Dynamic Risk

RISK MODEL WORK GROUP
Index Models and Applications
An Industry Perspective

June 15th, 2017

Technical Presentation #2
Index Models and Applications: Trevor MacFarlane (Dynamic Risk)
Content Considerations

- Are we missing obvious reliability indicators using relative ranking models?
- How do we identify and optimize risk reduction activities?
- How to migrate a relative model to a quantitative model?
- How to use data to verify and identify improvement opportunities?
- Understanding the disconnect between past performance and future results.
- What do we do about low frequency, high impact events?
Key Take Aways

1. The evolution of risk analysis – what’s changed?
2. A new definition of risk models – thinking beyond an Either / Or
3. The performance break-through
The evolution of pipeline safety

I. Before IM
- Cathodic protection
- Pigging
- Digging

II. Early days
- Framework of IM plan
- Event not a process
- Disconnected workflows

III. Maturing
- Relative risk models
- Ranking of HCA’s
- Data aggregation

IV. Current
- Data integration
- Consequence modeling
- Calibration of risk models
- Looking beyond HCA

V. Desired
- Risk-based decision making
- Enterprise Risk Management
- Corporate Sustainability

Enabling changes
Technology
Data Integration
ILI Inspection Results
Risk Model - Objectives

- Identify highest risk pipeline segments.
- Highlight pipeline segments where the risk is changing.
- Calculate the benefit of risk mitigation activities (P&M measures).
- Identify gaps or concerns in data quality and completeness.
- Support decision making and program development.
- Improve system reliability.
- Eliminate high impact events.
Risk Modeling is a continuum

- Small number of pure qualitative or pure quantitative risk models.
  - Most have some elements of both.
- Redefine our terms to include only:
  - Qualitative
  - Semi-quantitative
  - Quantitative
Qualitative Risk?

Failure Likelihood Score

- External Corrosion (21%)
- Third Party Damage (28%)
- Construction Related (4%)
- Incorrect Operations (10%)
- Equipment (18%)
- Internal Corrosion (6%)
- Manufacturing Defects (6%)
- SCC (3%)
- Outside Force (4%)

Managing System Integrity of Gas Pipelines
ASME Code for Pressure Piping, B31 Supplement to ASME B31.8

Dynamic Risk
External Corrosion - typical

\[ S = M \times \left\{ 1 - \left[ 1 - \left( \frac{B}{10} \right) \right] \times \left[ 1 - \left( \frac{C_F}{10} \right) \right] \times \left[ 1 - \left( \frac{FH}{10} \right) \right] \right\} \times A_F \]

Where,
- \( M \) = Material Type Score (0 or 1);
- \( S \) = External Corrosion Score (0-10);
- \( B \) = Baseline Susceptibility Score (0-10);
- \( C_F \) = Stray Current / Interference Factor (0-10);
- \( FH \) = External Corrosion Failure History Score (0-10); and,
- \( A_F \) = Integrity Assessment Mitigation Factor (1-10)

**Baseline Susceptibility Score \([B(0-10)]\)**
The Baseline Susceptibility Score is determined on the basis of a number of weighted factors – each assigned a score from 0 to 10.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor</th>
<th>Fractional Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>AF</td>
<td>0.20</td>
</tr>
<tr>
<td>Corrosion Allowance Factor</td>
<td>CAF</td>
<td>0.05</td>
</tr>
<tr>
<td>Coating System Type Score</td>
<td>MCT</td>
<td>0.30</td>
</tr>
<tr>
<td>CP Compliance Score</td>
<td>CP</td>
<td>0.20</td>
</tr>
<tr>
<td>Coating Condition Score</td>
<td>CC</td>
<td>0.20</td>
</tr>
<tr>
<td>Casings</td>
<td>CAS</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Inspection Data!

10 mile pipeline – 122 anomalies, 2 digs, zero anomalies remaining below 1.39

Not all inspected pipelines are equal...

10 mile pipeline – 7,274 anomalies, 7 digs, zero anomalies remaining below 1.39
External Corrosion – with ILI data

**Sample ILI Unity Chart for Tool Error**

- Field Measured Depth (% wt)
- ILI Depth (% wt)

**Depth Error Density Distribution**

Normal Distribution Approximation

Depth Error Density Distribution

<table>
<thead>
<tr>
<th>Depth (%)</th>
<th>Non-conservative</th>
<th>Conservative</th>
</tr>
</thead>
<tbody>
<tr>
<td>-53.23%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-40.84%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-28.45%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-16.06%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-3.67%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.72%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.11%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.50%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
External Corrosion – with ILI data

\[ P_{Tot} = 1 - \left[ (1 - P_{f,i}) \cdot (1 - P_{f,i+1}) \cdot (1 - P_{f,i+2}) \cdots (1 - P_{f,n}) \right] \]
External Interference

\[ = \text{Hit Susceptibility (H)} \times \text{Failure Susceptibility (S}_f)\]

Failure of a pipeline due to third party damage is the product of two independent factors:

- The susceptibility of the pipeline to incurring a hit by a third party (‘H’); and,

