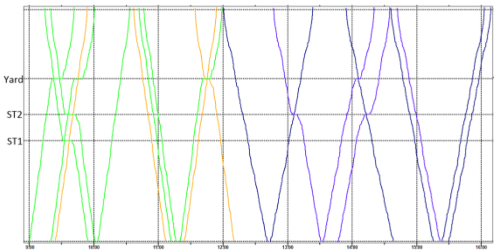
William W. Hay Railroad Engineering Seminar

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"

Chen-Yu Lin
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

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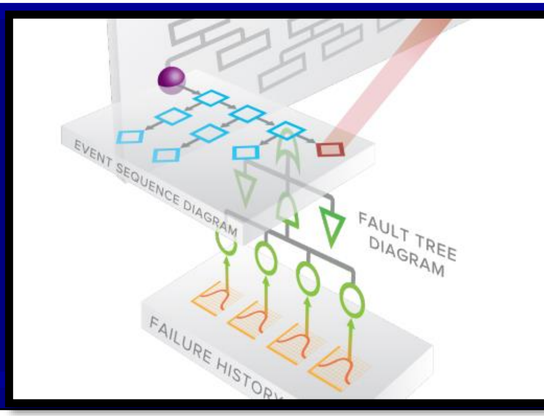
Hazards Associated with Shared-Use Rail Corridor Operations



Chen-Yu Lin
Dr. M. Rapik Saat
Dr. Christopher P.L. Barkan

William W. Hay Railroad Engineering Seminar
3rd April 2015

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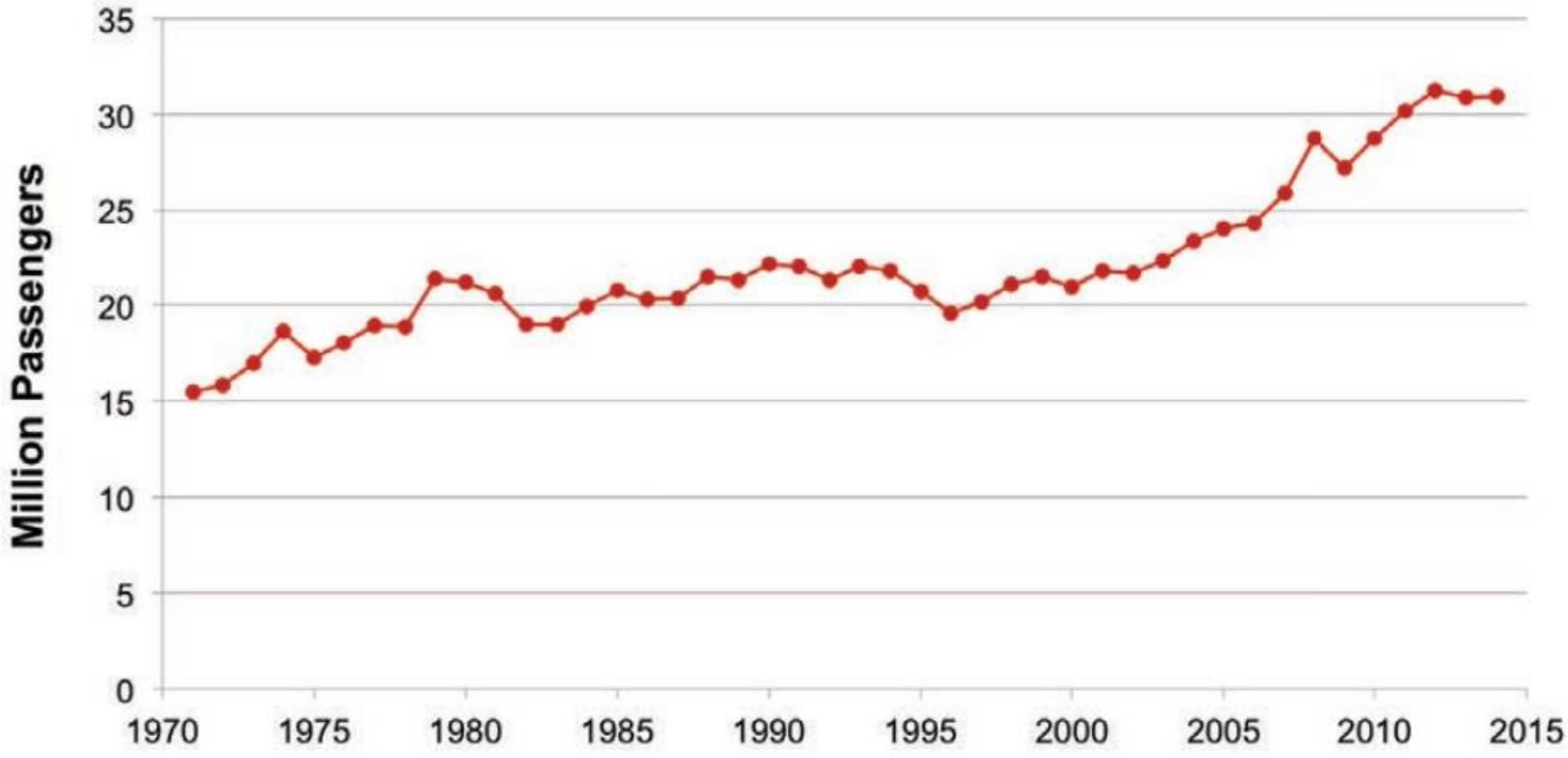
Outline

