Leveraging Risk Intelligence: Optimizing Preventative and Mitigative Measure Selection

November 3rd, 2016

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What If.....
Kalamazoo River, 2010

PoF: 1/1000yr \textit{(Example Only)}
CoF: $1B
Expected Loss: $1M/yr/10ft!

\textit{“Pre-Mortem Analysis”}
Risk Drivers:
- Freespan
- 25\% WT EC Feature
- Unknown Seam Type
Actions?
The Challenge

- A company risk program should be the centrepiece of their asset integrity management program; however...

<table>
<thead>
<tr>
<th>Risk Evaluation Requirements</th>
</tr>
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<tbody>
<tr>
<td>• Risk evaluation approaches need to be “investigative-oriented”</td>
</tr>
<tr>
<td>– Approach must tell us what can be done to reduce risk vs. simply knowing which parts of the pipeline represent the highest relative risk</td>
</tr>
<tr>
<td>– Generating risk numbers is not the end goal; a structured way to evaluate and reduce operational risk is the goal</td>
</tr>
<tr>
<td>– Past “index” models are generally not sufficient</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Connection to Decision Making</th>
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</thead>
<tbody>
<tr>
<td>• Risk evaluation results must have a connection to real-life decision making</td>
</tr>
<tr>
<td>– Point of risk evaluations is not to do a risk evaluation</td>
</tr>
<tr>
<td>– Risk insights must be integrated into routine integrity-related decision making</td>
</tr>
<tr>
<td>– Operators should be able to easily demonstrate how risk evaluation results influence operational work practices</td>
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<table>
<thead>
<tr>
<th>Preventive &amp; Mitigative Measures</th>
</tr>
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<tbody>
<tr>
<td>• Decision making includes identification/evaluation of preventive and mitigative measures</td>
</tr>
<tr>
<td>– Risk evaluations are a primary way to evaluate potential preventive measures and mitigative measures</td>
</tr>
<tr>
<td>– If risk methodology is unable to reflect any change in results for meaningful candidate measures, the methodology is inadequate</td>
</tr>
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Objective:
Understand the critical elements of an effective pipeline risk management system and how they form the foundation of a risk intelligence platform
Leveraging Risk Intelligence

Risk Management System

- Collective Pipeline Knowledge
- Risk Assessment
- Risk Analytics
- Decision Making Framework
- Preventative & Mitigative Measures
Collective Pipeline Knowledge

Risk Management System

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- Risk Assessment
- Risk Analytics
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- Preventative & Mitigative Measures
Integrate Pipeline Knowledge

- Know your data, know your risks
Integrate Pipeline Knowledge: Hierarchy of Information

Data Driven
• In-line Inspection Record
• Weld Records
• Pressure History

Data Assignments (SME knowledge)
• ROW Condition
• Aerial Patrol Frequency
• Mitigation Effectiveness

Data Defaults
• Industry data or ranges
• Establish the level of conservatism

Supplemental Data:
• Earthquake data
• HVAC power lines
• Landuse Type
• Lightning Strikes
• Airports
• Railroads
• Sinkholes
• Mining
• Soil Data
Integrate Pipeline Knowledge: Quantifying Uncertainty

- Incorporate a way to measure and communicate conservatism in risk estimates when data is not available or subjective
  - PXX
  - P50 → most likely case
  - P99 → worst probable case

![Property Damage Due to US Pipeline Incidents 1970-2006](image)
Integrate Pipeline Knowledge: Quantifying Uncertainty

- Using the PXX approach allows for running separate analysis to calculate the difference between the P50 and P99 risk scenarios
  - Directly quantifies uncertainty and can help guide future data collection.
Integrate Pipeline Knowledge: The Role of Historical Incidents

Problems:
- Historical incident data not always useful in current situations
- Rare-event scenarios do not often happen
- Requires a representative population
  - Behavior of the individual vs population

Uses:
- Model calibration (“tuning”) when evaluating system-wide risk results
Risk Assessment Essential Elements

Collective Pipeline Knowledge
Risk Assessment
Risk Analytics
Decision Making Framework
Preventative & Mitigative Measures

