ROUNDTRIPPING THE UNPIGGABLES

Corey Richards, Christopher Holliday (Canada) and Simon Irvine (UK), ROSEN, consider approaching 'unpiggable' pipelines from all angles to find the best integrity management solution.

Pipelines, like all energy assets, are a critical part of our societal infrastructure. They provide us with the ability to heat our homes, supply our drinking water, drive our cars, fly our planes, and even to transport critical hydrocarbons required for the development of plastics. With such crucial functions, ensuring these assets are protected and safeguarded is the main priority of pipeline operators. Stringent integrity programmes help operators with this task through regular inspections, followed by integrity assessments and, when required, repair and rehabilitation measures. While these methods are straightforward for more standard pipelines that are setup for inline inspections (ILI), a large gap remains for assets outside of the norm, such as, in particular, challenging to inspect or 'unpiggable' pipelines.

The pipeline industry can be divided into three major segments: upstream, midstream and downstream. Much of the critical pipeline infrastructure consists of transmission pipelines, which are a part of the midstream sector. According to a variety of references and studies, approximately 40% of those lines are 'unpiggable'. Considering the large number of pipelines operating in the upstream sector – for instance in-field (onshore and offshore), storage and loading lines, as well as pipelines used downstream, including high-pressure distribution pipes – the total length of lines requiring inspection globally is considerably higher than 2 000 000 km, so the number of pipelines that are challenging to inspect is even higher. Business is a balance of risk and economic efficiency. Inspecting all 2 000 000 km in one year is simply impossible; therefore, we need to know where specifically to focus our people, resources and budgets. Essentially, we cannot readily inspect them all, so which pipelines are the highest priority?

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When looking at ensuring the safety of an entire network, operators need to apply a full 360° approach: starting with an outline of the assets that are the highest risk, followed by the selection of solutions available to inspect the pipeline, evaluation of the data, remediation and the feeding of all the information gained back into a controlled system used to evaluate other assets in the network. When looking at a small or large network of assets deemed 'unpiggable', determining where to begin is a daunting task in itself.

Typically, this task is complemented by system-wide risk assessments in which the likelihood of a certain event – e.g. loss of containment – is calculated, as is the consequence of such an event happening – e.g. environmental damage. This is usually done at a pipeline level rather than at a joint level, so we are metaphorically looking at our pipelines with the naked eye, rather than with a microscope.

As a result of these risk assessments, a pipeline will be segmented into risk categories such as low, medium and high risk. A risk category will be determined for a variety of pipeline integrity threats, such as corrosion, fatigue, geohazards, third-party damage, stress corrosion cracking etc. Those pipelines that are considered higher risk will be the priority for inspection, and the inspection technology will be selected based on which threats are considered most likely or of the highest consequence. These risk assessments can be quite coarse and could benefit from a more granular approach, such as a risk assessment conducted on a joint-by-joint basis, rather than a pipeline-by-pipeline basis. This more-detailed assessment would consider local variations in conditions such as soil pH, localised coating types, ground conditions and slopes. This is where predictive analytics can come in to support.

Predictive analytics and applying the digital warehouse

For the greater part of 40 years, ILI technologies have been collecting data on pipelines from all over the world. Now, the accumulated data lake has matured to a point where it can begin to power modern artificial intelligence (AI) solutions for inspection, integrity and risk analysis.

But where and what is the information exactly? How can it be used to support integrity and risk analyses?

As part of the Integrity Analytics project, ROSEN has developed, and continues to expand, a large repository of historical ILI results (feature listings) and corresponding pipeline information called the Integrity Data Warehouse (IDW). To date, the IDW contains detailed information for over 12 000 pipelines from around the world. The IDW is growing rapidly and will soon include information from the majority of inspections since 2000, as well as information from all newly completed inspections. This data – paired with relevant geo-enriched, socioeconomic or operational metadata – provides a clear foundation for scalable AI solutions.

Historically, unpiggable pipelines have been managed with direct assessment techniques, which involve traditional modelling or susceptibility analyses, followed by direct examination. Although this can be effective, it is a costly process that may not scale well across a network, especially if accurate and timely data is not available.