- Shared-use rail corridor safety challenges
- Risk management for shared-use rail corridor hazards
- Conclusion and future work

Increasing Passenger Train Service Demand



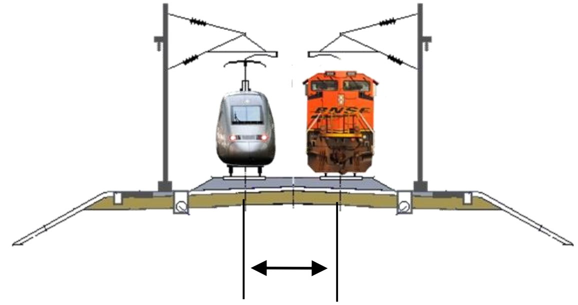
Two key decisions in HSR development

- 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

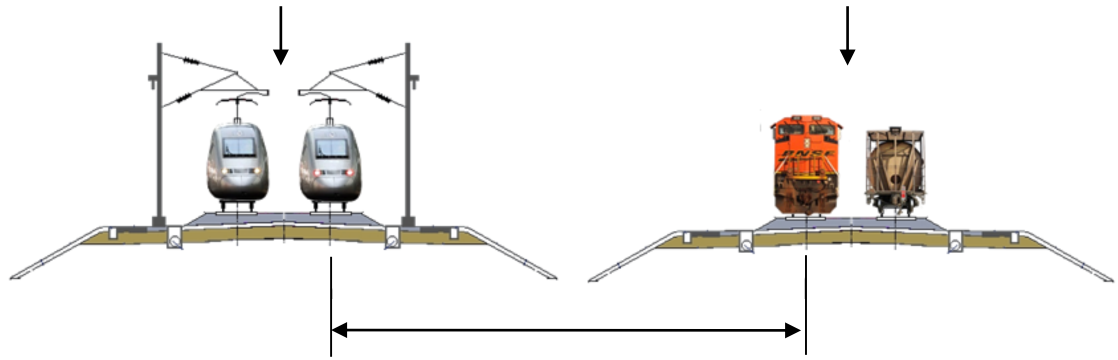


Adjacent track centers ≤ 25’

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

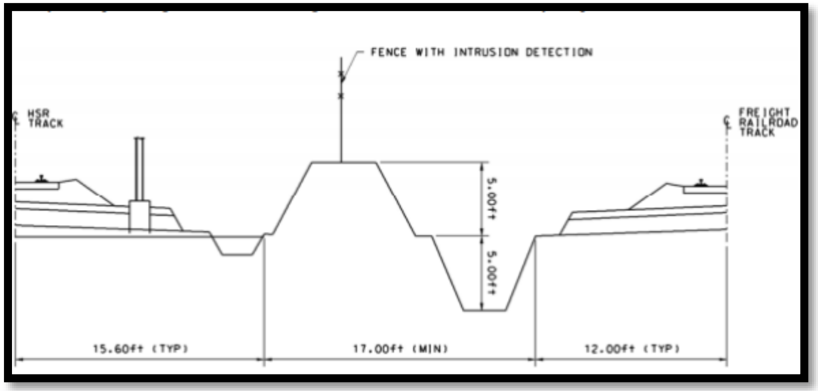
- The Federal Railroad Administration (FRA) set out to develop a Guidance Document which provides guidance and procedures for the risk assessment of potential hazards on shared-use rail corridors
- The document is divided in two parts:
  - General hazard assessment procedure
  - Detail risk assessment 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.