Risk Management System
The Essential Elements – A Foundation To Build On

- Establish the Objective
- Measurements in Verifiable Units
- Proper Probability of Failure Assessment
- Characterization of Potential Consequences
- Full Integration of Pipeline Knowledge
- Sufficient Granularity
- Bias Management
- Profiles of Risk
- Proper Aggregation

First Published in 2012
Risk Assessment: Failure Frequency Modeling Overview

- All threats are evaluated simultaneously within a defined 'dynamic segment' allowing threat interaction to be assessed
  - PHMSA risk workshop definition of threat interaction: \( P(\text{threat}_1 + \text{threat}_2) > P(\text{threat}_1) + P(\text{threat}_2) \)
Information Use: Internal Corrosion

- Corrosion coupon results
- ILI results (x2)
- Fluid composition
- Maintenance pigging frequency
- Inhibitor efficiency
- Flow Rate
Frequency Values & Units

- Includes the assessment of both Frequency of Damage and Frequency of Failure
  - Frequency of Damage (FoD) = exposure x (1 - mitigation)
  - Frequency of Failure (FoF) = FoD x (1 - resistance)
    \[\text{FoF} = \text{exposure} \times (1 - \text{mitigation}) \times (1 - \text{resistance})\]

- Failure units are events/year for time independent mechanisms and mils/year (mpy) for time dependent
Quantifying Exposures: Planes, Trains and Automobiles

- Which scenario has a higher exposure rate for an above ground pipeline?
  - Feeding an airport storage facility
    - 6E-3 events per year at an airport
  - Running parallel to a train track for 1000 feet with 10 trains/day
    - 2E-6 events per year
  - Running parallel to a highway for 1000 feet
    - 2E-3 events per year
Mitigation Benefit Through Barrier Analysis

- What information would you consider when evaluating the independent mitigation effectiveness ranges of:
  - Patrol
  - One-Call
  - Depth of cover
  - Public Education
  - Signs/markers

Can leverage a wealth of statistical industry data

<table>
<thead>
<tr>
<th>Mitigation</th>
<th>Impact on risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground tape marker</td>
<td>60% reduction in mechanical damage</td>
</tr>
<tr>
<td>Additional signage</td>
<td>40% reduction in mechanical damage</td>
</tr>
<tr>
<td>Increased one-call awareness and response</td>
<td>50% reduction in mechanical damage</td>
</tr>
<tr>
<td>Increased ROW patrol</td>
<td>30% reduction in mechanical damage</td>
</tr>
<tr>
<td>Increased ROW patrol</td>
<td>30% heavy equipment-related damages; 20% ranch/farm activities; 10% homeowner activities</td>
</tr>
<tr>
<td>Improved ROW, signage, public education</td>
<td>5–15% reduction in third-party damages</td>
</tr>
</tbody>
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Estimating Resistance

- Sources:
  - Pipe specifications (original)
    - Historical issues
    - Low toughness
    - Hard spots
    - Seam type
    - Manufacturing
  - Pipe specifications (current)
    - ILI measurements
    - Calculations from pressure test
    - Visual inspections
    - Effect of estimated degradations
  - Required pipe strength to support normal internal pressure
Excavation Damage Example:

- Based on industry statistics, it is estimated that there will be 0.8 excavations per mile-year at this location.
- Based on annual surveys, the company evaluates the 1-Call program to be 70% effective at preventing unauthorized excavations.
- The pipeline is buried 36” at this location leading to a 20% threat reduction based on published literature.
- This section of the pipeline is patrolled weekly using fixed-wing aircraft which is estimated to be 20% effective at identifying unauthorized excavations at this frequency.
- Based on the available pipe wall, this area is expected to resist 50% of all excavator impacts.

\[
\text{FoF} = 0.8 \text{ events/mi-year} \times [1-(1-0.7) \times (1-0.2) \times (1-0.2)] \times (1-0.5)
\]

\[
= 0.8 \times (1-81\%) \times (1-50\%)
\]

\[
= 0.077 \text{ events/mi-yr}
\]
Fully Characterize Consequence of Failure

- Identifies the full range of possible consequence scenarios
  - Consider ‘most probable’ and ‘worst case’ scenarios
- Consequences and associated units can be tailored:
  - Human health, environmental, repair costs, etc.
  - $/incident vs. consequence units/incidents
- Basis of the assessment is established ‘hazard zones’
Consequence of Failure Example:

**PIR / Specific Site Intersection**

Example With Ignition (Houses)
- Property Count: 8
- Average People Count / House: 3
- Average Property $: 160,000
- Property Damage Rate: 50%
- Value of Injury: $200,000*
- Injury Rate: 5%
- Value of Fatality: $9.1M*
- Fatality Rate: 1%

Consequence Calculation (highlighted segment):
- Property: 8 houses x $160,000 x 50% = $640,000
- Injury: 8 houses x 3 people/house x $200,000 x 5% = $240,000
- Fatality: 8 houses x 3 people/house x $9,100,000 x 1% = $2,184,000
- TOTAL: $3,064,000/incident along this segment

*Recall: 0.077 events/mi-yr x 20% POI x $3,064,000 = $47,186/mi-yr in RISKEX™

*DOT Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analyses
Risk Analytics
Risk Analytics

- What you can get out of the risk model is just as important as what goes in.
Decision Making Framework
## Decision Making Checklist

### What
- What can be done to manage the risks and drivers identified?

### Where
- Where are P&MM necessary or optimal?

### Why
- Why one P&MM over another?

### Who
- Who needs to know about the identified risks?
- Who is responsible for managing these risks?

### When
- When are the P&MM due?
What can be done to manage the risks and drivers identified?

- P&MM Selection Process

- ASME B31.8S Table 4 outlines various potential P&MMs
  - This list can be further refined based on the identified risk drivers

<table>
<thead>
<tr>
<th>Table 4: Acceptable Threat Prevention and Repair Methods</th>
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<tbody>
<tr>
<td><strong>Prevention, Detection, and Repair Methods</strong></td>
</tr>
<tr>
<td><strong>Threat</strong></td>
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<tr>
<td>TF/DF</td>
</tr>
<tr>
<td>Aerial patrol</td>
</tr>
<tr>
<td>Inspection</td>
</tr>
<tr>
<td>Visual/mechanical inspection</td>
</tr>
<tr>
<td>Leak detection</td>
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<tr>
<td>Leak detection and repair</td>
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<td>Leak detection and repair</td>
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Where are P&MM necessary or optimal?
- Establishing Risk Thresholds

- Risk thresholds are the basis for action
  - Where do we need to act?
  - How much is enough?

![Typical Upstream Risk Matrix](image)
Where are P&MM necessary or optimal?
- Establishing Risk Thresholds

- Pipeline example risk threshold based on corporate risk metrics:
Where are P&MM necessary or optimal?
- Continuous Improvement

- Example risk management strategy based on statistical analysis (Statistical Process Control):

  
  ![Expected Loss per Segment](image)

  - Total Expected Loss
  - Pipeline Expected Loss
  - Pipeline Expected Loss + 2Sigma
  - Pipeline Expected Loss + 3Sigma
  - Global Expected Loss
  - Global Expected Loss + 2Sigma
  - Global Expected Loss + 3Sigma
  - Mechanical Damage FoF
  - Incorrect Operations FoF
  - Sabotage & Theft FoF
  - Geohazard FoF
  - External Corrosion FoF
  - Internal Corrosion FoF
  - Cracking FoF

  Minimize expected loss per segment.
Why one P&MM over another?
-Cost Benefit Analysis

Option 1
- Increased DOC from 12” to 48” for 100’ of pipe
- Cost at $1,000 per foot = $100,000
- Risk Reduction: $17,853 per year
- CBA: $5.6 dollars to reduce $1 per year of risk; Breakeven: 5.6 years

Option 2
- Installation of concrete mat just below grade (@ 95% Effective)
- Cost: $50,000
- Risk Reduction: $28,626 per year
- CBA: $1.8 dollars to reduce $1 per year of risk; Breakeven: 1.8 years

Option 3
- If the DOC is a default, digitizing DOC survey data for use in the risk assessment leading to actual 48” DOC
- Cost: $10,000
- Risk Reduction: $17,853 per year
- CBA: $0.6 dollars to reduce $1 per year of risk; Breakeven: 0.6 years
Preventative and Mitigative Measure Evaluation Case Study: High Risk at a water Crossing