- The susceptibility to failure of the pipeline, given a hit (‘S_f’).
Pipeline
hit by third-party
during excavation

Excavation on pipeline
alignment

Failure of preventive measures

Excavation depth
exceeds
cover depth

Alignment not properly marked

Operator unaware of activity

Activity not notified by third-party

No patrol during activity

Activity not detected by other company employee

Failure of permanent markers

Failure of alignment markers

Failure of temporary markers

Third-party unaware of pipeline

Third-party negligent

Absence of temporary markers

Incorrect temporary markers

Third-party unaware of one-call

ROW signs not recognized

Failure of permanent markers

Third-party chooses not to notify

Third-party fails to avoid pipeline

Excavation prior to operators' response

Third-party fails to avoid alignment

Temporary markers incorrect

Third-party fails to avoid alignment
<table>
<thead>
<tr>
<th>No</th>
<th>Event</th>
<th>Conditions</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Excavation on pipeline alignment (function of land use)</td>
<td>Commercial/Industrial</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High density residential</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low density residential</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Agricultural</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Remote/Water Body</td>
<td>0.06</td>
</tr>
<tr>
<td>B2</td>
<td>Third-party unaware of one-call (function of method of communicating one-call system)</td>
<td>Advertising via direct mail-outs and promotion among contractors</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Above + Community meetings</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Community meetings only</td>
<td>0.50</td>
</tr>
<tr>
<td>B3</td>
<td>Right-of-way signs not recognized (function of placement frequency for signs)</td>
<td>Signs at selected crossings</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Signs at all crossings</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All crossings plus intermittently along route</td>
<td>0.17</td>
</tr>
<tr>
<td>B4</td>
<td>Failure of permanent markers (warning tape)</td>
<td>No buried markers</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>With buried markers</td>
<td>0.10</td>
</tr>
<tr>
<td>B5</td>
<td>Third-party chooses not to notify (function of type of penalty for failure to advise of intent to excavate)</td>
<td>Voluntary</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mandatory</td>
<td>0.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mandatory plus civil penalty</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Right-of-way agreement</td>
<td>0.11</td>
</tr>
<tr>
<td>B6</td>
<td>Third-party fails to avoid pipeline</td>
<td>Default value</td>
<td>0.40</td>
</tr>
<tr>
<td>B7</td>
<td>ROW patrols fail to detect activity (function of patrol frequency)</td>
<td>Semi-daily patrols</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daily patrols</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bi-daily patrols</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weekly patrols</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biweekly patrols</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monthly patrols</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Semi-annual patrols</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual patrols</td>
<td>0.995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Default value</td>
<td>0.97</td>
</tr>
<tr>
<td>B8</td>
<td>Activity not detected by other employees</td>
<td>Response at the same day</td>
<td>0.02</td>
</tr>
<tr>
<td>B9</td>
<td>Excavation prior to operator's response (function of response time following advice of intent to excavate)</td>
<td>Response within three days</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>By company records</td>
<td>0.20</td>
</tr>
<tr>
<td>B10</td>
<td>Temporary mark incorrect (function of marking method)</td>
<td>By magnetic techniques</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>By pipe locators/probe bars</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provide route information</td>
<td>0.35</td>
</tr>
<tr>
<td>B11</td>
<td>Accidental interference with marked alignment (function of means of conveying information pertaining to location of pipeline during excavation by others)</td>
<td>Locate/mark</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Locate/mark/site supervision</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pipe exposed by hand</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cover depth &lt;= 2.5 ft</td>
<td>0.42</td>
</tr>
<tr>
<td>B12</td>
<td>Excavation depth exceeding cover depth (function of depth of cover)</td>
<td>2.5 ft &lt; Cover depth &lt;= 3 ft</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 ft &lt; Cover depth &lt;= 4 ft</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 ft &lt; Cover depth &lt;= 5 ft</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cover depth &gt; 5 ft</td>
<td>0.06</td>
</tr>
</tbody>
</table>
## Impact Frequency

<table>
<thead>
<tr>
<th>Modeled Impact Frequency (hits/mile-yr)</th>
<th>Value of “F”</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 8.0E-4</td>
<td>1</td>
</tr>
<tr>
<td>≥ 8.0E-4 to &lt; 1.3E-3</td>
<td>2</td>
</tr>
<tr>
<td>≥ 1.3E-3 to &lt; 1.7E-3</td>
<td>3</td>
</tr>
<tr>
<td>≥ 1.7E-3 to &lt; 2.2E-3</td>
<td>4</td>
</tr>
<tr>
<td>≥ 2.2E-3 to &lt; 2.7E-3</td>
<td>5</td>
</tr>
<tr>
<td>≥ 2.7E-3 to &lt; 3.1E-3</td>
<td>6</td>
</tr>
<tr>
<td>≥ 3.1E-3 to &lt; 3.6E-3</td>
<td>7</td>
</tr>
<tr>
<td>≥ 3.6E-3 to &lt; 4.1E-3</td>
<td>8</td>
</tr>
<tr>
<td>≥ 4.1E-3 to &lt; 4.5E-3</td>
<td>9</td>
</tr>
<tr>
<td>≥ 4.5E-3</td>
<td>10</td>
</tr>
</tbody>
</table>
Consequence – Impact on Population
## Impact Chart