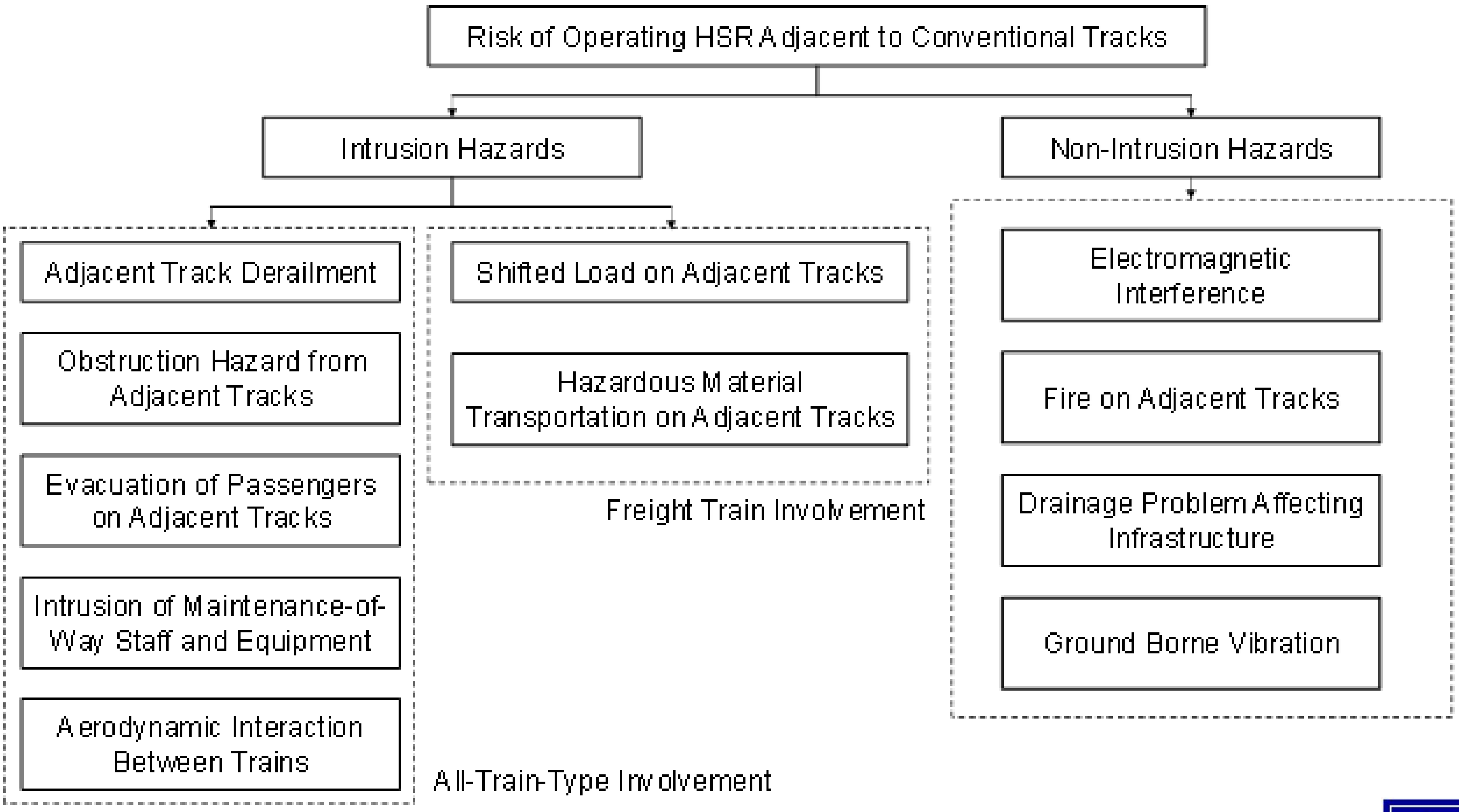
Hazards are identified and specified in the guidance document and their relevance to those issues are discussed for further risk assessments



