Embracing Technology for Railroad Track Inspection

GARY CARR
CHIEF, TRACK RESEARCH DIVISION
Office of Research and Development
Office of Railroad Policy and Development
To examine and reconsider the track inspection process in order to get the most value out of an integrated inspection strategy
Future Railroad Capacity

- Railroads will increase axle loads, train frequencies, train lengths, and operating speeds.
- Expected higher rates of track component fatigue, wear, and overall track structural degradation.
- Railroads are adapting by using better component designs, materials, procedures and processes.

Next 25 years

100 Million more people

2.8 Billion more tons of freight
Railroads State of Good Repair

• Considerations
  – Increased track usage decreases available track time for inspection and repair
  – Heavier trains on standard components in long-term service accelerates fatigue risks
  – Higher speeds will tighten allowed geometry variations, accelerating the maintenance cycle
  – Longer train lengths may require stronger track structure to support additional in-line train forces
Railroad Safety Trends

YEAR

Number of Derailments
0  1000  2000  3000  4000  5000  6000  7000  8000  9000  10000

Track causes  Signal causes  Miscellaneous causes  Human factor causes  Equipment causes
Why do we derail?

- Assume after an inspection we have good knowledge
  - Our ability to detect is not perfect
  - We don’t know what we are missing
  - We don’t measure the proper indicators
- We don’t identify the critical situations before resulting in a derailment
- We conduct inappropriate repairs or don’t follow up
- Derailments are combinations of simultaneous events not just single failures anymore.
Inspection Plays a Critical Role
Experienced Inspectors and Automated Inspection Devices

Experienced Inspectors/Manual

- More Detailed Inspection
- Better decision-making on found defects
- Capable of searching for larger variety/type
- Easier adjustment of search parameters

Automated Inspection Devices

- Higher speed
- Better at locating
  - Small variations from normal
  - Not plainly visible
- Minimizes human influences/errors
- Consistent and Precise inspection
  - Day and night
Hybrid Inspection System Approach

Previous Research has shown:

- Neither the human nor the automated systems achieved an outstanding performance
- The automated system was better at locating the defects (search) but could not classify them as acceptable or rejectable (decision-making) as well as the human inspectors
- Earlier studies indicated that human inspections typically find only ~80% of the defects (Juran 1974)

“Allocating the search function to machines and the decision-making function to humans results in better performance than pure human or pure machine”.

What is Autonomous Track Inspection?

- **Autonomous Inspection**: Process of inspecting the track from revenue service trains using *unattended instrumentation*.

- Vision is to **improve track safety and maintenance** practices by enhancing conditional awareness.

> “Autonomous inspection technology is designed to enhance, rather than replace, traditional inspection methods.”
Autonomous System Technical Arrangement

ONBOARD UNIT

PROCESSING SERVER

Communication Link

Inspection Results

Database
Autonomous Track Geometry Measurement System (ATGMS)

Key benefits of car body mounted approach include:

• Simpler design, mounts on any railcar, remote access
• Earlier identification of anomalies through more frequent inspections;
• More efficient inspections at much lower overall costs;

*Amtrak 82602 Installation
Remote Desktop Control Room

- Immediate knowledge of inspection status

- Facilitates remote system operation, data analysis, and data quality control

- Visualization of route surveyed, prioritization, and modification

- Library of track inspection data to be used in accident investigations and line upgrade opportunities

- Satellite and local imagery of locations
Inspection Frequency is key for Track Safety

Expected # of Accidents

14 day inspections w/ 1 day remediation and zero misses
7 day inspections w/ delayed remediation and misses

0.634 (19% less)

<table>
<thead>
<tr>
<th>Inspection Interval (days)</th>
<th>Delay to Remediation (days)</th>
<th>Probability of missing a fault</th>
<th>Expected # of Accidents after 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1</td>
<td>0</td>
<td>0.783</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>0</td>
<td>0.634 (19% less)</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>0.23</td>
<td>0.634 (19% less)</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>0.13</td>
<td>0.635 (19% less)</td>
</tr>
</tbody>
</table>

Source: Dr. Rome’s Markov program
Don’t Fear the Data

DATA
Facts, Numbers, Pictures, ...

INFORMATION
Processed Data Within Context

KNOWLEDGE
Personal Map of World, Relationships Between Pieces of Information
Data Generator: FRA Joint Bar Inspection System

How it works:

Data Collection Computer

GPS

Satellite

Automated Crack Detection

Editor/Database

Wheel Encoder

Lighting
Information Supplied:

• 19,105 miles surveyed*
  – 7,205 CWR
  – 11,900 Jointed

• ~2,600,000 Joints (5,200,000 Joint Bars)

• 17,070 defective joints found, including:
  – 5,640 center cracks
  – 1,600 center breaks
  – 7,400 quarter cracks and breaks
  – 150 double center cracks
  – 50 double center breaks
  – 2,230 FRA bolt defects

*Statistics from the FRA System and the Three Service Cars from three years of testing
Manual Inspection & Information

INTACT LOCATIONS

TYPE A DEFECT:
- FULL QUARTER BREAKS ON LONG TOE BARS
- PARTIAL BOTTOM QUARTER CRACKS ON LONG TOE BARS
- ALL BOLT HOLE CRACKS/BREAKS ON ALL BAR DESIGNS

