Engineering: Past, Present and Future

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CN Network

Network Track Miles

<table>
<thead>
<tr>
<th>Category</th>
<th>Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainline Core</td>
<td>8,617</td>
</tr>
<tr>
<td>Non-core</td>
<td>12,602</td>
</tr>
<tr>
<td>Non-Mainline</td>
<td>8,178</td>
</tr>
<tr>
<td>Total</td>
<td>29,397</td>
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Infrastructure Capital Spending

<table>
<thead>
<tr>
<th>Year</th>
<th>Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>C$1.6B</td>
</tr>
<tr>
<td>2017 Estimated</td>
<td>C$1.6B</td>
</tr>
</tbody>
</table>
CN Engineering Safety Performance

- Engineering accidents down 65% and tonnage up 25% since 2006
My Family History

• 4th Generation Railroader

• John H. Ferryman
  • Depot Agent, GNR
  • Wenatchee, WA

• William “Henri” Ferryman
  • Superintendent Engineering, GNR
  • Seattle, WA

• William H. Ferryman Jr.
  • Chief Engineer, Denver Region, BN
  • Denver, CO
Railway Maintenance Planning
Innovation

Past process

• Requests received from field employees based on their visual inspections

• Management reviewed submissions and relied heavily on subjective field input

Current process

• Use multiple technologies collecting automated data sets

• Generate capital programs from objective data collection and risk-based scores

Future process

• Autonomous inspections

• Cognitive data streams

\[ NPV = \sum_{t=0}^{n} \frac{R_t}{(1+k)^t} - C_0 \]
Rail Maintenance & Replacement

Improvements

Rail Maintenance

• Created a centralized team accountable for rail grinding, rail lubrication and establishing proper curve superelevations

• Objective – optimize rail maintenance to extend rail life

Rail Replacement

• Developed a tangent rail replacement model

• The model identifies areas to relay based on a risk matrix

• Curve relay locations are based on review of historical wear rates
Risk Modeling of Tangent Rail Programs

Theoretical Rail Life Review

- CN replaced a significant amount of tangent rail in the late 1970’s/early 1980’s
- Currently relaying portions of that rail to match the theoretical life
- As we install higher strength steel, the theoretical life will increase
- Created a tangent rail replacement model that identifies areas of higher risk using objective metrics
- The risk matrix focuses on several individual items to prioritize locations for replacement
Interdepartmental Collaboration

Engineering and Mechanical

• Analyzed high impact wheels (HIW) and ISRF data to better understand the correlation

• Data review led to a standard for track inspections on dark territories for specific HIW

Engineering, Mechanical and Transportation

• Operations investigation team that collaborates to find solutions to problems

• Use data and modeling to provide an objective view for challenging situations

• Objective – develop proactive strategies to reduce the potential risk of specific operations
The Future of Engineering Technology

More automated data collection

• Autonomous geometry systems
• Non-stop rail flaw testing
• VTI units
• Tie condition assessment
• Ground Penetrating Radar (GPR)
• Monitoring change run-over-run

Better utilize the information to prioritize work

• Review data trends to develop capital and maintenance programs
• Use data to improve and optimize capital and workforce planning models
• Develop comparable and objective track health scores
Asset Management based on Life Cycles

**Current Strengths**

- Understanding trends for visual, RFD and Geometry exceptions
- Adjusting test frequencies and capital strategies based on trend lines
- Mapping track inventory using GIS

**Opportunities**

- Improve tools and reports to make it easier for field employees to access and consume relevant data
- Use multi-variable analysis to better understand track health
- Move toward a predictive/prescriptive maintenance model
- Enhance data governance and quality
Engineering Reliability Analytics (ERA)

- Inspection, Condition and Repair Oversight
- GIS Enabled
- Asset Health Scores
- Capital Planning Tools
ERA – Operational Module

Territory Overview and Oversight

- Quick access to territory overview
- Review inspection status
- Monitor track conditions
- Audit repairs while in the field
- Download reports and data to plan activities
- Visualize track health scores by track segment
ERA – Planning Module

Capital Planning Tools

• Reports that provide objective and comparable data
• Rail, tie and surfacing models that assist with capital planning
• Life-cycle asset management
• Foundation for predictive analytics
Workforce Planning Model

Guideline for Comparing Territories

- Point system for managing proper resource allocation
  - Tonnage
  - Amount of track by class
  - Features
  - Headcount

- Conditions
- Projected Traffic
Moving Toward the Future

- Developing actionable predictive models
- Establishing a scalable enterprise solution for “big data”
- Making track data easy to access and easy to understand
- Getting the data to speak to users
- Using information to lead our decision making
- One day, have the data make proper decisions on its own
Thank You