine the propensity for failure to occur. Some classic examples of this include pipeline coating type, pipeline fabrication type and surrounding soil characteristics.

b) **Historical Incident Data** - based on statistics, where previous information on the failure is considered to extrapolate probability.

c) **Susceptibility studies** – scenario based and probabilistic models based on analytic methods, where mathematical tools are applied to express probabilities distribution.

In reality a combination of all three methods may be applied to arrive at likelihood. Either way, the processes, tools and models implemented to estimate probability of failure shall be documented. Likewise, implicit uncertainties in the analysis made shall be recorded.

**Determining Consequence of Failure**

The Consequence of Failure analysis shall estimate the severity of the incident’s impact on the environment (environmental), the population health and safety (social) and together with facilities and property (economic). Though these perspectives of consequence may be maintained in separate “layers”, it is more common for
them to be aggregated, provided a common currency of unit may be applied to them all. For example, the PIRAMID tool allows for each consequence to be attributed a financial value, regardless as to whether it is environmental, social or economic.

The recommended factors to be considered when estimating consequences are:

**Environmental impact (including financial implication)**
1. Volume and type of fluid spilled or released to the atmosphere.
2. Trajectory and dispersion mechanism enabling the fluid to reach and impact on the population or cause environmental damage.
3. Effect the spilled fluid will have.
4. Environmental damage.
5. Effects of non-ignited gas clouds

**Social impact (including financial implication)**
6. Fluid volume that can reach the population through such physical paths.
8. Population proximity to the pipeline (including natural or man-made/artificial barriers providing some protection level).
9. Proximity of population with limited mobility or handicapped (hospitals, schools, nurseries, asylums, prisons, leisure areas), especially in areas without external protection)
10. Public needs and comfort.

**Economic impact (distinct from those above)**
11. Property damage.
12. Service Interruption costs
13. Penalties for breach of contract
14. Pipeline Repair costs
15. Product Quality costs

Quantification of all of these factors needs to include consideration for *Exposure time* – the period that the pipeline is either in failure mode but not isolated or is out of commission – and for the propensity for Secondary failures to occur.

In terms of population consequence, it is consistent with Gas code-based practice in the United States to classify segments according to class location. Class location analysis must extend 200 meters on either side of the centreline of a pipeline (that is, at each side of the pipeline’s longitudinal axis) per mile of the pipeline route.
Class 1 Location: *The following are considered Class 1 Locations:*
An off-shore area;
Any class location unit that has 10 or fewer buildings intended for human occupancy.

Class 2 Location: *The following are considered Class 2 Location:*
Any class location unit that has more than 10 but fewer than 46 buildings intended for human occupancy.

Class 3 Location: *The following are considered Class 3 Location:*
Any class location unit that has 46 or more dwellings intended for human occupancy;
An area where the pipeline lies within 100 yards (91 meters) of either a building or a small, well-defined outside area (such as a playground, recreation area, outdoor theatre, or other place of public assembly) that is occupied by 20 or more persons on at least 5 days a week for 10 weeks in any 12-month period. (The days and weeks need not be consecutive).

Class 4 Location: *The following are considered Class 4 Location:*
Any class location unit where buildings with four or more storeys above ground are prevalent.
These classifications assist in the allocation of population related consequence on a scale of 1 to 4. This 1 to 4 scale must be adjusted to fit that of the overall chosen consequence analysis technique.

With regard to environmental impact, segments that cross rivers or, in the case of liquid hydrocarbons, segments where spilled product that could reach a river due to topographical characteristics should be considered as high environmental consequence areas. Similarly, high environmental consequence should be attributed to liquid hydrocarbon pipelines located subsea.

When examining liquid hydrocarbon pipelines from the perspective of environmental consequence, sites containing drinking water and/or natural resources that are more susceptible to long-term or irreversible damages must be highlighted.

As with all consequences, beyond the return to service time, the length of time to which the surroundings to any particular segment remains affected must be considered – this is especially relevant in the case of water course pollution.
As with attempts to quantify Probability of Failure, implicit uncertainties in the analysis made to determine Consequence of Failure shall be recorded.

Calculating Risk

With Probability of Failure and Consequence of Failure quantified, Risk can also be quantified as the product of these two factors. Risk values for each identified and quantified potential threat along with its corresponding consequence shall be calculated. Total segment Risk shall be obtained by the summation of all calculations for every threat and consequence.

\[
\text{Risk} = P_i \times C_i \quad \text{for only one threat}
\]

\[
\text{Risk} = \sum_{i=1}^{9} (P_i \times C_i) \quad \text{for all threat categories}
\]

Risk Segment overall risk = P_1 \times C_1 + P_2 \times C_2 + \ldots + P_9 \times C_9

where

\begin{align*}
P & = \text{Failure probability} \\
C & = \text{Failure consequences}
\end{align*}

All Failure threat categories (see section 2.4)

The method implemented in risk analysis shall consider all pipeline threats individually. As a result of risk assessment, a risk scoring on a segment-by-segment basis shall be calculated. Where pipeline segments exceed the pipeline unit upon which the risk calculation is being performed, the highest component unit score should be carried forward to the segment. Each segment’s risk score must be expressed in such a way as to distinguish high Probability/high Consequence events from high Probability/low Consequence events as well as identifying overall risks.