List of Hazards Associated with Shared-Use Rail Corridors

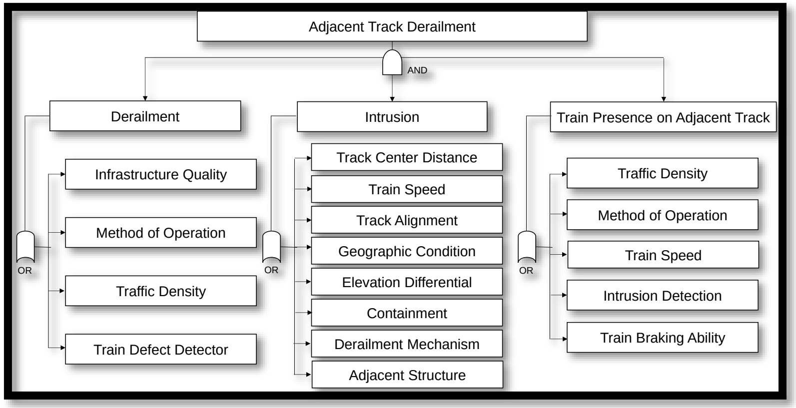
- Derailment on adjacent tracks
- Shifted load on an adjacent track
- Aerodynamic interaction between trains on adjacent tracks
- Ground borne vibration and its effect on HSR track geometry
- Intrusion of maintenance of way staff and equipment working on the adjacent track
- Obstruction hazard resulting 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

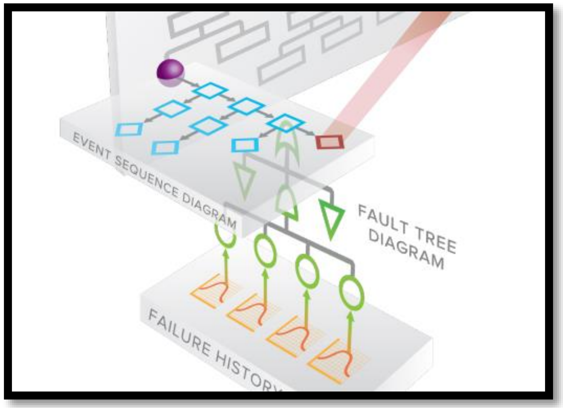
Shared-Use Rail Corridor Hazard Framework



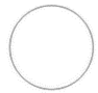
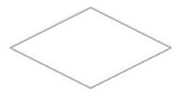
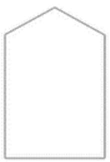
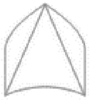
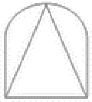
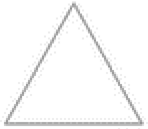
Fault-Tree Analysis

