Pipeline risk assessment: risk profiling

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In earlier instalments of this column, the essential elements of pipeline risk assessment were introduced. That guideline is a list of elements that must be included in any pipeline risk assessment before that assessment can be considered complete.

Following this guideline helps to ensure a technically sound risk assessment that should satisfy all stakeholders, including regulators, and provide useful decision-making support to owner/operators. The essential elements (EE) risk assessment is a quantitative risk assessment (QRA).

Numerical estimates of risk – a measure of some consequence over time and space, like 'losses per mile-year' – are the most meaningful measures of risk that can be created. Anything less is a compromise. Compromises lead to inaccuracies; inaccuracies lead to diminished decision-making, leading to misallocation of resources; leading to more risk than necessary. Good risk estimates are highly valued. If the most meaningful numbers can be achieved at the same cost as compromise measures, why would you settle for less?

However, a pipeline QRA risk assessment differs in important ways from a QRA typically seen in the nuclear, chemical, and aerospace industries. In this instalment, let's note some key differences and examine the essential element dealing with one of those differences – the need for a risk profile.

Profiles

The idea of a risk profile – changes in risk over 'space' – is what sets pipeline risk assessment apart from many other QRA applications. Traditional QRA is normally applied to facilities that do not occupy a constantly changing 'space'. Even air and spacecraft QRA's have limited use of changing environmental conditions – they tend to focus on the extreme conditions that govern design requirements.

There are many similarities in QRA approaches, but some key differences when applied to a pipeline. Pipeline QRA's are best performed using reductionism and are unique from others in several key respects:

1. Efficient and independent examination of three distinct probability of failure (PoF) ingredients: exposure, mitigation, resistance
2. Methodology that accommodates long, linear assets with constantly changing environmental and loading conditions
3. Substantially reduced reliance on historical incident rates.

The creation of a risk profile is a key differentiating aspect. A profile acknowledges the unique aspects of long, linear assets, recognising that there are many 'individual' pipe segments among the 'population' of segments that make up a pipeline. As with any treatment of populations vs individuals, behaviour is much more accurately predicted for populations compared to individuals.

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Traditional QRA relies heavily on historical incident rates. When applied to pipelines, this means that a pipeline – a population of pipe segments in varying environments – is modelled to behave as point estimates of populations of other, supposedly comparable pipelines – also collections of individual segments. As the foundation for a risk assessment, this is potentially very inaccurate. Let's examine some of the implied assumptions embedded in this approach:

1. Comparison population (collections of pipe segments from similar pipelines) is accurately represented by a single value – ignoring extremes is appropriate; i.e., the fact that some segments of pipelines may carry much less or much more risk, is not germane.
2. Subject pipeline, considered as a whole, is fairly represented by the comparison population.
3. All parts of subject pipeline behave similarly – the sum of the parts equals a value represented by the comparison.

Obviously, such assumptions will very often be very incorrect. It is a classic error of using the behaviour of a population to estimate the behaviour of an individual when trying to understand the individual – i.e., what are the risk issues for this particular segment of pipeline? Risk management occurs on the segment level.

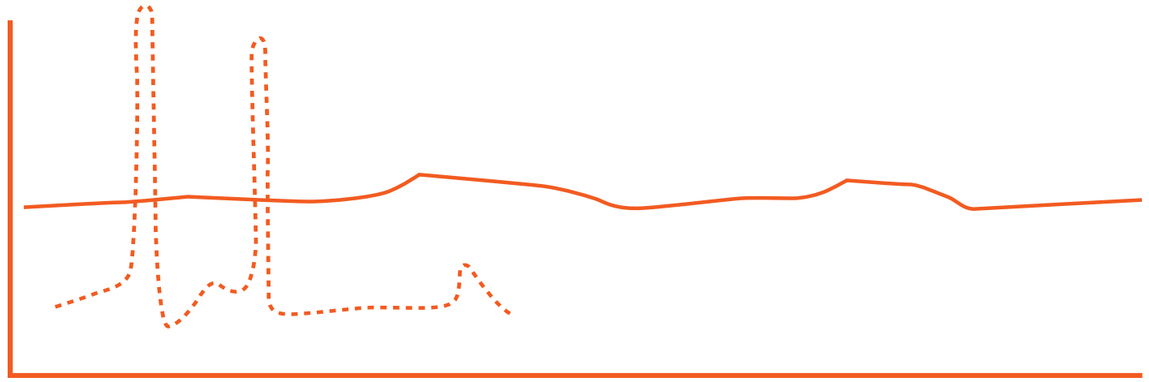
The production of a profile forces the consideration of changing factors along the route – pipe properties (wall thickness, age, coatings, etc.); operational parameters (pressure, temperature, etc.); and, the many environmental changes (soil types, population density, nearby structures, etc.). Some of these factors will change every few feet along the pipeline. So, a key first step is to divide the pipeline into segments appropriate for risk analysis.

Segmentation

The full risk assessment solution to any variation in any risk variable is to 'dynamically segment' on that variation. This means that a new segment should be created for any feature or length of pipe that has different characteristics from its neighbours. Every change in any aspect creates a new segment, reflecting a different crack potential, corrosion potential, ability to resist external force, consequence, or any of dozens of other factors. This will generate many segments.

A potential criticism to this high-resolution approach is that 'management of such a high count of segments is problematic'. The response is direct and intuitive – these segments are currently already being 'managed' in the real world. Each segment really does have failure issues distinct from the adjacent pipe and must be managed accordingly. The risk assessment should acknowledge this reality. Furthermore, with today's computers, high segment counts cause no real efficiency issues.

Proper risk management cannot even begin until the risk profile is understood. That is why the profile is an essential element of pipeline risk assessment.



Sample Figure: Comparing two pipeline risk profiles; risk (vertical axis) vs length (horizontal axis).

Risk management

The end game in risk assessment is of course risk management. In risk management practice as with risk assessment, a potentially high segment count emerging from full risk assessment should not be worrisome. The count will not be burdensome to processes that rely on the assessment results since profiles can be readily summarised. Proper aggregation allows a 'summary' risk value for any stretch of pipe, regardless of the number of changes in risk properties along that stretch.

Once a pipe section – a collection of segments – becomes a candidate for risk management, the initial drill-down quickly reveals the cause(s) of all risk issues. Risk mitigation plans are made accordingly. Proper aggregation is important since any improper approach can lead to masking of real issues. This will be discussed further in a subsequent article.

Prior to any summarisation, however, the full profile itself reveals some risk management challenges. Note the sample figure: the two pipelines have different lengths and widely different risk profiles. Even if the risk estimates underlying these profiles is perfect, risk management solutions are not immediately obvious – which pipeline warrants more immediate attention? Longer lengths of 'medium risk' pipeline may be just as troubling as 'risk spikes'. But without the profiles, understanding of the risk is incomplete.

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