Topic #1 “Introducing Hybrid Optimization of Train Schedule (HOTS) Model as Timetable Management Technique”

Hamed Pouryousef
Michigan Technological University

Topic #2 “Hazards Associated with Shared-Use Rail Corridor Operations”

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University of Illinois at Urbana-Champaign

Date: Friday, April 03, 2015
Time: Seminar Begins 12:20
Location: Newmark Lab, Yeh Center, Room 2311
University of Illinois at Urbana-Champaign

Sponsored by
Hazards Associated with Shared-Use Rail Corridor Operations

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William W. Hay Railroad Engineering Seminar
3rd April 2015
Outline

- Shared-use rail corridor safety challenges
- Risk management for shared-use rail corridor hazards
- Conclusion and future work
Increasing Passenger Train Service Demand
Two key decisions in HSR development

- **Approach to HSR**
  - Incremental upgrade of existing line
  - New dedicated line

- **Track and right-of-way usage**
  - Shared Track
  - Shared Right of Way
  - Shared Corridor

- Each has different implications regarding speed, performance, cost, operational, institutional and regulatory considerations
Shared-Use Rail Corridor

- **Shared track**: passenger and freight trains (or other rail service) use the same track.

- **Shared right-of-way (ROW)**: passenger trains operate on dedicated tracks separated from freight or other service tracks up to 7.62 meters (25 feet).

- **Shared corridor**: passenger trains operate on dedicated tracks separated from freight or other service tracks by 7.62 – 60.96 m (25 – 200 feet).

Shared track & shared ROW

Adjacent track centers ≤ 25’

Shared corridor

High-speed rail service

Freight or conventional passenger rail service

Adjacent track centers > 25’ and ≤ 200’
Shared-Use Rail Corridor Risk Management

- Risk Management Planning
- Risk Identification
- Risk Assessment
  - Qualitative Risk Assessment
  - Quantitative Risk Assessment
- Development and Evaluation of Risk Mitigation Strategies
- Risk Monitoring
Guidance Document for Risk Management of Shared-Use Rail Corridors

• The Federal Railroad Administration (FRA) set out to develop a Guidance Document which provides guidance and procedures for the risk assessment of potential hazards on shared-use rail corridors.

• The document is divided in two parts:
  – General hazard assessment procedure
  – Detail risk assessment for identified hazards
Guidance Document for Risk Management of Shared-Use Rail Corridors

Development of the document and its final contents consider the following issues:

- Minimum track and Right-of-Way (ROW) spacing
- Use of intrusion detection or protection devices
- Use of physical barriers or crash walls
- Other relevant considerations such as protection from activities along ROW access roads, etc.

Hazards are identified and specified in the guidance document and their relevance to those issues are discussed for further risk assessments.
List of Hazards Associated with Shared-Use Rail Corridors

- Derailment on adjacent tracks
- Shifted load on an adjacent track
- Aerodynamic interaction between trains on adjacent tracks
- Ground borne vibration and its effect on HSR track geometry
- Intrusion of maintenance of way staff and equipment working on the adjacent track
- Obstruction hazard resulting from an adjacent track (non-derailment and grade-crossing collisions)
- Drainage problem affecting either the HSR track or the adjacent track
- Evacuation of passengers from trains on the adjacent track
- Hazardous Materials on the adjacent track
- Fire on the adjacent track
- Electromagnetic interference between trains and wayside equipment on adjacent tracks
Shared-Use Rail Corridor Hazard Framework

Risk of Operating HSR Adjacent to Conventional Tracks

Intrusion Hazards
- Adjacent Track Derailment
- Obstruction Hazard from Adjacent Tracks
- Evacuation of Passengers on Adjacent Tracks
- Intrusion of Maintenance-of-Way Staff and Equipment
- Aerodynamic Interaction Between Trains

Shifted Load on Adjacent Tracks

Hazardous Material Transportation on Adjacent Tracks

Freight Train Involvement

Non-Intrusion Hazards
- Electromagnetic Interference
- Fire on Adjacent Tracks
- Drainage Problem Affecting Infrastructure
- Ground Borne Vibration

All-Train-Type Involvement
Fault-Tree Analysis

- A deductive process to break down a top event and all possible ways for this event to occur are systematically deduced
- A graphical representation of the various contributions of failures that lead to the occurrence of the dangerous event
- The probability of the top event can be calculated by calculating the probabilities of basic events
Fault-Tree Analysis Configuration