- 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

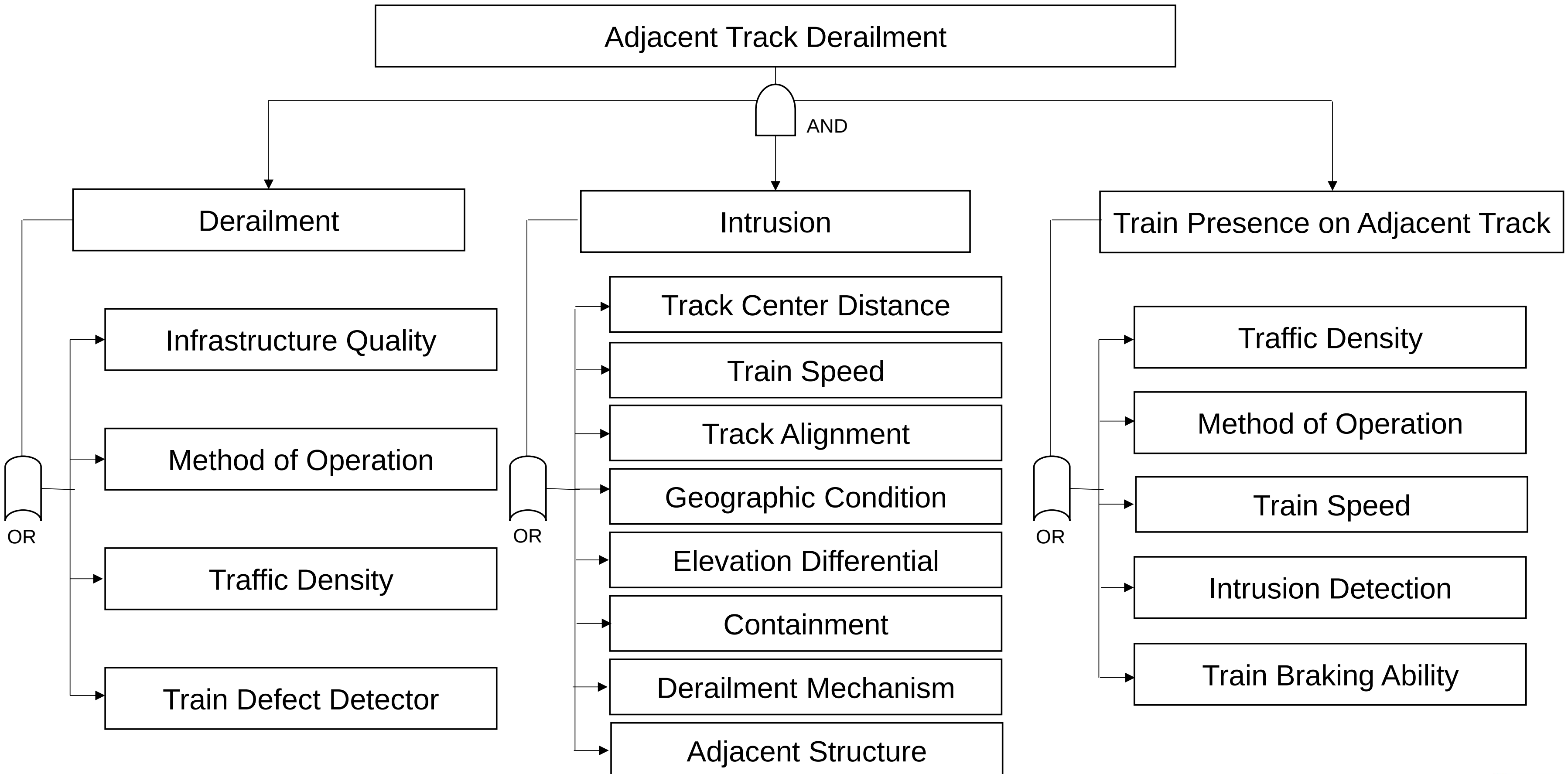




Fault-Tree Analysis Configuration

- 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



General Locations Where Each Hazard Is Eminent

	Hazard	Locations
1	Derailment on adjacent tracks	Along a shared-use rail corridor with multiple tracks
2	Shifted load on adjacent tracks	Along a shared-use rail corridor with freight train services
3	Aerodynamic interaction between trains on adjacent tracks	Along a shared-use rail corridor with multiple tracks, tunnels and stations where trains operate at high speed
4	Ground borne vibration and its effect on HSR track geometry	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)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible] adjacent tracks (non-derailment collisions)	[illegible] yards, grade crossings)
7	Drainage problem affecting either the HSR track or adjacent tracks	Along a shared-use rail corridor especially at high-precipitation/snow areas, vegetation and with insufficient drainage systems
8	Evacuation of passengers from trains on adjacent tracks	Along a shared-use rail corridor with multiple tracks
9	Hazardous material transportation on adjacent tracks	Along a shared-use rail corridor with freight trains transporting hazardous materials
10	Fire on adjacent tracks	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)
11	Electromagnetic interference between trains and wayside equipment on adjacent tracks	Along a shared-use rail corridor where the high-voltage overhead catenary wires present

Hazard	Locations
Derailment on adjacent tracks	Along a shared-use rail corridor with multiple tracks
Shifted load on adjacent tracks	Along a shared-use rail corridor with freight train services

Key Influencing Factors of Hazards

	Hazard	Key Influencing Factors
1	Derailment on adjacent tracks	Track center spacing, train speed, human factor, track geometry, type of rail infrastructure, train control systems
2	Shifted load on adjacent tracks	Track center spacing, train speed, human factor, track geometry, train control systems
3	Aerodynamic interaction between trains on adjacent tracks	Track center spacing, train speed, train equipment design, wind condition
4	Ground borne vibration and its effect on HSR track	Track center spacing, train speed, track geometry, type of rail
	tracks (non-derailment collisions)	train control systems
7	Drainage problem affecting either the HSR track or adjacent tracks	Track center spacing, soil foundation/subgrade characteristics, track geometry, type of rail infrastructure
8	Evacuation of passengers from trains on adjacent tracks	Track center spacing, train equipment design, human factor
9	Hazardous material transportation on adjacent tracks	Track center spacing, train equipment design, hazardous materials traffic volume
10	Fire on adjacent tracks	Track center spacing, train equipment design, human factor, flammable product traffic volume
11	Electromagnetic interference between trains and wayside equipment on adjacent tracks	Train equipment design, type of rail infrastructure, train control systems