- **Alternative 1: HDD**
  - **ECONOMIC ANALYSIS (49 year lifetime)**
  - $\text{PRESENT \textit{DAY VALUE}} = (\text{YEAR 1 RISK SAVINGS}) \times \frac{1 - [(1 + \text{INFLATION \%})^{N}] - [\text{CONSEQUENCE INCREASE \%}^{N}]}{(1 + \text{INFLATION \%})^{N}}$
  - $\text{PRESENT \textit{DAY VALUE FROM HDD}} = $411,911
  - $\text{SOFT SAVINGS} = $61,911
  - $\text{Risk savings with inflation (S)}$
  - $\text{Benefit from horizontal directional drilling yearly risk reduction – inflation adjusted}$
  - $\text{Cost of Horizontal Directional Drilling (HDD)}$
  - $\text{\$350,000.00}$

- **Alternative 2: Automatic Shutoff Valve Installation**
  - **ECONOMIC ANALYSIS (49 year lifetime)**
  - $\text{PRESENT \textit{DAY VALUE}} = (\text{YEAR 1 RISK SAVINGS}) \times \frac{1 - [(1 + \text{INFLATION \%})^{N}] - [\text{CONSEQUENCE INCREASE \%}^{N}]}{(1 + \text{INFLATION \%})^{N}}$
  - $\text{PRESENT \textit{DAY VALUE FROM ASV}} = $7,143,625
  - $\text{SOFT SAVINGS} = $7,013,625
  - $\text{Risk savings with inflation (S)}$
  - $\text{Benefit from automatic shutoff valves yearly risk reduction – inflation adjusted}$
  - $\text{Cost of Automatic Shutoff Valves (ASV)}$
  - $\text{\$130,000.00}$
Who needs to know about the identified risks? Who is responsible for managing these risks? When are the P&MM due?

<table>
<thead>
<tr>
<th>Risk Criteria</th>
<th>Tolerable Risk</th>
<th>Medium Risk</th>
<th>Intolerable Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tolerable</strong></td>
<td>Tolerable</td>
<td>ALARP</td>
<td>Intolerable</td>
</tr>
<tr>
<td>No Further immediate controls are required. Continue with existing mitigation activities to maintain the current risk level. Required authority = Managerial Level (i.e. Manager Pipeline Operations, Manager Pipeline Maintenance, Manager Offshore Operations). Response Timeframe = Not applicable.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure risk is as Low As Reasonably Practicable. Required Authority = Vice President Level (VP Gas Transmission and Distribution, VP technical Services, VP Legal Services). Response Timeframe = Evaluate and/or implement selected risk reduction measures with one month.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task must not be undertaken. It requires immediate action to avoid the hazard or substantially reduce the risk by further controls. Required Authority = Executive Management Team/President/Board of Directors. Response Timeframe = Immediate response required to reduce the risk.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

![Risk Criteria Table]

![Expected Loss per Dynamic Segment]

![ALARP Matrix]
Leveraging Risk Intelligence –
-A Case Study

Risk Management System

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Risk Assessment
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Decision Making Framework
Preventative & Mitigative Measures
Case Study Example
# P&M Analysis

