CN Safety Technology: Overview of cutting-edge technologies and efforts to make freight and passenger rail safer

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Outline of presentation

Introduction to geo-hazard risk management at CN

Hazards and technology to mitigate:

1. Slide detection
2. Change detection
3. Track substructure evaluation

UAV program

Bridge Monitoring/Inspection
Geo hazards at CN

Western Region
Mountains
- Rock fall
- Debris
- Earth Slides

Eastern Region
Sensitive clays
Harsh winter
Beavers

Southern Region
Level terrain
Hurricanes
Floods
Scours
Causes of derailments
A Special Study of Main Track Derailments –
by Transport Canada

- Rail breaks
- Other
- Track geometry
- Wheels
- Geo hazards

15% due to geo hazards

Scope of problem

- Natural hazards: significant (although not predominant) cause of accident & service disruption
- Natural hazards are less frequent than most Engineering incidents ~15%
- But each incident has a potentially higher impact
- Triggered by weather events

Sticking with the Risk Management Plan and applying yearly resources for proactive mitigation is good business.
Subgrade issues

Not recorded as a direct cause of problems but is a major contributing factor in many cases

Geo-hazard events distribution

- Rock Hazards: 22%
- Earth Slides: 24%
- Hydraulic Erosion: 21%
- Debris Slides: 10%
- Frost: 12%
- Avalanches: 1%

Mud spots
Example of **rock fall hazards**

White Canyon – Mile 109, Ashcroft Sub

We’ve reduced disruptions with rock cut risk rating system & stabilization detection fences
Example of rock fall hazards

White Canyon – Mile 109, Ashcroft Sub
Jackass Mountain, BC, Canada

Risk Mitigation in place: Trip Wire Fence and rock sheds
Example of rock fall hazards

White Canyon – Mile 109, Ashcroft Sub
Jackass Mountain, BC, Canada

Natural hazards are unpredictable and can always surprise us.
Preventing rock fall hazards

Micro Seismic Detection to Replace Trip Wire Fence:

1. Remote reset – No repairs needed
2. Fewer false alarms – low impacts
3. Safer for S&C (no need to repair wires in dangerous slope area)
4. Uses fiber optic already in ground
Distributed Acoustic Sensing

- Detection of rockfalls using existing buried fiber optic cables as sensors along the track
- 15 mile trial section in mountains 3 hours east of Vancouver, Canada
- Measures acoustic energy (noise and vibration) in the surroundings of the fiber
- Beam of light sent down fiber will react, system can pinpoint location of disturbance, thereby permitting possible warning to oncoming train
- Currently too many ‘false alarms’ working on trying to reduce them
Preventing rock fall hazards

Need to be proactive in systematic risk management

Ashcroft Mile 109 triggered the acceleration of change detection
Change Detection
Change detection

Need to incorporate implementation of new technologies to keep improving safety vs natural hazards.
Change detection

Assist in monitoring what we can’t see from the track

Potential dangers from uphill beaver dam failures and washouts
Precursors of large slope failure (rock)

Technology:
1. Interferometric Analysis
2. Lidar - Photogrametry
3. Satellite imageries
4. Developing algorithm and intelligence behind it
Change detection

2006/05/14

7 meters High

Old dam about to fail
Change detection

Impact of beaver dam failure

Consequences at track level; Washout
Change detection
B.A.H.A. GIS mapping & rating process

1- Watershed/track system permanent vulnerability rating. (Sev = 5)

2- Beaver dam Severity assessment (for each dam)

3- Over All BAHARating (390)

Air photos of Hazard areas and Dams (each with GPS)

GPS of each dam

Erosion

Rock

Uphill slide

Culvert Location (GPS + linked to info.)