Derailment on adjacent tracks | Track center spacing, train speed, human factor, track geometry, type of rail infrastructure, train control systems
Shifted load on adjacent tracks | Track center spacing, train speed, human factor, track geometry, train control systems

Proposed Risk Mitigation of Hazards

	Hazard	Potential Risk Mitigation Strategies
1	Derailment on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training
2	Shifted load on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training on cargo securement
3	Aerodynamic interaction between trains on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, reduced train speed

Derailment on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training
Shifted load on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training o cargo securement

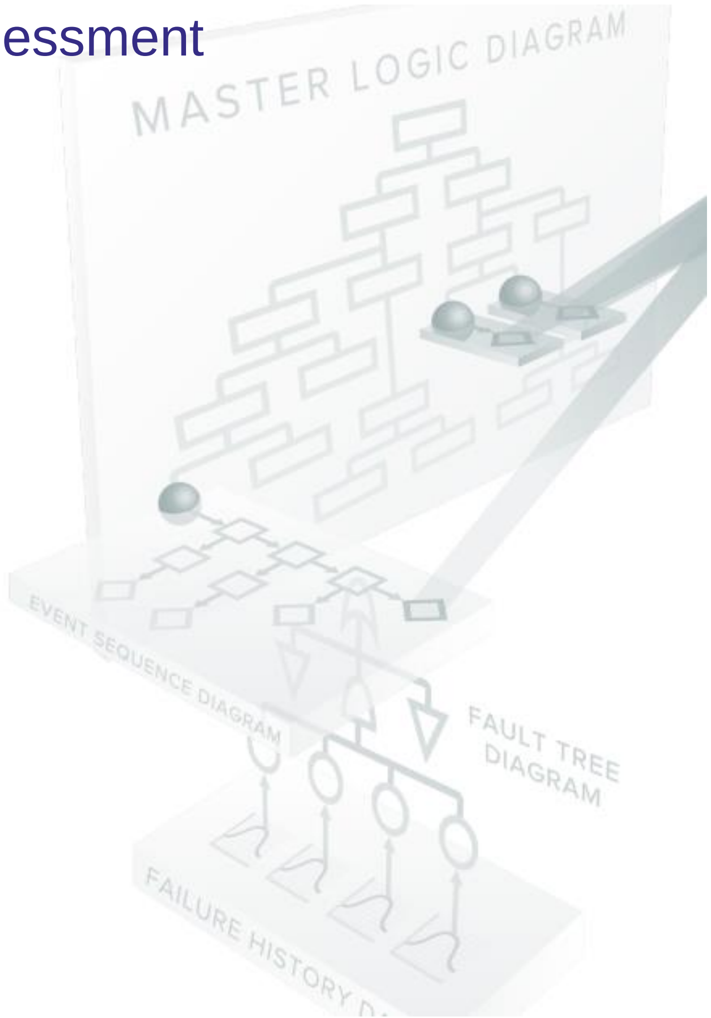
	Obstruction hazard resulting from an adjacent tracks (non-derailment collisions)	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training, grade crossing protection
7	Drainage problem affecting either the HSR track or adjacent tracks	Proper track center spacing, soil improvement, improved drainage
8	Evacuation of passengers from trains on adjacent tracks	Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training on safe passenger evacuation, enhanced rail equipment design
9	Hazardous material transportation on adjacent tracks	Proper track center spacing, building physical barriers, temporal separation, enhanced rail car design to prevent hazardous material release
10	Fire on adjacent tracks	Proper track center spacing, building physical barriers, temporal separation, enhanced rail equipment design
11	Electromagnetic interference between trains and wayside equipment on adjacent tracks	Improved employee training, better rail equipment design to prevent or reduce electromagnetic field effect

