Engineering: Past, Present and Future

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CN Network

Network Track Miles

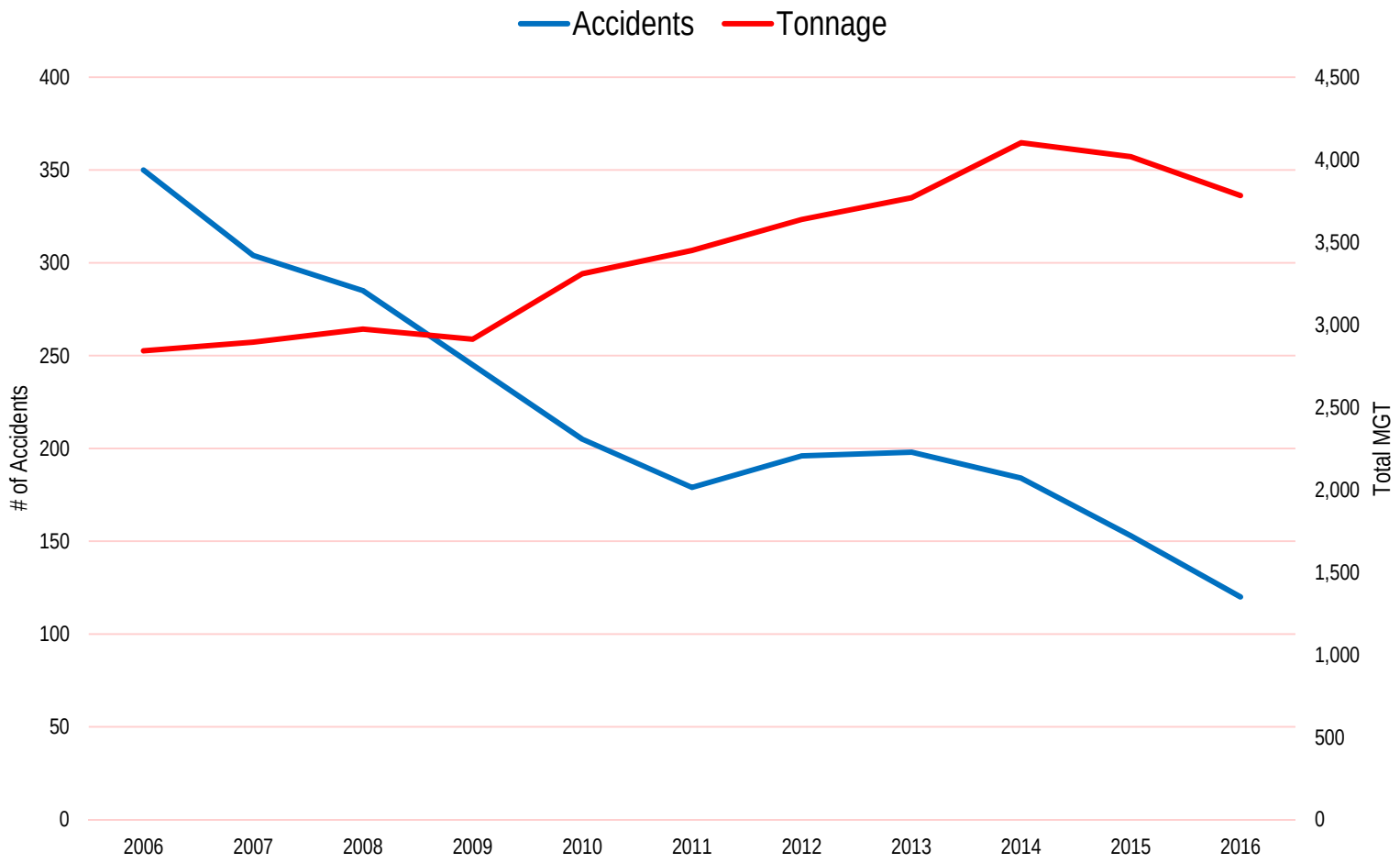
Mainline	Core	8,617
	Non-core	12,602
Non-Mainline		8,178
	Total	29,397