- Event symbols
  - Basic Event
  - Conditioning Event
  - Undeveloped Event
  - Intermediate Event
  - External Event

- Gate (Logic) Symbols
  - AND
  - OR
  - EXCLUSIVE OR
  - PRIORITY AND
  - INHIBIT

- Transfer Symbols
An Example of Fault-Tree Analysis: Derailment on Adjacent Tracks

- **Adjacent Track Derailment**
  - **AND**
  - **Derailment**
    - Infrastructure Quality
    - Method of Operation
    - Traffic Density
    - Train Defect Detector
  - **Intrusion**
    - Track Center Distance
    - Train Speed
    - Track Alignment
    - Geographic Condition
    - Elevation Differential
    - Containment
    - Derailment Mechanism
    - Adjacent Structure
  - **Train Presence on Adjacent Track**
    - Traffic Density
    - Method of Operation
    - Train Speed
    - Intrusion Detection
    - Train Braking Ability
## General Locations Where Each Hazard Is Eminent

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Derailment on adjacent tracks</td>
<td>Along a shared-use rail corridor with multiple tracks</td>
</tr>
<tr>
<td>2 Shifted load on adjacent tracks</td>
<td>Along a shared-use rail corridor with freight train services</td>
</tr>
<tr>
<td>3 Aerodynamic interaction between trains on adjacent tracks</td>
<td>Along a shared-use rail corridor with multiple tracks, tunnels and stations where trains operate at high speed</td>
</tr>
<tr>
<td>4 Ground borne vibration and its effect on HSR track geometry</td>
<td>Along a shared-use rail corridor where trains operating at high speed especially at locations with subgrade and track infrastructure conditions susceptible to vibrations, and at special track locations (e.g. switches and turnouts)</td>
</tr>
<tr>
<td>5 Intrusion of maintenance of way staff and equipment working the adjacent tracks</td>
<td>Along a shared-use rail corridor where track maintenance activities are frequently taken place and locations with limited clearances (e.g. bridges, tunnels)</td>
</tr>
<tr>
<td>6 Obstruction hazard resulting from adjacent tracks (non-derailment collisions)</td>
<td>Along a shared-use rail corridor close to other rail or highway vehicles (e.g. yards, grade crossings)</td>
</tr>
<tr>
<td>7 Drainage problem affecting either the HSR track or adjacent tracks</td>
<td>Along a shared-use rail corridor especially at high-precipitation/snow areas, vegetation and with insufficient drainage systems</td>
</tr>
<tr>
<td>8 Evacuation of passengers from trains on adjacent tracks</td>
<td>Along a shared-use rail corridor with multiple tracks</td>
</tr>
<tr>
<td>9 Hazardous material transportation on adjacent tracks</td>
<td>Along a shared-use rail corridor with freight trains transporting hazardous materials</td>
</tr>
<tr>
<td>10 Fire on adjacent tracks</td>
<td>Along a shared-use rail corridor with freight trains transporting flammable liquids and/or gases, and other locations near fuel-based activities (e.g. power stations, gas stations)</td>
</tr>
<tr>
<td>11 Electromagnetic interference between trains and wayside equipment on adjacent tracks</td>
<td>Along a shared-use rail corridor where the high-voltage overhead catenary wires present</td>
</tr>
</tbody>
</table>
## Key Influencing Factors of Hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Key Influencing Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derailment on adjacent tracks</td>
<td>Track center spacing, train speed, human factor, track geometry, type of rail infrastructure, train control systems</td>
</tr>
<tr>
<td>Shifted load on adjacent tracks</td>
<td>Track center spacing, train speed, human factor, track geometry, train control systems</td>
</tr>
<tr>
<td>Aerodynamic interaction between trains on adjacent tracks</td>
<td>Track center spacing, train speed, train equipment design, wind condition</td>
</tr>
<tr>
<td>Ground borne vibration and its effect on HSR track</td>
<td>Track center spacing, train speed, track geometry, type of rail infrastructure</td>
</tr>
<tr>
<td>Intrusion of maintenance of way staff and equipment working the adjacent tracks</td>
<td>Track center spacing, train speed, human factor</td>
</tr>
<tr>
<td>Obstruction hazard resulting from an adjacent tracks (non-derailment collisions)</td>
<td>Track center spacing, train speed, human factor, track geometry, train control systems</td>
</tr>
<tr>
<td>Drainage problem affecting either the HSR track or adjacent tracks</td>
<td>Track center spacing, soil foundation/subgrade characteristics, track geometry, type of rail infrastructure</td>
</tr>
<tr>
<td>Evacuation of passengers from trains on adjacent tracks</td>
<td>Track center spacing, train equipment design, human factor</td>
</tr>
<tr>
<td>Hazardous material transportation on adjacent tracks</td>
<td>Track center spacing, train equipment design, hazardous materials traffic volume</td>
</tr>
<tr>
<td>Fire on adjacent tracks</td>
<td>Track center spacing, train equipment design, human factor, flammable product traffic volume</td>
</tr>
<tr>
<td>Electromagnetic interference between trains and wayside equipment on adjacent tracks</td>
<td>Train equipment design, type of rail infrastructure, train control systems</td>
</tr>
</tbody>
</table>
# Proposed Risk Mitigation of Hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Potential Risk Mitigation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Derailment on adjacent tracks</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training</td>
</tr>
<tr>
<td>2 Shifted load on adjacent tracks</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training on cargo securement</td>
</tr>
<tr>
<td>3 Aerodynamic interaction between trains on adjacent tracks</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, reduced train speed</td>
</tr>
<tr>
<td>4 Ground borne vibration and its effect on HSR track geometry</td>
<td>Proper track center spacing, reduced train speed</td>
</tr>
<tr>
<td>5 Intrusion of maintenance of way staff and equipment working the adjacent tracks</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training, grade crossing protection</td>
</tr>
<tr>
<td>6 Obstruction hazard resulting from an adjacent tracks (non-derailment collisions)</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training, grade crossing protection</td>
</tr>
<tr>
<td>7 Drainage problem affecting either the HSR track or adjacent tracks</td>
<td>Proper track center spacing, soil improvement, improved drainage</td>
</tr>
<tr>
<td>8 Evacuation of passengers from trains on adjacent tracks</td>
<td>Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training on safe passenger evacuation, enhanced rail equipment design</td>
</tr>
<tr>
<td>9 Hazardous material transportation on adjacent tracks</td>
<td>Proper track center spacing, building physical barriers, temporal separation, enhanced rail car design to prevent hazardous material release</td>
</tr>
<tr>
<td>10 Fire on adjacent tracks</td>
<td>Proper track center spacing, building physical barriers, temporal separation, enhanced rail equipment design</td>
</tr>
<tr>
<td>11 Electromagnetic interference between trains and wayside equipment on adjacent tracks</td>
<td>Improved employee training, better rail equipment design to prevent or reduce electromagnetic field effect</td>
</tr>
</tbody>
</table>
Shared-Use Rail Corridor Risk Management Guidance Document Outline