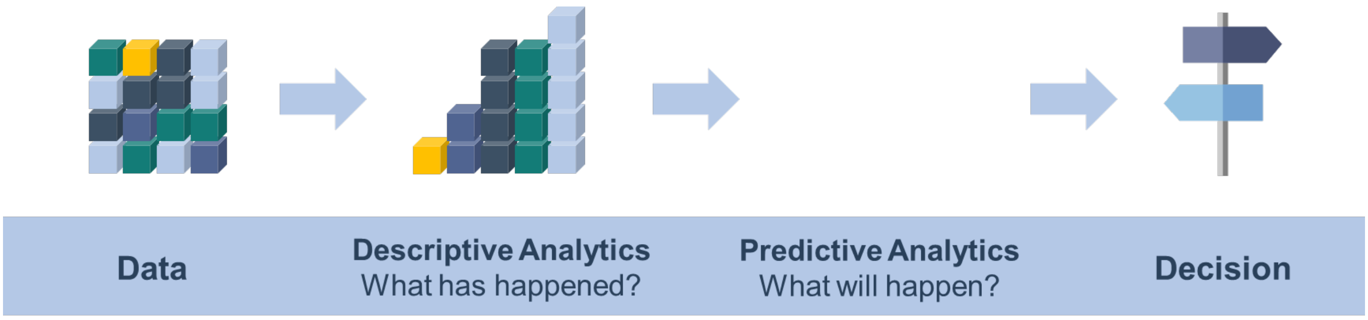

Figure 1. Predictive analytics can be used as a tool by operators who want to make more-informed decisions.

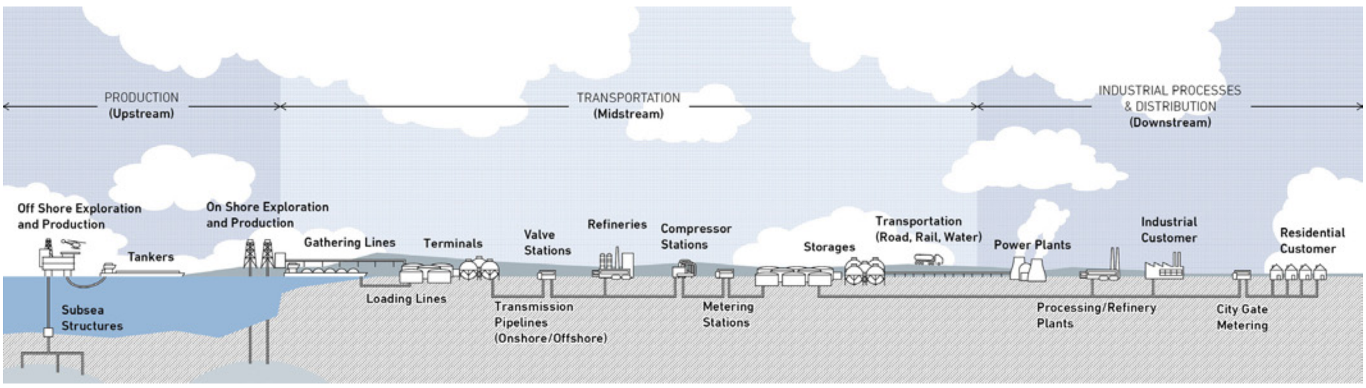

Figure 2. Pipelines, unpiggable or not, are a critical part of our societal infrastructure.