Infrastructure Capital Spending

2016	C$1.6B
2017 Estimated	C$1.6B

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

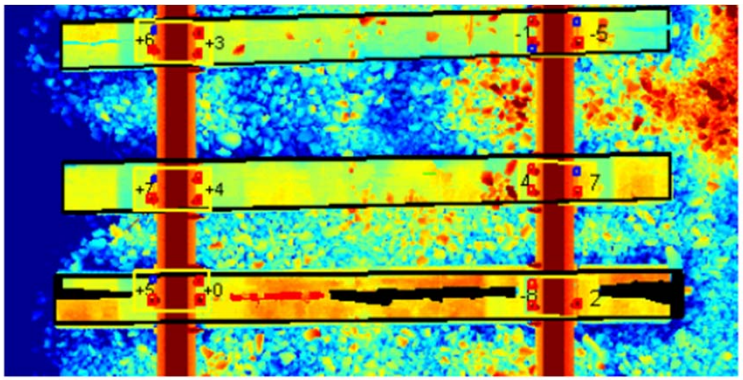
Railway Maintenance Planning Innovation

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

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+k)^t} - C_0$$

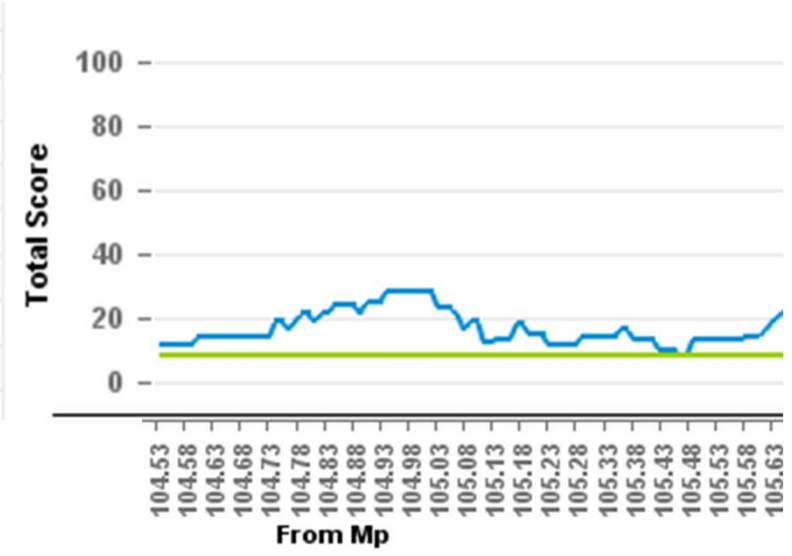
Rail Maintenance & Replacement Improvements