Culvert 163.24 Size=1.5 Depth=4.7

Culvert 163.11 Size=1.5 Depth=8.7

WaterShed Mi.162.55 - SEV=5 - (Overall BAHARating = 390)
Change detection

Global Risk = 325

Dam #1 = 5

Dam #2 = 5

Point of impact on track: Vulnerable
Change detection

Serious threats from uphill mountain dams

Space Beavers Project
Space Beavers Project

Proposed Automatic monitoring of uphill threats from Dams using fused satellite remote sensing can detect:

• New dangerous beaver ponds
• Size and extent of lake
• Can even monitor difference in water level

-Would improve frequency level
-Less risky
-Could have automatic warnings
Change detection

**Space Beaver Project**
Automatic Monitoring of Beaver ponds using fused satellite remote sensing
Space Beaver Project
Automatic Monitoring of Beaver ponds using fused satellite remote sensing

Change detection

Old road?

Dam seems open at this time

previously flooded area
Slope Change Detection Project

Fountain Slide

Lidar Scan example
Fountain Slide; Lillooet mi. 167

Tunnel Earth Flow

Fountain Slide
Change detection

Lidar Scan example
Fountain Slide; Lillooet mi. 167

Figure 1: Airborne LiDAR data coverage area (data from June 2009)
Interferometric Movement Analysis
Lidar Scan; Fountain Slide
Interferometric Movement Analysis
Lidar Scan; Fountain Slide

2010 vs 2006
Interferometric Movement Analysis
Lidar Scan; Fountain Slide

2011 vs 2006
Interferometric Movement Analysis
Lidar Scan; Fountain Slide
data video generated from photos captured from a helicopter with the door removed, the point cloud was generated using the structure-from-motion photogrammetric technique. (Trevor Evans & Mat July, 2015)
High upper slope monitoring

- Interferometric LiDAR
- Ground Born and Air Born
- Photogrammetry
- Drones
High upper slope monitoring
Update: Change detection using Aiborne LiDAR

Results confirm high level of precision on detecting movement on natural rock face, even below tree cover.

Was able to detect growing threat to the track by “viewing” changes above the track which can not be see by rail.
**Proof of Concept to use interferometric Lidar & Photogrammetry to monitor High Slopes → OK**

**Proposal**
Get Air Born Lidar Survey of the whole BC South
- Preliminary air photo evaluation for initial screening of areas of concerns
- Base line lidar over risk areas (1 to 2 km wide).
- Obtain future lidar on regular intervals to compare with base line.
- Continue to develop analytical tools
Track substructure evaluation
Track **substructure** evaluation

Heavy freight + peat

= Stress on rails
Most of the time the old “observational” method worked just fine
Track substructure evaluation

1. Ballast management & quantified assessment (GPR)
2. Soft Track; Measurement of Track deflection & Subgrade modulus
3. BIG DATA: Multi year, multi data analysis - Diagnosis & Trending evaluation
4. Multi option analysis; Optimizing Strategic Management of assets by evaluation of impact on risks control and serviceability
Track substructure evaluation

Poor substructure Problems

- Condition of track substructure has a profound influence on track performance
- It is “THE” main reason for track geometry degradation;
  - One of main causes of wear and degradation of rail, tie, fastener, special track work, and joint
  - Rail fatigue, Broken rail, Derailment
  - Affects rolling stocks

On one US Railroad (2007)
- $10m/y to fix mud spot
- ~TSO’s, Outages (600/y)
- ~Over $200M/y ballast maintenance
  (>95% in the upper 20 inches)

Need to get better: They did!
Track substructure evaluation

What is the source of the problem? Get proper Diagnosis before the fix?

• UK investigate rail breaks including the “big picture” (foundations, drainage and surroundings)
Track substructure evaluation

How deep is the problem?

- Hazards from soft roadbed
  - What is causing it?
    - ballast degradation
    - subgrade pumping
    - Plastic deformation
    - Subgrade failure
    - Poor drainage

How do you fix it?

- Keep tamping it…over and over
- Skin lift? Cover it with ballast lift (hide it?)
- Big rail- swamp ties
- Undercut
- Reinforce subgrade

Need investigation & analysis to find out
Track substructure evaluation

Need to evaluate impact of spring thaw on bearing capacity; To control risks over most vulnerable area (similar to highways)

- Frozen Ground: High Capacity in Winter
- Thawing Ground: Low Bearing Capacity
- Summer Capacity: Varies with Moisture content

~2,000 psf

Required Track bed bearing Capacity

Feb March April May June July
Track substructure evaluation

Substructure Research Program

1. To develop the means to map the extent and stiffness of soft subgrade beneath rail structure
   Tools:
   • M-Rail track deflection car
   • Ground Penetrating Radar (GPR)
   • Ballast Sampler, Soil Tests
   • Terrain analysis mapping – (Air photos; Lidar)
   • Historical look at Track Problems (Big Data)
   Track Geometry & Surfacing Records for comparison to trends in track geometry, defects correlation with Modulus (transition and soft locations)
   Challenge: Collect, assemble multi-year data and align them perfectly together.