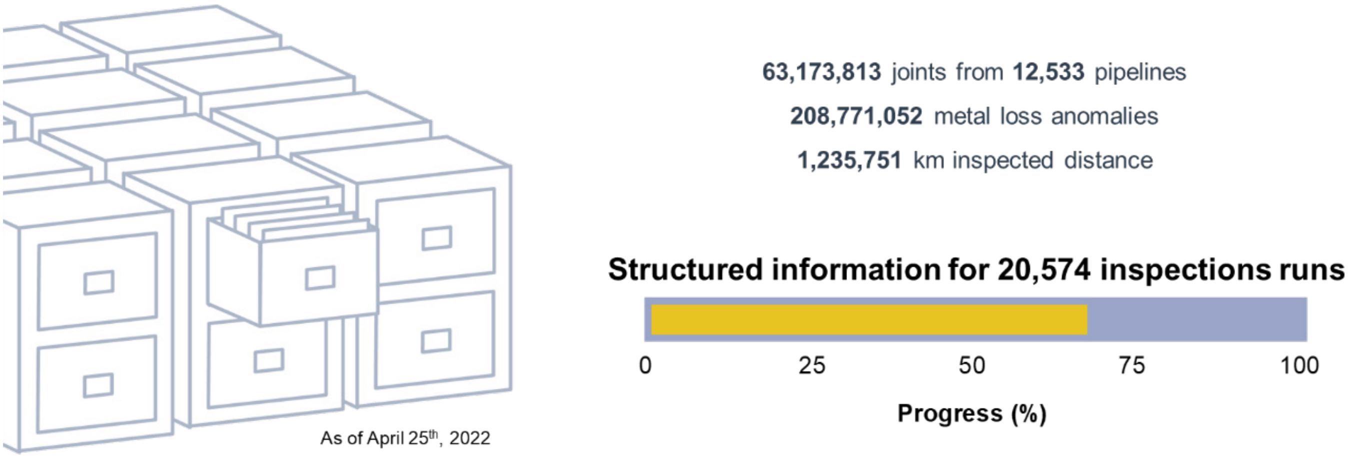

Figure 3. The Integrity Data Warehouse (IDW) contains over 200 000 000 metal loss anomalies.

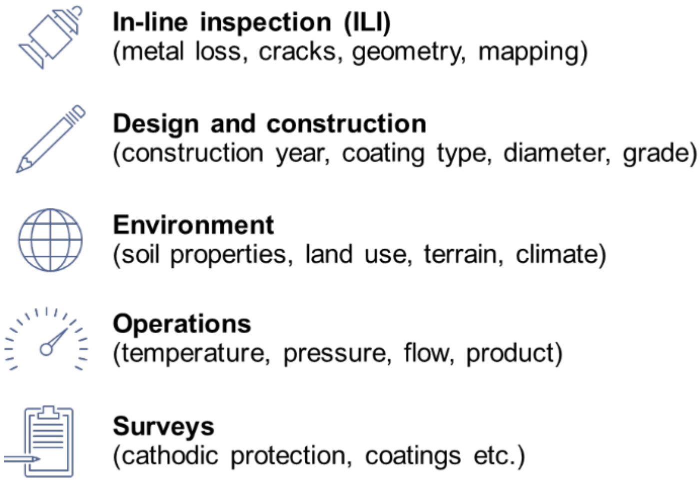

Figure 4. The IDW features metadata from ILI listings and relevant sources.

We therefore tend to know relatively little about the true condition of uninspected pipelines, particularly when they are at the bottom of the ocean or buried underground.

This is an example of how data science can bring real value: by learning from the condition of similar pipelines that have been inspected in the past, we can begin to understand the different variables that predict pipeline threats and develop models to predict the condition of uninspected pipelines.

We can observe trends in inspected pipelines and apply what we have learned to uninspected pipelines.

This technique can be applied to a number of different pipeline threats, but initial work has focused heavily on the endemic and ever-present threat of external corrosion. These models serve as 'ECDA-lite', because they do not require the same volume of target pipeline data, and because they can be very useful when comparing pipelines within a network. They can provide an operator with a clear ranking of 'problem pipelines' in their network (whether unpiggable or not) and focus resources on more-targeted ECDA desk studies. Greater insights also allow operators to adjust inspection intervals or, in the case of some larger companies, the ability to foresee where they need to perform in-field work to optimise logistics and resource planning.

Condition prediction can be conducted on a pipeline-by-pipeline basis. However, the benefits multiply when it can be done on a joint-by-joint basis; an approach that produces a far more refined approach to identifying joints in poor condition than other, more-traditional approaches such as direct assessment (ECDA, ICDA, SCCDA, etc.), which are costly and time-consuming because they require excavation and possibly even a temporary reduction of the operating pressure. While direct assessment, unlike 'virtual ILI', does provide a real view of the pipeline condition, it is highly dependent on ensuring the correct joints have been excavated. Each joint is typically mutually exclusive; for example, just because one joint is free of a given anomaly type – e.g. corrosion, SCC, etc. – that does not mean a joint a few 100 m away also is not affected by the same anomaly type. Conversely, we cannot assume the entire pipeline is damaged just because one joint is in really bad condition.

