APPLICATION OF QUANTITATIVE RISK ASSESSMENT

PPIM (30th ANNIVERSARY)

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DYNAMIC RISK
Risk = Probability x Consequences

Why?

Possibly you have been asleep for the past 100 years
Why do airlines continue to demonstrate how to put on a seatbelt?

Possibly because you haven’t been in a car since 1963!

Understand the Stakeholders/Audience

Compliance versus Effectiveness
APPLE is a computer company just like anyone else, but they are more innovative than others.

1. We believe in thinking differently in everything we do
2. Beautifully designed, easy to use
3. We just happen to make great computers. Want to buy one?

APPLE COMPUTER Marketing

1. We make great computers
2. Uniquely designed, easy to use
3. Want to buy one?

Start With WHY!
WHAT-HOW-WHY we do risk assessment, for example

1. We perform risk assessment
2. Use semi-quantitative approach
3. Compliance
Risk Model – **WHAT** We Do

- 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
- **Compliance** is a minimum expectation
Risk Modeling Is A Continuum

HOW We Do It

• 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
WHY We Do
Risk Assessment

• Purpose / Cause:
  • Safe and reliable transportation of hydrocarbons
  • Demonstrates confidence in communicating pipeline performance to Stakeholders
  • Relies upon technical excellence in information analytics
  • Creates knowledge to support decision making
1. Perform a risk assessment of alternatives
2. Quantified risks and identified barriers
3. Requested by State of Michigan

1. Demonstrate the operational reliability of an existing pipeline when compared to various alternatives
2. Fully aggregate all available information and apply demonstrated analytical approaches
3. Provide stakeholders with knowledge to evaluate a complex problem

Case Study
Straits of Makinac
The SOW (Alternatives Analysis Contract with Dynamic Risk – July 2017), the Final Report (Alternatives Analysis for the Straits Pipeline - Final Report - November, 2017) and the agreement between the State and Enbridge (Agreement Between the State of Michigan and Enbridge Energy on Line 5 in Michigan - November, 2017) can be downloaded from the State’s website:
https://mipetroleumpipelines.com/resources-reports
Case Study
Straits of Makinac

- Feasibility analysis
- Design-based cost estimates
- Economic feasibility
- Socio-economic impacts (jobs, income, government revenue, social impacts)
- Spill risk analysis
  - compare risk of infrastructure required to replace existing Straits Segments
  - existing Straits Segments considered as base case for comparison purposes
- Components
  - threat assessment
  - spill probability assessment
  - safe and reliable operating life
  - spill release modeling
  - oil spill behavior and impact modeling
  - NGL release modeling
  - spill consequence analysis (safety, environment, economic impact)
  - market impacts
Case Study
Straits of Makinac

Alternative 1: New Pipeline Route

Alternative 2: Utilize Pre-existing Alternative Pipeline Infrastructure
- Partial capacity exists on short segments – not significantly different from Alt 1

Alternative 3: Alternative Transportation Methods
- Water Transport – Tankers / Barges
  - $4.3 billion investment required in tank farms and fleet of vessels
- Truck Transport
  - 1 truck loaded/unloaded every 40s, 24 hrs./day, 7 days/week
  - Dedicated fleet of 3,200 trucks required
  - Public costs, strain & congestion on highway infrastructure + public risk
- Rail

Alternative 4: Replace Straits Crossing
- New Trenched Crossing
- New Tunnel Crossing

Alternative 5: Maintain Existing Straits Crossing

Alternative 6: Decommission and Abandon Straits Crossing
## Case Study
### Straits of Makinac

<table>
<thead>
<tr>
<th>Principal Threats</th>
<th>Alt 5 Existing Operations (Base Case)</th>
<th>Alt 4a New Trenched Crossing</th>
<th>Alt 4b New Tunnel Crossing</th>
<th>Alt 6 Abandon Line 5 &amp; Crossing</th>
<th>Alt 1 New Pipeline Route</th>
<th>Alt 3 Alt Transport (Rail)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anchor Drag, Incorrect Operations, Spanning, Vortex-Induced Vibration</td>
<td>Anchor Drag, Incorrect Operations</td>
<td>Negligible</td>
<td>N/A</td>
<td>Per Incident Statistics</td>
<td></td>
</tr>
<tr>
<td>Oil Spill Outflow – Rupture (bbl)</td>
<td>2,629</td>
<td>5,859</td>
<td>None</td>
<td>N/A</td>
<td>3,784</td>
<td></td>
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<tr>
<td>Oil Spill Outflow – Puncture (bbl)</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>N/A</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Oil Spill Outflow – Leak (bbl)</td>
<td>North: 2,902; South: 4527</td>
<td>North: 5,820 South: 9,801</td>
<td>None</td>
<td>N/A</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Failure Frequency -Rupture (/y)</td>
<td>3.575x10^-04</td>
<td>2.430x10^-06</td>
<td>Negligible</td>
<td>N/A</td>
<td>1.84x10^-02</td>
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</tr>
<tr>
<td>Failure Frequency – Puncture (/y)</td>
<td>N/A</td>
<td>N/A</td>
<td>Negligible</td>
<td>N/A</td>
<td>1.67x10^-03</td>
<td></td>
</tr>
<tr>
<td>Safety Risk (fatalities/y)</td>
<td>2.69x10^-06</td>
<td>1.68x10^-07</td>
<td>Negligible</td>
<td>0.00</td>
<td>3.66x10^-01</td>
<td></td>
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<tr>
<td>Total Economic Risk ($/y)</td>
<td>41,500[^a]</td>
<td>8,870[^a]</td>
<td>Negligible</td>
<td>0.00</td>
<td>1,920,000[^a]</td>
<td></td>
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<tr>
<td>Monetized Environmental Risk ($/y)</td>
<td>24,900[^a]</td>
<td>5,320[^a]</td>
<td>Negligible</td>
<td>0.00</td>
<td>841,000[^a]</td>
<td></td>
</tr>
</tbody>
</table>