2. Quantify Ballast Condition / state of deterioration / forecast when replacement is needed and on what priority

3. Quantify the stiffness of soft subgrades beneath rail structures.
5. Evaluate Impact of Low Modulus:
   - Comparison of measured stiffness and subgrade type to trends in track geometry and maintenance data, on maintenance costs, operations, and the extent of the risk / reliability

6. Quantify the ‘performance’ of the track which is being measured. (Rail breaks, track geometry defects & recorded maintenance activities)

7. Provide a risk based assessment of track and substructure.
   1. Track performance based on historical rate of generation of defects.
   2. Spatial density of recorded rail breaks.
   3. Subgrade stiffness as a measure for the potential to develop issues (maintenance costs, track outages, foundation failures, rail breaks).

8. To evaluate the effectiveness of different remedial methods used to upgrade the performance of rail tracks at soft subgrade sections
Track substructure evaluation

GPR, Laser and image surveying
Track substructure evaluation

Findings and Preliminary Results – GPR
Section 196.2 to 196.7

- Water in ballast
- Bearing capacity failure; mud in ballast
- At-grade Crossing
Track substructure evaluation

Track Deflection – Mrail
To define extent of softer tracks and relative bearing capacity by recording rail deflections under moving heavy cars.
Track substructure evaluation

Test results - Close up view near mile 241.5 area

2 miles

Challenge: multi-year data & align them perfectly together.

Track Ranking every 1/10th mile
Track substructure evaluation

Grouping additional data to get the best diagnosis from Test Car to Defect to Maintenance records on a multi year basis - BIG Data --> then Analyse;
The data exist: Let’s use it for best diagnosis and maintenance strategy

Distribution of maintenance allocation

Distribution of Geometry defects
Track substructure evaluation

Example/Key

Ruel Sub Mile 121.5
Example: Lac Labiche Track foundation rating

- **Track Substructure assessment**
  
  **TOOLS**
  - Ground Penetrating Radar (GPR)
  - F.W.D. Ballast Sampler
  - M-Rail track deflection car
  - Track Geometry & Surfacing Records (Big Data)

  → **Assessed Conditions**: Ballast Fouling, Trapped Moisture, Subgrade deformation, Track Stiffness, Drainage

- **Foundation Quality ranking**
  
  - Every 1/10th mile track section evaluated: work priority
  - Condition Scoring from 1 (good) to 5 (weak)
  - Diagnosis of source of poor track condition

**Recommendations for Improvements**

**Main Goal**: Meet standard requirement for HAL;

- Work from above to reduce stresses on soil with structural improvement. (Major part of required investment; Rail & Ballast)
- Foundation work; Work from below to increase soil bearing capacity (as needed on specific locations).
UAV (drone) Program & Bridge Inspection
New Technology – UAV (drone) Program

- Ariel Survey
  - Design & Construction Site Survey
  - PTC Entry Track Survey’s
  - Yard Mapping

- Bridge Inspection
  - Structural Inspections
  - Pin Connections
  - Scour Conditions

- Emergency Response:
  - Expansion to provide extended range, real-time imagery
  - Line of Sight limitations
Structural inspections

• Detailed visual inspections of restricted access areas (underside or very high)

• Overall bridge models -3D recreation

• Detailed measurements and structural assessment can be performed in targeted applications less risk and more accurate
Structural inspections

- Visual inspections
  - Realtime emergency response site visualization
  - Difficult access site assessments for natural hazard events

Site Survey – Point cloud creation for Yard or Construction Surveys
Bridge inspection

Displacements by radar

Allows deflection measurements without a fixed reference point next to the point of interest
Thank you