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

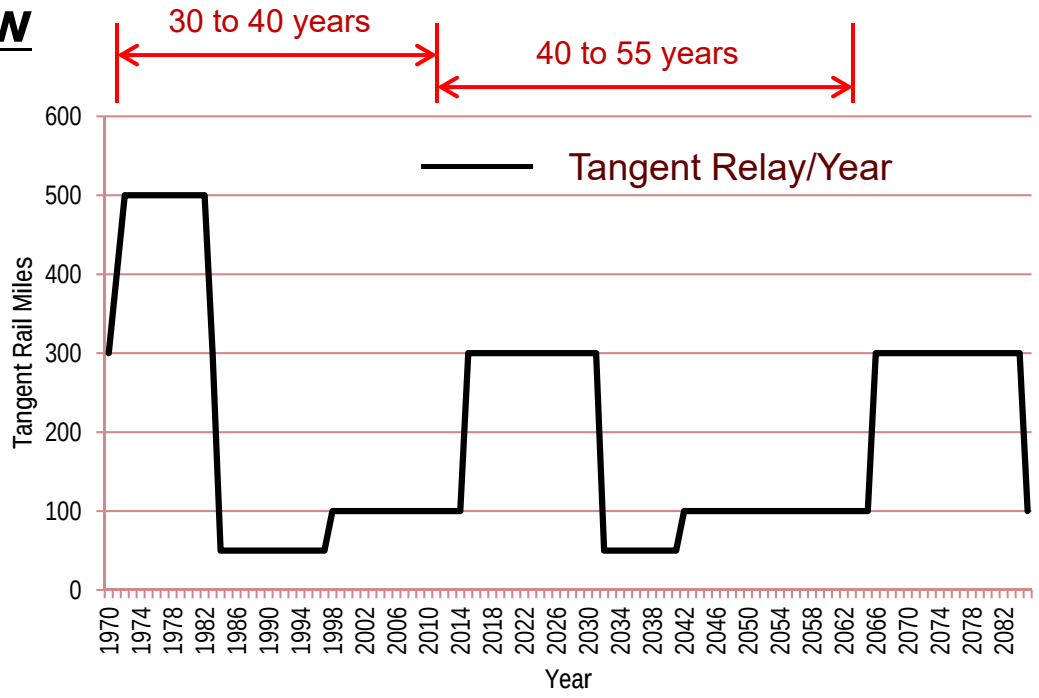
Rail Replacement

- 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

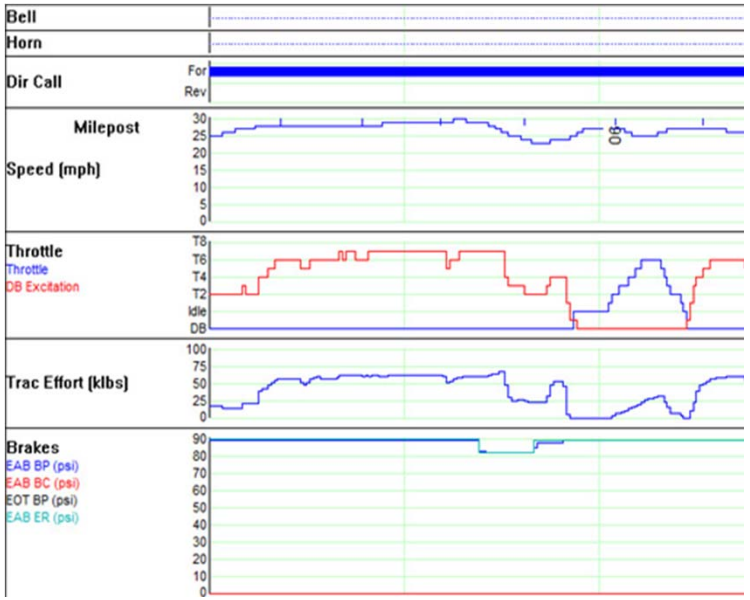
Interdepartmental Collaboration

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

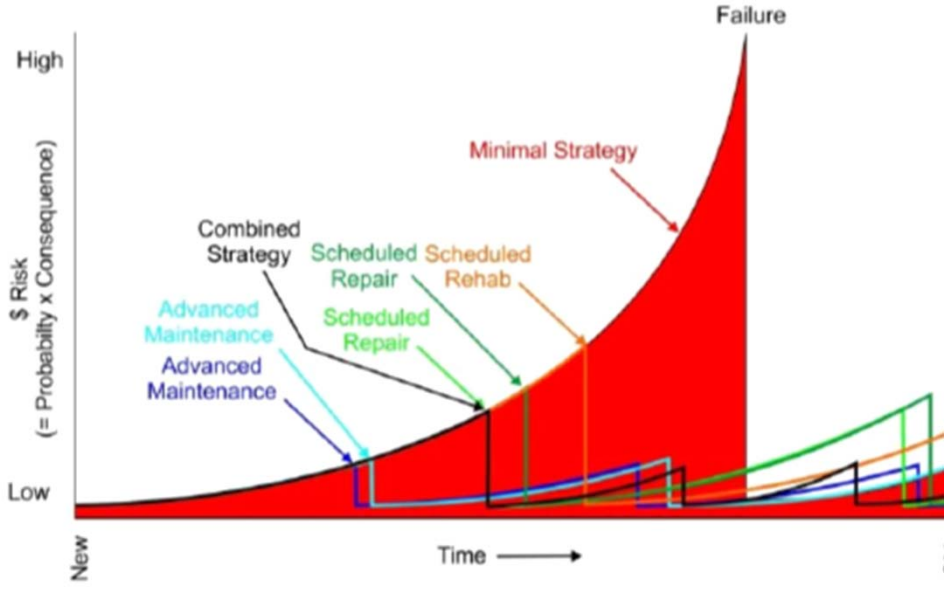
Better utilize the information to prioritize work