- Risk Management Planning
- Risk Identification
- Risk Assessment
  - Qualitative Risk Assessment
  - Quantitative Risk Assessment
- Development and Evaluation of Risk Mitigation Strategies
- Risk Monitoring
Quantitative Risk Assessment

- Probability and Consequence Assessment
- Historical Data Analysis
- Precursor Analysis
- Fault-Tree Analysis on Probability
- Risk Model Development
- Integrated Risk Framework
Adjacent Track Accidents (ATA)

- ATAs refer to train accident scenarios where a derailed railroad equipment intrudes adjacent tracks, causing operation disturbance and potential subsequent train collisions on the adjacent tracks.
- Other ATA scenarios include collisions between trains on adjacent tracks (raking between trains), turnouts, and railroad crossings.
- A typical adjacent track accident scenario:

![Diagram showing normal operation, derailment, intrusion, and collision stages with clearance envelope and equipment loading gauge.]
Adjacent Track Accident

- Higher speed of proposed passenger rail services increases risk posed by derailed trains on adjacent tracks
- Warning of a derailed train fouling tracks may not always arrive soon enough.
- Use of barriers can create access problems for maintenance
- This research tends to answer the following questions:
  - What factors could affect the probability and/or consequence of adjacent track accidents
  - How to evaluate and mitigate adjacent track accident risk
Conceptual Framework for Adjacent Track Accident Risk

1. Initial Accident
   - Collision
     - Presence of Multiple Tracks
       - Yes
       - No
     - Intrusion
       - Yes
       - No
   - Derailment
     - Presence of Train on Adjacent Track
       - Yes
       - No
Proposed Semi – Quantitative ATA Risk Model

\[
R = P(A) \times P(I|A) \times P(T|I) \times C
\]

where

\( R \): Risk of Adjacent Track Accident (ATA)