TYPE B DEFECT:
- FULL CENTER BREAKS AND ALL PARTIAL CENTER CRACKS ON ALL BAR DESIGNS
- PARTIAL TOP QUARTER CRACKS ON LONG TOE BARS
- FULL QUARTER BREAKS AND ALL PARTIAL QUARTER CRACKS ON STANDARD DESIGN BARS

Vertical Joint Movement Overview

Class 2 Repeat Failure

Class 3 Repeat Failure
Knowledge: Joint Bar Inspection System

- **Deteriorated joint support** as the most prominent condition distinguishing failed joint bar locations.
- Vertical movement over **0.5 inches** appear to have an increased risk of joint bar failure.
- **Rail end conditions** appear to be a contributing factor to joint bar failure in higher track classes (Class 3 and higher) in both JNT and CWR territories.
- Short chord surface measurements, such as **10-foot MCO**, have a potential as an identifier of locations with deteriorated joint support.
Knowledge: Joint Bar Inspection System

- On this track segment, \( \approx 0.90 \) defects per mile average remained in the track after the standard highrail/manual weekly inspections.
Systems that Address Track Defect Incidents

Source: FRA Office of Safety Database
One-Pass Manned Inspection Car

Car Capabilities Include:
- Capture all standard geometry issues
- Detect rail wear
- Tie and fastener performance
- Detect cracks or defective ties, joint bars, missing ties and fasteners

✓ Capture drainage and ballast fouling levels
✓ Find high wheel impact locations
✓ Locate subgrade issues and track support issues
✓ Detect internal rail flaws
✓ Assure PTC communications are working properly
✓ To measure and determine humped grade crossings

Adopting a multilayer inspection approach to enhance traditional inspection methods with advanced technologies that notify railroads of their infrastructure safety risks
INSPECTION SYSTEMS

**Track Geometry System**
Capture all standard geometry issues

**GRMS**
Tie and fastener performance

**VTI**
Find high wheel impact locations

**Grade Crossing Mapping System**
To measure and determine humped grade crossings
*Items available but not currently installed

**Rail Profile**
Detect rail wear

**Vision Based Inspection***
Detect rail breaks, joint bars, missing ties and fasteners, defective ties
*Items available but not currently installed

**Rail Defect Detection***
Detect internal rail flaws
*Items available but not currently installed

**GPR***
Capture drainage, ballast fouling levels and ballast thickness
*Items available but not currently installed

**Vertical Stiffness***
Locate subgrade issues and track support issues
*Items available but not currently installed

**Train Control Monitoring System**
Assure PTC communications are working properly
**Items not currently available**
Track and Track-Side Video System*

• Virtual Environment
  – Immersive video environment for visual surveys.
  – Natural interface to a large quantity of high-quality imagery that replicates the experience of actually being track-side.
  – Benefits such as:
    • Geographic navigation of video.
    • Auto geo-location.
    • Object tracking.
    • Visualisation, manipulation and creation of GIS objects.
  – Displays GIS objects as video overlays in their real-world locations.

*Product of CREATEC – Create Technologies Ltd
Track and Track-Side Video System* Cont.

Binds together external survey data, displaying data in a consistently intuitive manor.

*Product of CREATEC – Create Technologies Ltd
Introducing Technology to the Industry

Implementation

Threat of Job Loss
Capital Funding
Cost Benefits
Safety Benefits
Positive Impact on Performance
Regulatory Issues
Perfection is the enemy of the good!

When is the developed technology good enough?

• Typical responses:
  – To many false positives!
  – The software needs to improved!
  – It doesn’t do everything it needs to do!
  – It doesn’t develop knowledge only more data!
    • I don’t need more data, we don’t do enough with what we already have!

“Perfection is fear; Excellence is taking a risk"
Miss the Plane!

“If you never miss a plane, you are spending too much time at the airport”
- George Stigler, Nobel Prize in Economics
Industry Benefits with New Technology

A World Transformed: What Are the Top 30 Innovations of the Last 30 Years? *

- Internet, broadband, WWW (browser and html)
- PC/laptop computers
- Mobile phones
- E-mail
- DNA testing and sequencing/Human genome mapping
- Magnetic Resonance Imaging (MRI)
- Microprocessors
- Fiber optics
- Office software (spreadsheets, word processors)
- Non-invasive laser/robotic surgery (laparoscopy)
- Open source software and services (e.g., Linux, Wikipedia)
- Light emitting diodes
- Liquid crystal display (LCD)
- Global Positioning Systems (GPS)
- Online shopping/ecommerce/auctions (e.g., eBay)
- Media file compression (jpeg, mpeg, mp3)
- Microfinance
- Photovoltaic Solar Energy
- Large scale wind turbines
- Social networking via the Internet
- Graphic user interface (GUI)
- Digital photography/ videography
- RFID and applications (e.g., EZ Pass)
- Genetically modified plants
- Bio fuels
- Bar codes and scanners
- ATMs
- Stents
- SRAM flash memory
- Anti retroviral treatment for AIDS

*Nightly Business Report (PBS) 02/2009
What can we do in the future!
Future

• Professors and Students are encouraged to continue to develop new ideas, Railroad knowledge, and complementary technology

• Railroads temporarily accept limitations of current technologies and invest to gain the knowledge and benefits of new technology

“While you’re sitting there thinking about it someone else is out there doing it.” —Rodger Halston
Summary Points

- Embrace the Technology
- Don’t Fear the Data
- Miss the plane every once and a while