- 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

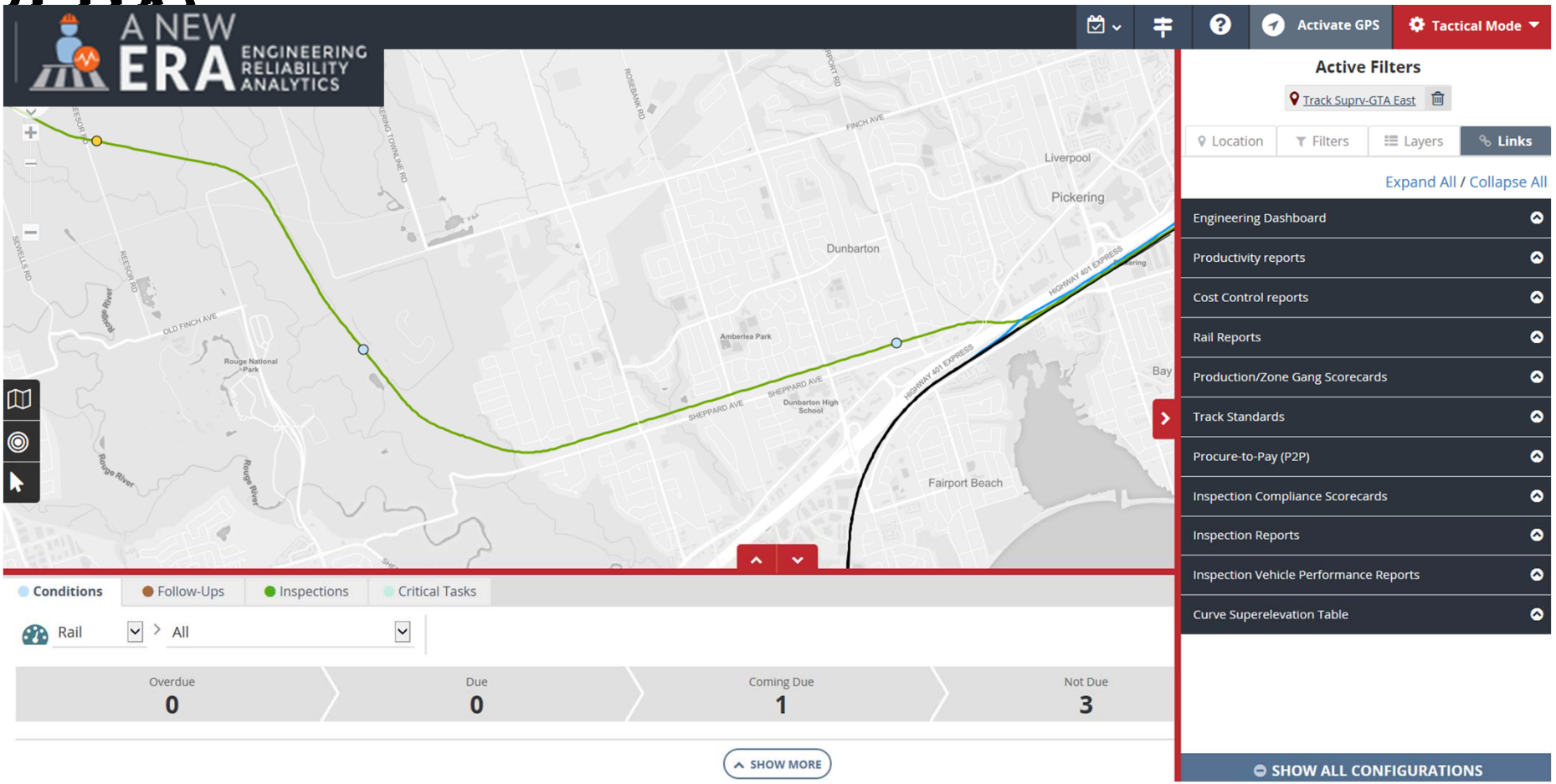
- Understanding trends for visual, RFD and Geometry exceptions
- Adjusting test frequencies and capital strategies based on trend lines
- Mapping track inventory using GIS



