TransCanada’s Risk Management System for Pipeline Integrity Management

Warren Peterson
Louis Fenyvesi

CORS
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The PRIME project was started in 1998 to develop a Risk Management process for Pipeline Integrity and the infrastructure necessary to support it.

Through the PRIME project, the following items and processes were developed/acquired:

- Facilities and integrity data model.
- System wide facility data.
- A GIS system.
- PRIME Process: The Risk Management and Decision Analysis process used to develop TransCanada's Integrity Programs.
- PRIME Risk Models: The Hazard, Consequence, Risk Assessment and Decision Analysis Models used to execute the PRIME Process.
The PRIME Process is a risk-based decision making process used to develop and evaluate the majority of maintenance programs:

- MFL In-Line Inspections
- Hydrostatic Tests
- Condition Monitoring Investigations & Repairs
- Discrete Pipe Replacement/Recoating.
Risk-Based Program Development

PRIME Process Flow Diagram

- **Data Management**
- **Analyze Risks**
  1. Hazard Identification
  2a. Consequence Analysis
  2b. Hazard Frequency Analysis
  3. Risk Analysis
- **Audit Results**
- **Stakeholder Participation**
- **Evaluate Risk Acceptability**
  - Not Enough Information
  - Unacceptable
  - Acceptable
- **Condition Monitoring**
- **Risk Control**
- **Pipeline Surveillance**
PRIME contains a framework for evaluating risk acceptability that provides:

- Common Goals
- Common Measures
- Common Decision Criteria

…to facilitate decision making
Pipeline Maintenance Goals

A Risk Management methodology should flow from the goals of a company’s pipeline maintenance program.

Decision Criteria should reflect and be directly traceable to the company’s goals.
Pipeline Maintenance Goals

TransCanada’s Pipeline Maintenance Goals include:

1. Provide an adequate level of safety to the public and employees.

2. Maintain lowest long-term operating and capital costs, except where there is conflict with the above goal.

...among others
Measures of Safety

Goal: 1. Safety of Public and Employees

Measure: Individual Risk

Individual risk is a measure of the total risk faced by a risk receptor from all potential risk sources measured as an annual risk of fatality.
Measures of Safety - Individual Risk

Individual Risk can be calculated both for known population and generically.

- Specific population data can quickly become ‘out-of-date’.

- Generic or ‘inherent’ individual risk can be used to establish and maintain a ‘baseline’ level of safety for a pipeline.
Measures of Safety -
Inherent Individual Risk

‘Inherent’ individual risk assumes constant occupation by a single individual on top of the right-of-way.

Main variable is failure frequency.

Each meter of ROW is evaluated independently.

Individual Risk is calculated for each meter (Risk Source) of P/L relative to a specific point on the ROW (Risk Receptor).
The sum of the risk from each meter of pipe highlighted gives the Individual Risk for the point on the ROW below.

Pipe beyond these points do not have an effect on the point under evaluation.

Point on ROW under analysis

\[ Individual\ Risk = \int_{-X}^{+X} F_x \times (P_{\text{Ignition}} \times P_{\text{Fatality}}(R, R')) dx \]
Goal: 1. **Safety of Public and Employees**

Measure: **Individual Risk**

Decision Criteria: **MIACC Land Use Guidelines**

MIACC (Major Industrial Accidents Council of Canada) published risk-based land use guideline in the early 1990’s.

Land uses types have been interpreted in the context of pipeline class location definitions.
Risks exceeding the risk acceptance threshold for the pipeline’s corresponding class must be reduced to a level below that threshold.
Safety Decision Criteria

Goal: 1. **Provide an adequate level of safety to the public and employees.**

Measure: **Individual Risk** measure of the annual risk of fatality. **Inherent risk and risk to known receptors.**

Decision Criteria: **MIACC Land Use Guidelines** define ‘an adequate level of safety’.
Goal: 2. *Lowest long-term operating and capital costs*

Measure: *‘Value Ratio’ VR*

Key to achieving low long-term costs is considering both the cost of pipeline incidences and the cost to mitigate risk.

VR generated on a project by project basis.

VR = Risk Reduced ($) / Cost of Project ($)
A pipeline failure can generate a variety of consequences.

- Consequences are measured as:
  - A short-term direct financial loss.
  - A longer term indirect financial loss.
  - Losses to the company or society that are not financial in nature.