\( P(A) \): Probability of a derailment or collision occurring on multiple track territory

\( P(I|A) \): Conditional probability of intrusion (CPI) given a derailment or collision on multiple track territory

\( P(T|I) \): Conditional probability of the presence of a train on adjacent track given an intrusion

\( C \): The level of consequence
Holistic ATA Risk Analysis Framework

ATA Risk

\[ R = P(A) \times P(I|A) \times P(T|I) \times C \]

- **Derailment**
  - Infrastructure Quality
  - Method of Operation
  - Traffic Density
  - Train Defect Detector

- **Intrusion**
  - Track Center spacing
  - Track Alignment
  - Geographic Condition
  - Elevation Differential
  - Containment
  - Adjacent Structure
  - Derailment Mechanism

- **Train Presence**
  - Traffic Density
  - Method of Operation
  - Train Speed
  - Intrusion Detection

- **Consequence**
  - Train Speed
  - Equipment Damage Resistance
  - Containment
  - Hazmat

Train Accident Analysis
Precursor Analysis
Potential Application of the Risk Model

\[ R = P(A) \times P(I|A) \times P(T|I) \times C \]

- Calculate and compare ATA risk of different segment on the shared-rail corridor network.
- Identify the “risk hotspot” of the network
- Evaluate the implementation of risk mitigation strategies.
Case Study

\[ R = P(A) \times P(I|A) \times P(T|I) \times C \]
Case Study

Risk Index

Probability P

P(A) X P(I|A) X P(T|I)

Accident Factor 1

Accident Factor 2

Accident Factor 3

Intrusion Factor 1

Intrusion Factor 2

Intrusion Factor 3

Presence Factor 1

Presence Factor 2

Presence Factor 3

Consequence C

Consequence Factor 1

Consequence Factor 2

Consequence Factor 3

Consequence...

Consequence...

Consequence...
Conclusion and Future Work

• Shared-use rail corridor is one of the feasible solutions for implementing and increasing high or higher-speed passenger rail services in the United States.

• Holistic risk assessment is able to identify the potential hazards for the shared-use rail corridors operations, including their eminent locations, influencing factors, and potential risk mitigation strategies.

• Future work includes complete fault-tree analysis on hazards and quantitative risk model development as well as the development of an integrated risk assessment framework.
Acknowledgement

NURail Center

National University Rail Center (NURail Center)

A Tier-1 University Transportation Center (UTC) under the US Department of Transportation (DOT) Office of the Assistant Secretary for Research & Technology (OST) program.
Thank you!

Questions and comments are Welcomed!

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Mainline Passenger Train Accident Analysis

- **Average Frequency**: 40
- **Average Severity**: 2.115

- **Signal and Communication**
- **Mechanical Defects**
- **Train Operation**
- **Human Factors**
- **Infrastructure**

Accidents Per Million Train-Mile vs. Average Number of Cars Derailed
Mainline Passenger Train Accident Analysis

The top ten accident cause groups with the highest risk are:

- Failure to Obey/Display Signals (05H)
- Wide Gauge (03T)
- Train Speed (10H)
- Turnout Defects – Switches (10T)
- Broken Rails or Welds (08T)
- Use of Switches (11H)
- Joint Bar Defects (07T)
- Other Miscellaneous (05M)
- Misc. Track and Structure Defects (12T)
- Non-Traffic and Weather Causes (02T)
Mainline Freight Train Accident Analysis

Average Number of Cars Derailed vs. Accidents Per Million Train-Mile

- **Average Frequency**: 1,333
- **Average Severity**: 8.59

Factors:
- Signal and Communication
- Miscellaneous
- Train Operation
- Human Factors
- Mechanical Defects

Infrastructure
Mainline Freight Train Accident Analysis

The top ten accident cause groups with the highest risk are:

- Broken Rails or Welds (08T)
- Buckled Track (05T)
- Track Geometry (excl. Wide Gauge) (04T)
- Wide Gauge (03T)
- Broken Wheels (Car) (12E)
- Bearing Failure (Car) (10E)
- Train Handling (excl. Brakes) (09H)
- Joint Bar Defects (07T)
- Track-Train Interaction (04M)
- Failure to Obey/Display Signals (05H)