Generalisable ML models are useful for predicting condition (from severity to density) at the network, pipeline or joint level, but real value can only be delivered by combining subject-matter expertise from the operator and consultants with high-quality data inputs to improve the models and inform robust validation methods (i.e. ILI). Studies leveraging data science not only provide pipeline owners with useful insights to support their integrity management decision-making, they also foster a culture of purposeful data collection and governance. Once data-science principles are adopted and practices aligned with business needs, these capabilities, datasets and insights can be applied to other threat types and other business problems beyond the purely technical.

ROSEN has been advancing this initiative, and partnering with operators, to explore many applications of the IDW, such as: corrosion prediction, external interference hit rate, crack prediction, condition metrics benchmarking and ranking, and corrosion growth rate prediction for uninspected pipelines. Future areas of interest include condition of offshore assets, pipeline movement, bending strain and enhancing ILI anomaly classification.

When you do have to inspect

Of course, there will be a few cases where the AI engine and algorithms will not be able to give us all the answers, or will predict such a high-risk pipeline that an inspection is prudent or even necessary. So, when direct or indirect measurement data of an unpiggable pipeline is really needed, an ILI may become unavoidable. How should we approach an 'unpiggable' pipeline? This is where a 'toolbox' of solutions, approaches, technologies and experiences comes into play. A variety of challenges can be present, but most commonly, multiple challenges exist to make a pipeline truly 'unpiggable'.

When it comes to assessing a pipeline to determine piggability, three main factors must always be considered: accessibility, negotiability and propulsion.

Accessibility

- How do I get the tool into the line?
- Launchers and receivers?
- Single access only?
- Subsea launch?

Negotiability

- Any obstacles getting through the line?
- Bends?
- Diameter variations?
- Difficult valves or other installations?

Propulsion

- Can the tool be pumped?
- Can the tool be pumped, but with constraints and under difficult operational conditions (pressure, temperature, etc.)?
- Can the tool be pulled?
- Does the tool require its own drive?

As with any ILI, access to the pipeline is critical to provide an insertion/extraction point for the ILI tool. In standard pipelines, this is easily remedied with launchers and receivers, but with challenging lines, small modifications to both the tool and the pipeline itself may be required. In some lines, simply adding rental barrels may be a straightforward fix; others may require a cut into the line – possibly supported by hot tapping to reroute the product – to allow for temporary access. With standardised ILI technology, more conventional methods are needed, but using specialised tools, insertion and extraction can often be performed with just a spool piece tied in with a flange. In order to reduce the need for additional modifications to access points, tool technologies play a significant role. Where unidirectional technologies were once the main technology available, bidirectional tools across various measurement platforms, including magnetic flux leakage (MFL) and ultrasonic wall measurement (UTWM), are readily available on the market. Bidirectional tools allow for the reduction of separate tool insertion and extraction points into a single insertion/extraction point, greatly reducing operational expenditures.

Once one or more access points have been defined, the general pipeline layout needs to be understood in terms of installations such as bends, offtakes, diameter changes and wall thickness transitions. Also critical are geometric features that could impede the passage of an ILI tool. While most such features as 1.5D bends do not typically pose a risk for ILI tools, they may cause fluctuations in tool run behaviour, resulting in degraded data. More significant features, such as external damage or diameter changes, will require more specialised tool technologies. While most installations can be overcome with nonstandard tools, it is critical that close collaboration occurs between the vendor and operator to ensure all the details of the line are understood. This critical step ensures that all risks are fully aligned with all parties, resulting in proper tools being selected along with the corresponding work procedures.

ILI technologies are primarily designed to run with the flow of the product, with each tool having minimum pressure and/or flow requirements to ensure it will not only pass the line but pass the line with a stable velocity. Industry-wide, most high-resolution MFL, caliper and UT technologies can capture data that meets their specifications at velocities of up to ~5 m/sec. While most standard systems operate at flow speeds within this threshold, many operate at lower flow and low pressures. In these instances, without proper usages of low-friction tool technologies, speed excursions, stop-starts, and accelerations and decelerations may occur, causing missing or degraded data in potentially critical areas. Similarly to low-flow pipelines, the tool may experience intermittent speed fluctuations due to excessive tool drag and product bypass across the sealing cups/elements. Vendors who specialise in challenging assets tend to follow a toolbox technology-development approach where, in lieu of designing tools with a specific need to meet a vast market requirement, separate elements are built in order to custom-design a tool for each challenging application. In the case of a low-pressure line, a compact low-friction MFL tool may be built. Or, with a low-flow line, a high-sealing UT tool can be utilised. Or, in the case of a line without product flow, self-propelled