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

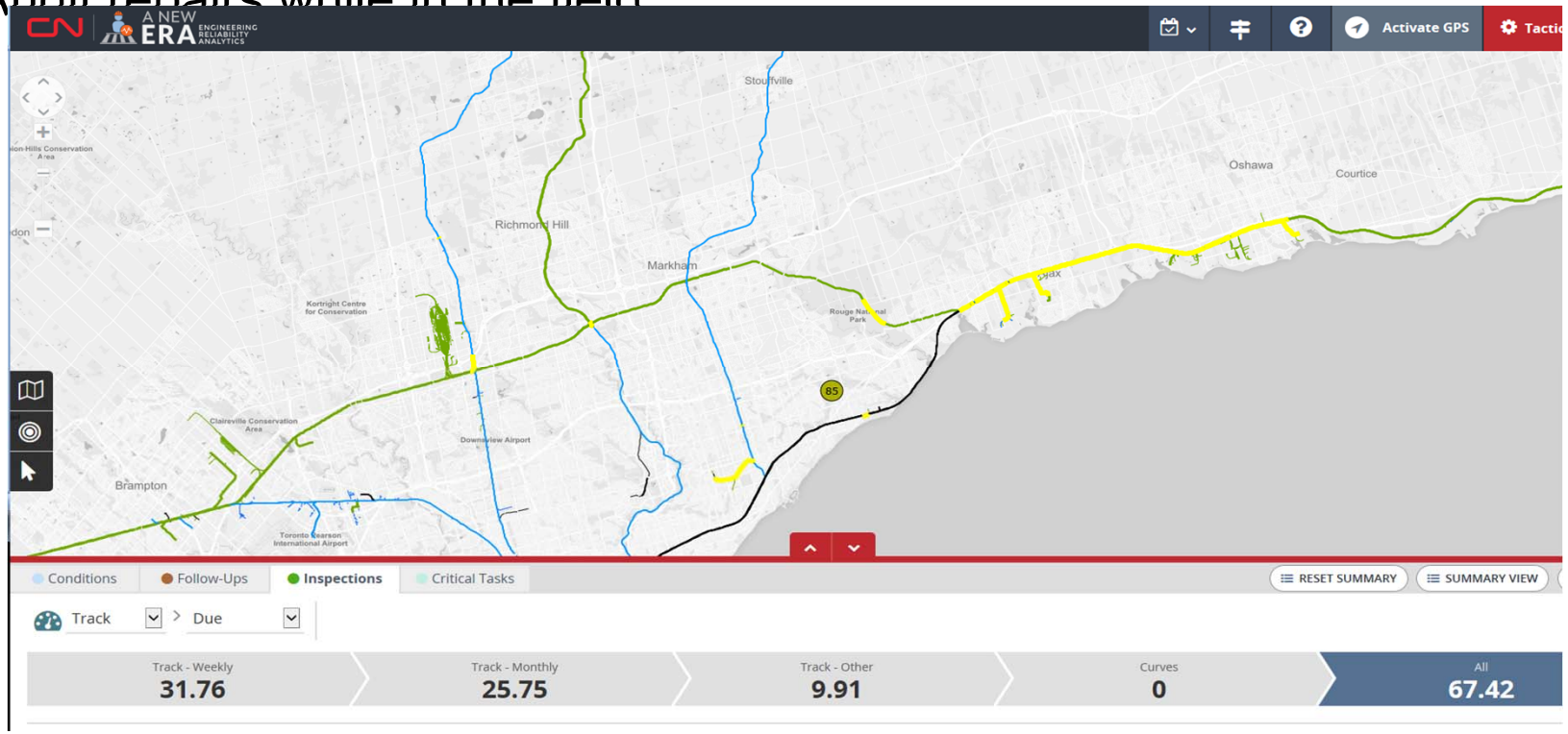
Asset Health Scores

Capital Planning Tools

ERA – Operational Module

Territory Overview and Oversight

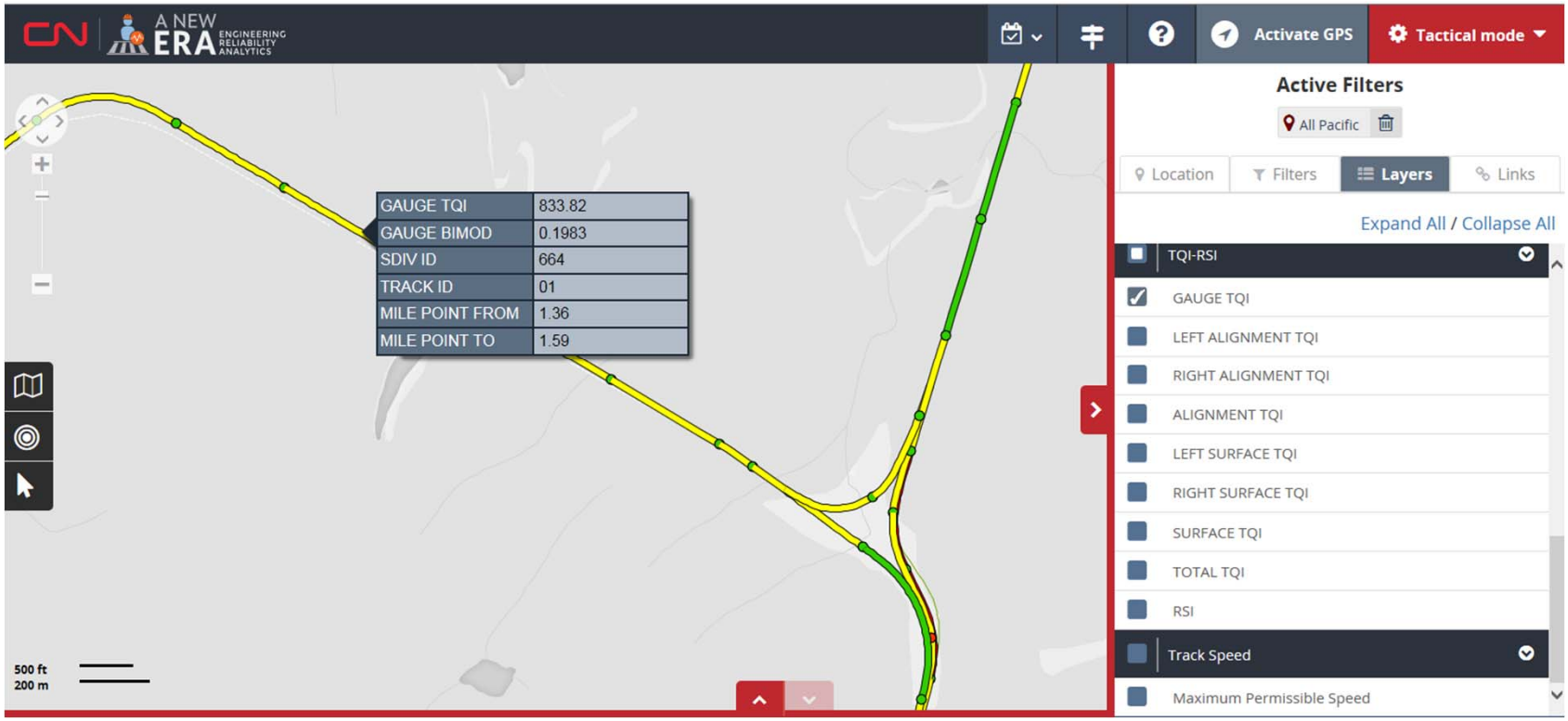
- Quick access to territory overview
- Review inspection status
- Monitor track conditions
- Audit repairs while in the field
- Download reports and data to plan activities
- Visualize track health scores by track segment



