Risk analysis has been a critical component of the integrity management process for a number of years. With the increasing availability of geographic information systems and quantitative inspection technologies for pipeline networks, there is now a growing expectation from operators worldwide to access a more quantitative approach to risk management.

The risk assessment process

Pipelines are recognised as one of the safest methods of transporting hazardous products but it must be appreciated that throughout their service life they are under constant threat from a variety of hazards, such as corrosion and third party damage. Risk assessment is therefore a critical element in the pipeline integrity management process.
A pipeline risk management scheme involves identifying and assessing the susceptibility and severity of credible threats to pipeline integrity, determining the likelihood of various failure scenarios and calculating their likely impact on people and the environment. The resulting failure probabilities and consequence values generate risk metrics. These factors are then used to develop various mitigation and inspection strategies to maintain pipeline integrity.

There are two groups of people in a pipeline company who benefit from a risk assessment, namely engineers and managers, with each having different areas of responsibility. An effective risk model should generate information that addresses the responsibilities and concerns of both these groups.

**Risk modelling**

A risk model must consider the susceptibility of a pipeline to various hazards, the probabilities of different failure scenarios together with the consequences arising from each of these failure scenarios, i.e. the model needs to address the following questions:

1. What can go wrong?
2. How likely is it to happen?
3. What are the consequences if it does happen?

Various techniques are available to evaluate risk factors for different threats and failure scenarios. These range from descriptive qualitative approaches based on engineering judgement, which generate relative risk values, through to detailed mathematical analyses in a fully quantitative assessment which express risk in absolute terms. However, the degree of model complexity used to determine a risk factor does not necessarily reflect the accuracy of the results.

Semi-quantitative risk models of varying complexity have been promoted for a number of years, but in the authors experience the algorithms and weighting factors commonly found in such models still rely heavily on engineering judgement, which can lead to inconsistencies across assessments. They also often lack sufficient resolution for meaningful assessments.

In most cases there is insufficient information available to justify applying a fully quantitative approach to assessing risk. However, with the growing availability of detailed pipeline data such as ILI results, CP survey data and geospatial information, operators now have an expectation that pipeline risk models will provide a more consistent and numerically based assessment of risk levels. As an example, determination of the consequences of failure is a key component of risk models and the availability of GIS-based tools is improving the definition of hazard zones and the impact on receptors in these zones.

An effective numerically based pipeline risk model should incorporate mathematical logic into its decision making process and generate risk factors in a consistent manner. Also, in addition to the standard risk factor (PoF x CoF), individual and societal risk levels feature in many pipeline regulations so there is a need for the model to create the parameters necessary to calculate these risk values along a pipeline.

It is essential the model incorporates a transparent decision making process that provides a clear audit trail. Regulatory authorities increasingly demand auditability so this effectively rules out many black-box software solutions where a single click generates an answer but the process is opaque.

**QPRAM risk model**

MACAW Engineering in collaboration with ROSEN Integrity Solutions developed QPRAM, a numerical pipeline risk assessment model, as a result of its...
experience and dissatisfaction with semi-quantitative risk models. QPRAM is modular and flexible so it can be readily configured to meet an operator’s specific requirements and is implemented in the Rosen Asset Integrity Management Software (ROAIMS) suite.

As well as generating numerical values for risk metrics, QPRAM differs from previous models in that it delivers a matrix of risk results at fixed interval along a pipeline, e.g. every metre, 10 m or 5 km, as required for risk reporting. In addition to readily identifying high risk areas, this level of detail enables a range of KPI’s to be created, e.g. measures of risk reduction arising from various mitigation actions. The facility to carry out cost-benefit analyses of different IMR strategies along a pipeline helps operators focus their budget expenditure. Furthermore, analysis of the risk results matrix in QPRAM identifies those pipelines at greatest risk in a network and enables a ranking of those pipelines for future IMR activities.

Pipeline risk factors are not fixed but represent a snapshot at a particular point in time. Hence it is essential to undertake a review of pipeline risks on a regular basis to capture any changes in pipeline operation or incorporate new inspection results. Regular updates are also necessary to demonstrate to regulatory authorities that an operator is maintaining the integrity of his pipeline network. This is essential to meet the growing need to extend the service life of ageing capital assets like pipelines. Rosen Integrity Solutions provides wide ranging technical support to its clients in the form of risk specialists to assist with reviewing risk levels, pipeline integrity expertise to interpret risk results and corrosion experts to help understand the cause of any high risk levels.

Meeting operators’ challenges

The QPRAM methodology is based on accepted international codes and industry best practices. It has a modular structure to accommodate improved numerical data such as ILI runs, data from geospatial layers and increasing levels of model complexity. QPRAM is also flexible so it can be readily configured to meet a broad range of applications including onshore and offshore pipeline networks transporting a wide range of gas and liquid products.

QPRAM continues to be developed in response to operator requirements. Recent examples that have benefitted from the introduction of automated GIS processing methods include:

1. Identification of high consequence areas and societal risk calculations.
2. Dispersion model for both onshore gas releases and subsea oil releases.
3. Lethality model for toxic gas (H₂S) releases.
4. Explosion model for gas build up in confined spaces.

QPRAM has been provided to clients around the world including Europe, Asia Pacific, India, Middle East, South America and North America. These clients operate a wide range of pipelines from offshore crude export lines to onshore gas transmission networks.