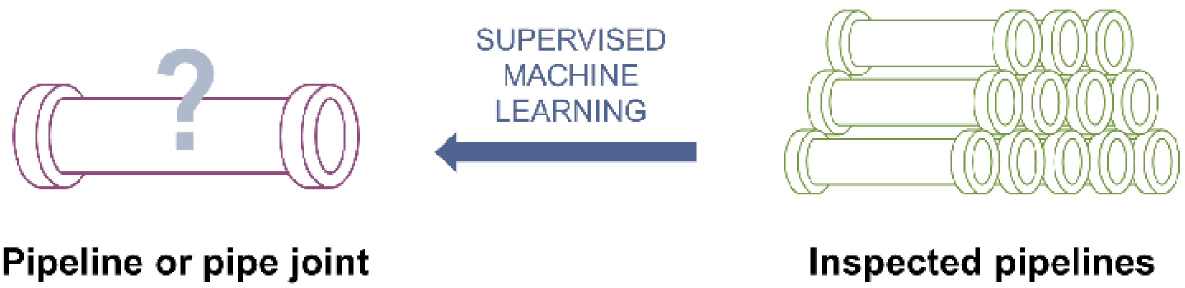

Figure 5. Supervised machine learning for condition prediction.

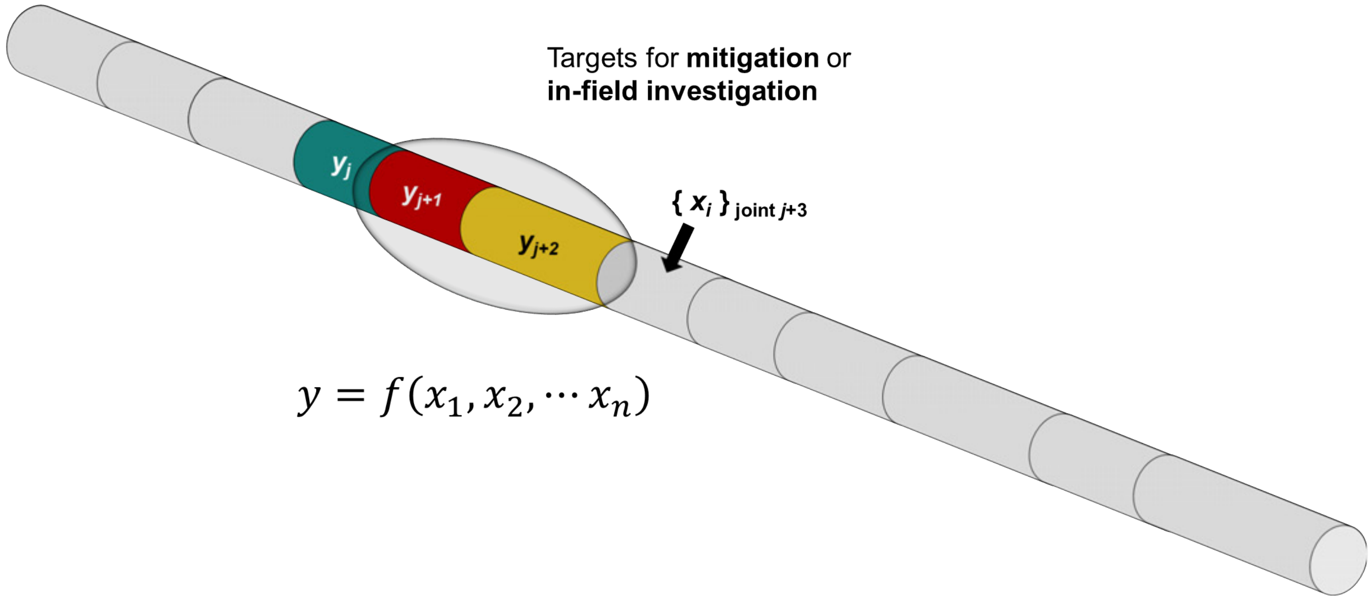

Figure 6. Predictive analytics can help operators to identify low to high-risk joints within a pipeline and prioritise those joints for investigation and mitigation.

drive units can be equipped for use on a variety of measurement technologies.

While indeed not all challenging pipelines have an 'off-the-shelf' solution, most can be solved with a toolbox approach.

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