ERA – Planning Module

Capital Planning Tools

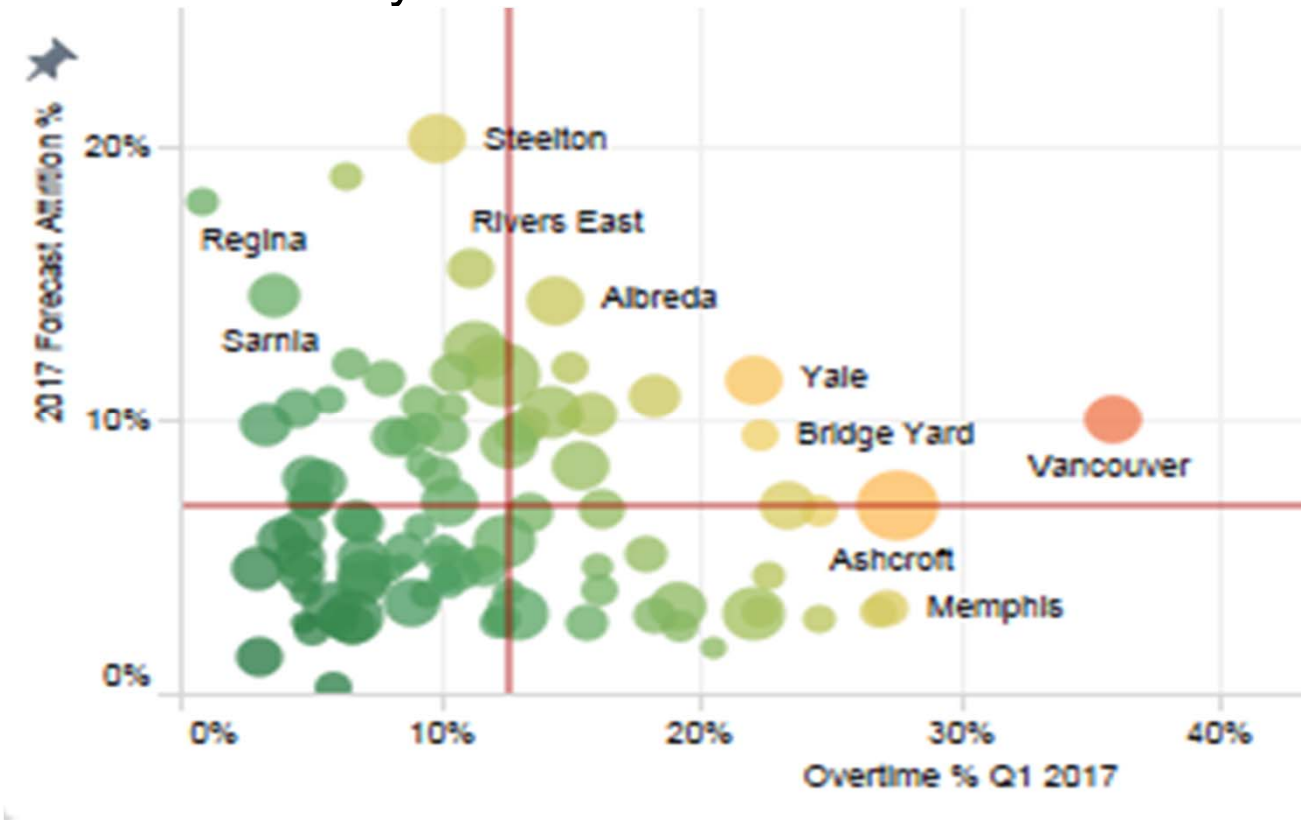
- Reports that provide objective and comparable data
- Rail, tie and surfacing models that assist with capital planning
- Life-cycle asset management
- Foundation for predictive analytics



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
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Thank You