<table>
<thead>
<tr>
<th>Type</th>
<th>Grind &amp; Recoat -- RD6</th>
<th>Recoit -- RD6</th>
<th>Pressure Containing Sleeves</th>
<th>Compression Sleeves</th>
<th>Cut Outs</th>
<th>Relocation</th>
<th>Concrete Slabs</th>
<th>Line Lowering</th>
<th>Leak Detection Upgrade</th>
<th>Increased or Expanded Inspection Frequency - Vehicle Patros</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All field repairs and all field joints.</td>
<td>0.9 0.99 NA</td>
<td>$10,000 / ft</td>
<td>$15,000/Sleeve + $10,000 / ft prep cost</td>
<td>1 0.99 0.75</td>
<td>Cost of material and construction: $2,000 per joint + tie-in cost of $50,000 per tie-in + cost of purge per section: $200,000</td>
<td>1 0.99 0.75</td>
<td>Cost of material and construction: $2,000 per joint + tie-in cost of $50,000 per tie-in + cost of purge per section: $200,000</td>
<td>1 0.99 0.75</td>
<td>$1M per mi + cost of purge per pump station: $150,000</td>
</tr>
<tr>
<td></td>
<td>Pressure Containing Sleeves</td>
<td>All threats not to exceed 1 joint; typical 10 foot length</td>
<td></td>
<td>1 0.99 0.75</td>
<td></td>
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<tr>
<td></td>
<td>Compression Sleeves</td>
<td>SCC, External corrosion and mech damage not to exceed 1 joint; cracks &gt; 40% depth; cracks on LSW; midwall or ID connected cracks</td>
<td></td>
<td>1 0.99 0.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Cut Outs</td>
<td>If accessibility isn’t a concern, 2 consecutive joints is a lower limit for considering cut outs. OR 2 joints separated by &lt; 150ft</td>
<td></td>
<td>1 0.99 0.75</td>
<td></td>
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<tr>
<td></td>
<td>Relocation</td>
<td>Density of repairs/cutouts exceeds 1/10 joints over a length &gt;1mi AND a higher consequence area can be avoided.</td>
<td></td>
<td>1 0.99 0.75</td>
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<tr>
<td></td>
<td>Concrete Slabs</td>
<td>Does not interfere with surface use and mechanical damage barriers are weak. Not suitable for long distances (&gt;100 ft).</td>
<td></td>
<td>NA NA 0.4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Line Lowering</td>
<td>3 joint minimum</td>
<td></td>
<td>NA NA 0.2</td>
<td></td>
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<tr>
<td></td>
<td>Leak Detection Upgrade</td>
<td>Applies to complete line sections between pump stations. Must be coupled with emergency response that can reduce consequences if initiated sooner.</td>
<td></td>
<td>NA NA NA 0.68 0.9</td>
<td></td>
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<tr>
<td></td>
<td>Increased or Expanded Inspection Frequency - Vehicle Patros</td>
<td>Value is to further monitor identified sites</td>
<td></td>
<td>NA NA 0.05</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Mitigation Strategy Number</td>
<td>Mitigation Applied</td>
<td>Total Risk ($/year)</td>
<td>Resulting Risk ($/year)</td>
<td>Risk Unit Reduction</td>
<td>Cost to Implement Reduction</td>
<td>CBA</td>
<td>Results</td>
<td></td>
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<td>-----------------------------</td>
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<tr>
<td>1</td>
<td>Leak Detection on entire pipeline; Grind/Recoat on non-consecutive joints still within the High Risk Area</td>
<td>3.00E+06</td>
<td>1.58E+06</td>
<td>47.3%</td>
<td>$2M</td>
<td>1.41</td>
<td>NO joints remain in High Risk area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Leak Detection on entire pipeline; Additional 2 block valves; Cut Outs on consecutive joints OR &lt;200ft; Grind/Recoat on non-consecutive joints with risk units still in the High or Moderate Risk area</td>
<td>3.00E+06</td>
<td>9.72E+04</td>
<td>96.8%</td>
<td>$74M</td>
<td>25.84</td>
<td>NO joints remain in High, nor Moderate Risk Area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Relocation around central urban area, Leak Detection on entire pipeline; Additional 2 block valves; Increased Patrols in smaller cities; Cut Outs on consecutive joints OR &lt;200ft; Grind/Recoat on non-consecutive joints still in the High or Moderate risk area.</td>
<td>3.00E+06</td>
<td>7.96E+04</td>
<td>97.3%</td>
<td>$79M</td>
<td>27.39</td>
<td>NO joints remain in High, nor Moderate Risk Area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Entire Pipeline Replacement</td>
<td>3.00E+06</td>
<td>6.27E+03</td>
<td>99.8%</td>
<td>$313M</td>
<td>116.91</td>
<td>Maximum Risk Reduction</td>
<td></td>
<td></td>
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</tbody>
</table>
Summary
With the right tools in place...

Optimized resource allocation leading to higher levels of public safety