[^a] results may reflect rounding

Notes:

- Median Spill 462 bbl
<table>
<thead>
<tr>
<th>Alternative</th>
<th>Safety Risk</th>
<th>Monetized Environmental Risk</th>
<th>Total Economic Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 3 (Rail Transport)</td>
<td>830,000 X Base</td>
<td>734 X Base</td>
<td>1,196 X Base</td>
</tr>
<tr>
<td>Alternative 1 (New Pipeline)</td>
<td>136,000 X Base</td>
<td>34 X Base</td>
<td>46 X Base</td>
</tr>
<tr>
<td>Alternative 4a (New Trenched Straits Crossing)</td>
<td>0.062 X Base</td>
<td>0.214 X Base</td>
<td>0.214 X Base</td>
</tr>
<tr>
<td>Alternative 4b (New Tunnel Crossing of the Straits)</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
</tr>
<tr>
<td>Alternative 6 (Abandonment of Line 5 and Straits Crossing)</td>
<td>Zero</td>
<td>Zero</td>
<td>Zero</td>
</tr>
</tbody>
</table>
Risk Management Journey

- **Direct Cause(s)**
  - corrosion, incorrect operations, etc.

- **Root Cause(s)**
  - people, plant, process

- **Contributing Factor(s)**
  - procedures, training, etc.
Risk Threshold

- **Total Risk Mitigation Efforts**
  - ACCEPTABLE
  - BENEFITS (Risk Reduction) for Certain Actions
  - COST (Risk) for Certain Actions

![Graph showing the relationship between Total Risk and Mitigation Efforts](image)

- **Acceptable Risk Threshold**
- **Green Line** represents BENEFITS (Risk Reduction) for Certain Actions
- **Red Line** represents COST (Risk) for Certain Actions

**Axes:**
- Y-axis: Total Risk
- X-axis: Mitigation Efforts
Full Risk Spectrum

• What is often missing?
• Are all risk attributes considered across the entire risk spectrum of integrity management?
Stakeholders, and Risk Communication
Quantitative Risk Considerations

Managing System Integrity of Gas Pipelines

Failure Likelihood Score

- External Corrosion (21%)
- Internal Corrosion (6%)
- Third Party Damage (28%)
- Manufacturing Defects (6%)
- Construction Related (4%)
- SCC (3%)
- Incorrect Operations (20%)
- Outside Force (4%)
- Equipment (18%)

Sample ILI Unity Chart for Tool Error

Depth Error Density Distribution Normal Distribution Approximation

Not all inspected pipelines are equal...

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

2. Use semi-quantitative approach

3. Compliance

1. We have an inherent responsibility for the safe and reliable transportation of hydrocarbons

2. We apply a fact-based and method driven approach to evaluate threats and consequences

3. We evaluate and communicate a risk perspective to all stakeholders

Start With WHY!

PIPELINE INDUSTRY
Risk Management

Dynamic Risk
• **WHY** we do risk assessment has changed significantly over the past few years

• **WHAT** we are achieving through risk management is continuing to evolve

• **HOW** we perform risk assessment has considered new data and advanced reliability methods

• There is no correlation between pipeline reliability and the type of risk model

• Each person inherently has a different acceptable risk tolerance
• Stakeholders have a growing interest with pipeline risk and safety

• Pipelines are often a focus for those promoting renewable energy
  – Hydrocarbon use is driven by policy and demand
  – Pipeline operators want to transport from Point A to Point B with limited risk

• Risk-informed decision making is an expectation

• **Nothing is free,** mitigation options often have risk

• Performing risk assessment should be driven by **WHY!**