<table>
<thead>
<tr>
<th>Health and Safety</th>
<th>Public / Employees</th>
<th>Physical Damage / Economic Loss</th>
<th>Environment</th>
<th>Regulatory Response</th>
<th>Corporate Image</th>
<th>Government Relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>$0</td>
<td>$E2</td>
<td>$E1</td>
<td>$E2</td>
<td>$E2</td>
<td>$E2</td>
</tr>
<tr>
<td>Low</td>
<td>$E3</td>
<td>$E3</td>
<td>$E2</td>
<td>$E3</td>
<td>$E3</td>
<td>$E3</td>
</tr>
<tr>
<td>Medium</td>
<td>$E4</td>
<td>$E4</td>
<td>$E3</td>
<td>$E4</td>
<td>$E4</td>
<td>$E4</td>
</tr>
<tr>
<td>High</td>
<td>$E5</td>
<td>$E5</td>
<td>$E4</td>
<td>$E5</td>
<td>$E5</td>
<td>$E5</td>
</tr>
<tr>
<td>Extreme</td>
<td>$E6</td>
<td>$E6</td>
<td>$E5</td>
<td>$E6</td>
<td>$E6</td>
<td>$E6</td>
</tr>
</tbody>
</table>

### Health and Safety
- No HSE issues
- Evacuation or Medical Aid or Near-Miss
- Acute Injury
- Severe Injury
- Fatalities

### Physical Damage / Economic Loss
- No service interruption
- <1 day / No loss of contracted service
- 1-2 days / Loss of interruptible service
- 2-7 days / Loss of interruptible service
- >1 week / Force Majeure

### Commodity Loss
- Controlled operating loss
- Light losses (Leak/Rupture in low pressure, small dia. Line)
- Moderate losses (Leak/Rupture in Intermediate Pressure, Small dia. Line)
- Heavy losses (Rupture in HP, medium diameter line)
- Rupture in HP large-diameter pipeline

### Company
- Minor Repair / Replacement
- Material Repair or Replacement
- Moderate Repair or Replacement
- Loss of Major Infrastructure (readily accessible for repairs)
- Loss of Major Infrastructure (difficult to access)

### Emissions
- Low level emissions
- Small / Minor emissions
- Significant emissions
- Heavy emissions
- Very large emissions

### Rehabilitation
- No significant impact
- Limited Impact / Low Consequence Area
- Moderate Impact / Moderate Consequence Area
- Heavy Impact / High Consequence Area
- Extreme impact / High Consequence Area

### Regulatory Response
- No regulatory involvement
- Informal meeting
- Order to comply / Regulatory Audit
- Review Practices / Loss of Influence on Policy
- Line shut-down or pressure restriction

### Corporate Image
- No public record
- Local coverage
- Regional coverage
- National coverage
- Global coverage

### Government Relations
- No impact
- Strained communications
- Erosion of trust as a safe operator
- Loss of influence on shaping policy / Lost lobby rights
- Total breakdown of relationship
Impact Summary (Weighted)

Impact Score = 50\% \left(S_F\right) + 30\% \left(E_F\right) + 10\% \left(Ec_F\right) + 10\% \left(RF\right)

= 6.9
Impact Summary (Or Gate)

Impact Score = \[ \left\{ \left[ 1 - \left( 1 - \frac{S_F}{10} \right) \right] \times \left( 1 - \frac{E_F}{10} \right) \times \left( 1 - \frac{E_{CF}}{10} \right) \right] \times \left( 1 - \frac{R_F}{10} \right) \right\}

= 9.8
Risk Mitigation Benefit

Cost-Benefit - Mitigation Programs

Hurdle Rate – 1.5
Risk Model – Why we do it?

- Identify highest risk pipeline segments.
- Highlight pipeline segments where the risk is changing.
- Calculate the benefit of risk mitigation activities (P&M measures).
- Identify gaps or concerns in data quality and completeness.
- Support decision making and program development.
- Improve system reliability.
- Eliminate high impact events.
Low frequency, but high impact events

- Goal for the Industry, Regulators and Public
- Focus and identify locations of possible “high impact” events
- Ignore the likelihood of the event occurring (initially)
- What barriers or activities for that specific “high impact” event could be undertaken to eliminate that outcome
- Think Fire Triangle – eliminating just one, eliminates the outcome.
Our Insight

- Dynamic Risk has developed and implemented risk analysis on more than 400,000 miles of pipeline in North America.
- We have designed and implemented 50+ company unique algorithms.
- We have used quantitative risk for all aspects of the pipeline life-cycle.
- Many of these companies have reportable incident rates of less than \( \frac{1}{2} \) of the industry average.
- A number of these companies have virtually eliminated high impact events.

And there is no correlation between this result and the type of risk model they use!
Performance Break-through

- There is a strong correlation with asset reliability performance and with this one activity:

Companies that use risk analysis to support IM planning and decision making consistently achieve the best reliability record.
Thank you for the opportunity to contribute to the RMWG.