Calculated Risk Validation

In order to ascertain sufficient confidence in the Risk Calculation results, a review of the data and the results should be performed. The selected proportion of information (sample data set) upon which this review is performed must be representative of the entire asset in a statistically significant manner. The operator should document the initial extent of this sample data set with an expression as to how it is representative.

A selected multidisciplinary validation team consisting of skilled and experienced staff should make the review on data and results. This team must be independent of those teams and individuals who have performed the initial quantification and calculation of Risk. Beyond basic information and process audit, this validation team will cross check segments to ensure that the methodology applied in risk assessment provides consistency with established Engineering Practice.
Validation of risk assessment results on the sample data set may be conducted by a selected set of inspections, tests and evaluations in locations upon a subset of segments at either end of the Risk score. This must be performed to establish if the methods are characterizing the risk properly. As a supplement to such inspections, tests and evaluations, validation can be achieved considering data from other sources. One such example is that of observed segment conditions during maintenance or before remediation operations. Data gathered during maintenance should be used as infield case studies to validate risk results and determine whether configurations and algorithms are correct and whether source data is accurate.

The purpose of the validation is to ensure that the Risk method implemented has produced applicable results from the perspective of operator experience and industry expectation. If as a result of the validation, there are areas that are not accurately represented in the risk assessment process, then two further courses of action are required. Firstly, the sample data set must be expanded to determine the extent of the inconsistency and secondly, the data gathering and evaluation processes must be examined to identify the route causes of such inconsistency. Re-evaluation will be required should any modification of the data gathering and evaluation process be required. A validation process to determine the accuracy of the calculated risk score should be considered a formal quality document.

Prioritising segments according to Risk

Once the risk assessment method and process has been validated, pipeline segments will be ranked by degree of risk. At the macro-level, this prioritisation will be based on the ordering of total segment risk score. A first step in prioritization is ordering risk results for each segment in decreasing order. When deciding where to implement an integrity evaluation or response operation, high priority should be given to the highest risk level. There are sub-sets of this macro-level; firstly the segments should be ranked according to decreasing levels of consequence – either as an aggregate consequence score or layered according to each consequence type. Should the operator so desire, a threshold may be applied to indicate what segments are considered to be within a high consequence area. Additionally, the segments may be ranked according to decreasing levels of failure probability – again, either at an aggregate threat level or according to each threat component. These sub-sets enable the operator to evaluate risk factors leading to the highest risk levels in particular segments.

The operator shall maintain risk results either with simple “high/medium/low” classifications or with numerical values attributed to each segment. When comparing segments with similar risk values, probability of failure and consequences shall be considered separately thus enabling prioritization of highest consequences segment. Pipeline importance and production requirements shall be taken into account when prioritizing.

Determining immediate actions

The results of the Risk assessment form the basis by which measures are prioritised to reduce risk level. Operators may choose to fast track some segments in parallel to the subsequent Integrity Evaluation step and
onto a requisite Corrective, Preventative or Reactive measure. Normally, justification for such a fast track will be consequence driven. For example, regardless of the pipeline condition that would be determined during the Integrity Evaluation step, a consequence of Engineering failure may be so high as to justify the installation of leak detection systems or emergency flow restricting devices.

Operators are reminded that a consequence driven fast track to such mitigation actions does not remove the need for an Integrity Evaluation but merely reduces the priority allocated to an evaluation for that particular pipeline segment. Regardless of the pipeline segments ranking from the perspective of the Integrity evaluation prioritisation, all segments must be evaluated within 12 years of the effective date.

Returning to the standard sequence of the Integrity management process, the risk scores and constituent components serve to choose, prioritize and schedule sites to conduct Integrity Evaluations. These Evaluations include hydrostatic test, in-line inspection or direct assessment. According to the threats and consequence associated with that segment, inspection operations may include alternative methods and technologies. When scheduling Integrity Evaluations, the effectiveness of the particular technology must be taken into account. For instance, comparing all the segments of a pipeline, a segment can be classified as extremely high for a single threat and present a much lower risk when considering all threats combined. Timely solution of the segment with the single highest threat may be more appropriate than the solution of the highest segment with all the combined threats.