- In order to produce the VR measure, non-financial losses need to be mapped to an equivalent dollar loss.
Financial Measures - Calculating ‘Risk Reduced’

Major consequence categories are:

- Direct Financial Impact
  - Cost of repair.
  - Purchase of linepack.
- Indirect Financial Impact
  - Fines
  - Proving the integrity or ‘fitness for service’ of the affected pipeline.
  - Longer term impact to the company’s image or ability to do business.
    - Community or regulatory relationship.
Financial Measures - Calculating ‘Risk Reduced’

Major consequence categories are:

- Customer Impact
  - Financial loss incurred by the customer
    - Through-put restriction
    - Impact to Firm Service contracts
- Third-Party Impact
  - Property Damage
  - Court Settlements
- Environmental Impact
  - Fines and Penalties
  - Site Restoration Costs
Financial Measures - Calculating ‘Risk Reduced’

The total consequence of a pipeline failure is the sum of the consequences calculated under the previous five categories.

The total failure frequency of a pipeline is the sum of the annual per meter failure frequencies contributed by each applicable hazard.

Risk = Total Consequence X Total Failure Frequency

Units of $/m*yr.
The risk reduction benefit of a pipeline maintenance project requires risk to be calculated for both the ‘as is’ or base case and the ‘after maintenance’ or remaining risk case.

\[
\text{RiskReduced} = \sum_{i=1}^{m} \left( \sum_{t=1}^{n} (R_{i,t}(\text{Base}) - R_{i,t}(\text{Remaining})) \right)
\]

\(m\) is the affected length of pipe.
\(n\) is the number of years over which the project will have a measurable benefit.
Financial Decision Criteria

Goal: 2. *Maintain lowest long-term operating and capital costs, except where there is conflict with the first two goals.*

Measure: **VR**

Decision Criteria: **VR’s greater than one represent projects whose cost is justified based on an expectation of future aversion of loss.**
Example

Evaluating a 35km NPS 36 Class I pipe.

Analysis Steps:

• Individual Risk is calculated and evaluated against acceptance criteria.

• Projects are identified that mitigate safety risk to an acceptable level.

• Project with most beneficial VR implemented.
These areas exceed safety criteria and require mitigation.
Example - Alternative Analysis

The following four options were identified as being able to reduce the safety risk to an acceptable level.

<table>
<thead>
<tr>
<th>Pipeline Maintenance Options</th>
<th>Cost</th>
<th>Risk Reduction</th>
<th>IPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrostatic Test</td>
<td>$900,000</td>
<td>$5,300,000</td>
<td>5.89</td>
</tr>
<tr>
<td>Traps + In-Line Inspection + Digs</td>
<td>$2,000,000</td>
<td>$2,300,000</td>
<td>1.15</td>
</tr>
<tr>
<td>Pipe Recoating (~5 km)</td>
<td>$5,100,000</td>
<td>$2,200,000</td>
<td>0.43</td>
</tr>
<tr>
<td>Pipe Replacement (~5 km)</td>
<td>$8,700,000</td>
<td>$2,500,000</td>
<td>0.29</td>
</tr>
</tbody>
</table>

The VR analysis identifies hydrostatic testing as providing the greatest risk reduction value.
Risk Based Decision Framework

This framework for quantitative risk-based decision making provides:

• Consistent decision making

• Clear relationship between company goals, risk measures, and decision criteria

• Prioritizes safety

• Facilitates alternative analysis
Risk Analysis - Hazard Identification

Focused on hazards that are a relevant to the TransCanada system, including:

- Corrosion
- Mechanical Damage
- Stress Corrosion Cracking
- Geotechnical - Slope Movement
Corrosion Management

The primary method for addressing the hazard of external corrosion is through MFL In-Line Inspection and Defect Management

- Majority of the system can be inspected

- ILI provides the most accurate information on External Corrosion of any available technique

- MFL data is still an indirect measurement
Standard Industry Practice

Standard industry practice is to excavate MFL defects based on deterministic depth and failure pressure criteria. TransCanada’s are:

- Depth > 70%
- Failure Pressure < 1.25(MOP)

Deterministic criteria implicitly accounts for uncertainty by increasing conservatism

Goal is to restore original design factor and prevent pipeline incidents
Probabilistic Criteria

Area = Failure Probability

Defect Length (mm) vs. Defect Depth (mm)

MOP
1.25 x MOP
Calculating Defect Failure Probability

Defect Risk Management Process:

- Probabilistically quantify:
  - depth error
  - length error
  - growth rate
    - As applicable
- Identify failure probability through simulation

\[
p(Rupture) = \frac{\sum_{i=1}^{N} I\{P(L_i, AD_i(L,W)) - P_{Err}(L,W) > M)\}}{N}
\]

- Simulation Size Depends on Desired Accuracy

- Assess defect acceptability (Risk Management Process)
MFL Data – Depth Uncertainty

Depth Accuracy: +/- 10% 80% of the time

• Equivalent to a normal distribution with:
  • Mean: 0%
  • Standard Deviation: 7.8%

• More complex corrosion:
  • Standard Deviation: 11%

• As more data is collected for a particular line, these statistics are updated
MFL Data – Peak Depth Accuracy

- MFL Reported Peak Depth vs. LPIT Measured Peak Depth
- Forecast: Fitted Depth Error Distribution

Frequency distribution chart showing the error distribution of MFL reported peak depth compared to LPIT measured peak depth.
MFL Data – Length Uncertainty

Length Accuracy: +/- 20mm 80% of the time

- Equivalent to:
  - Mean: 0 mm
  - Standard Deviation: 15.6 mm

- Also affected by complexity of the corrosion

- Clusters consisting of several boxes:
  - Standard Deviation: 22 mm
Signal Comparison

Estimating corrosion growth critical to determining when currently sub-critical defects will require repair

Corrosion growth rates estimated through a comparison of MFL signal data
Segmenting Pipeline by Measured Growth
Regression Tree Analysis

Root Node

Y Mean Value: 1.15
Standard Dev: 0.403
Cases: 200

Splitter 1
X1 <= 0.5

YES

Y Mean Value: 1.21
Standard Dev: 0.397
Cases: 190

NO

Terminal Node

Y Mean Value: 0.99
Standard Dev: 0.120
Cases: 10

...
Risk Acceptance – Individual Risk Criteria

**Escape Distance:** Pipe beyond these points do not have an effect on the point under evaluation.

**Point on ROW under analysis – Assumed constant occupation**

\[
\text{IndividualRisk} = \int_{-X}^{+X} P_x \times (P_{\text{Ignition}} \times P_{\text{Fatality}}(R, R')) \, dx
\]
Correlation Results – Risk Based Digs

MFL Safety Factor (Relative to MAOP)

LPIT Safety Factor (Relative to MAOP)
Risk Based Digs - Results

Increased Dig Program
- 27 Defects Deterministic -> 73 Defects Risk Based

Significant Defects Found and Repaired
- 18 Defects Deterministic -> 37 Defects Risk Based

Worst Defect Identified Through Risk Process
Improving Rupture Frequency Trend

Year

Frequency per km*yr


TransCanada
In business to deliver™
Pipe Maintenance Program Spending Trend
Conclusions

The PRIME process resulted in both:

• Significant cost savings relative to the industry standard approach

• Improving reliability and reduced risk exposure relative to the industry standard approach.

Provides a rationale for determining maintenance spending levels and allocating those resources

Provides a mechanism for continuous improvement through the incorporation of new quantitative information.
Second Generation Pipeline Risk Management Why Upgrade?

- Operating Experience
- Scope
- Regulatory Change
- Scientific Advancement
- Data Availability
- Computing Power
- Obsolescence and Support
Operating Experience

Decision criteria dominated by two types of consequence

High dependence on data
- Physical and spatial attributes
- Maintenance data
- Third-party data sources (ILI, LPIT, Imagery, etc.)
- Industry statistics

Platform dependence is an issue (OS, desktop, network, related apps)

Ongoing technical support burdens

Limited ability to revise and enhance
Scope

System growth, primarily through acquisitions
Support required for several pipelines in U.S.
Need for liquids pipeline support
Acquisition of off-shore facilities
Greater number of users; differing areas of expertise
Regulatory Change

Changes to Canadian regulations
Introduction and Changes to U.S. regulations
Changes to Industry standards (CSA Z662 and ASME B31)
Scientific Advancement

Improvements to existing engineering models
New engineering models
Capitalizing on previous R&D effort
Data Availability

Electronic access to 3rd party information
Migration of old data
Industry adoption of standardized data structures (ISAT, PODS, etc.)
Computing Power

Order of magnitude increase in desktop computing power
Order of magnitude increase in server/network throughput
Fewer compromises required
Better tools for development, deployment and support
Obsolescence and Support

Tools (PERL SDK, Tk, ODBC)
Platform (PERL runtime, Windows XP, IE, Office 2003, Oracle)
Stand-alone versus I.S. support
Thank you