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

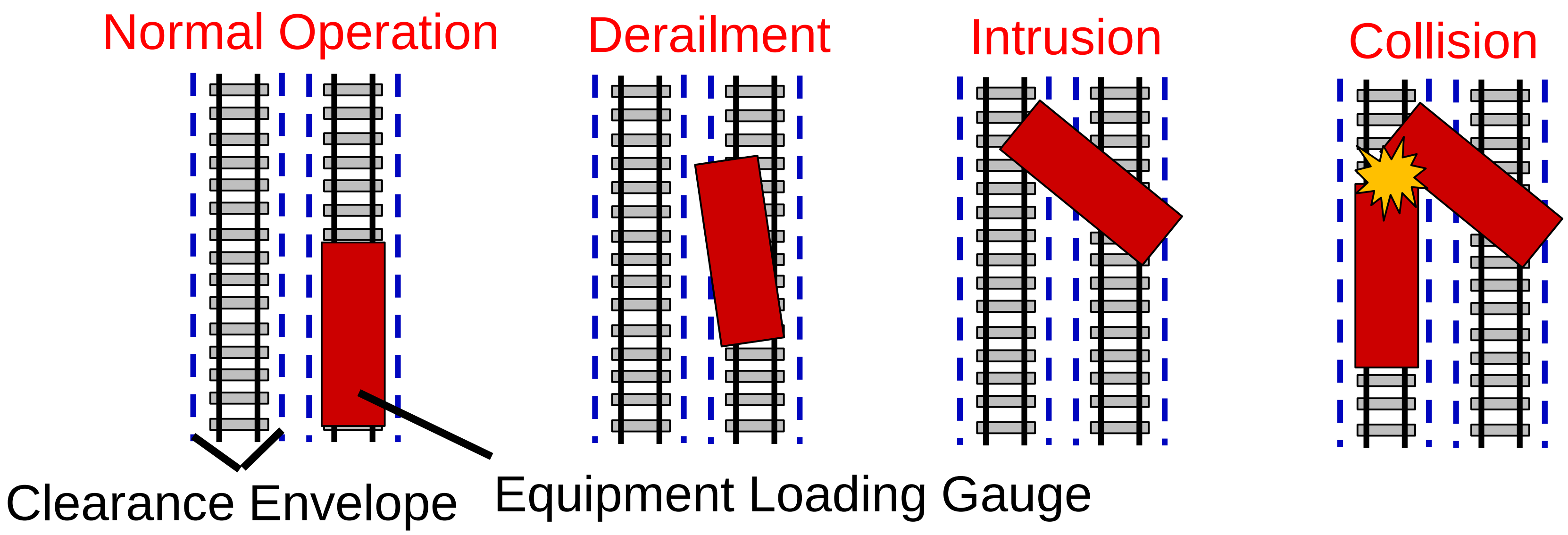
Quantitative Risk Assessment

- Probability and Consequence Assessment
- Historical Data Analysis
- Precursor Analysis
- Fault-Tree Analysis on Probability
- Risk Model Development
- Integrated Risk Framework



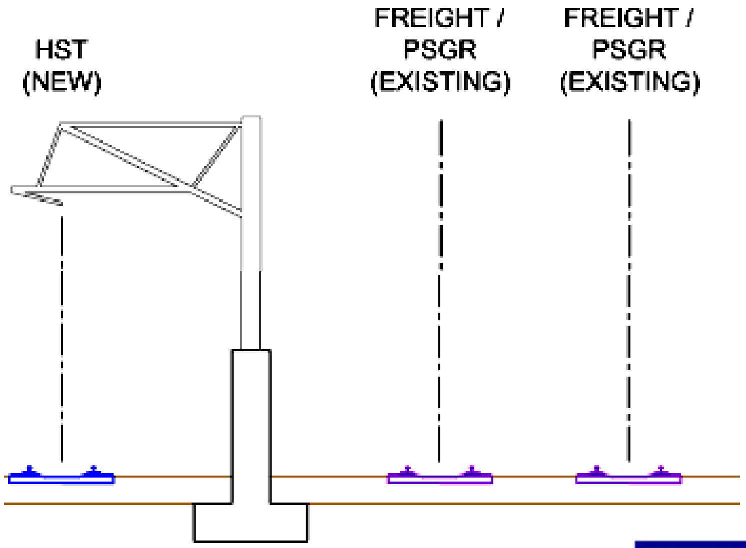
Adjacent Track Accidents (ATA)

- 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:

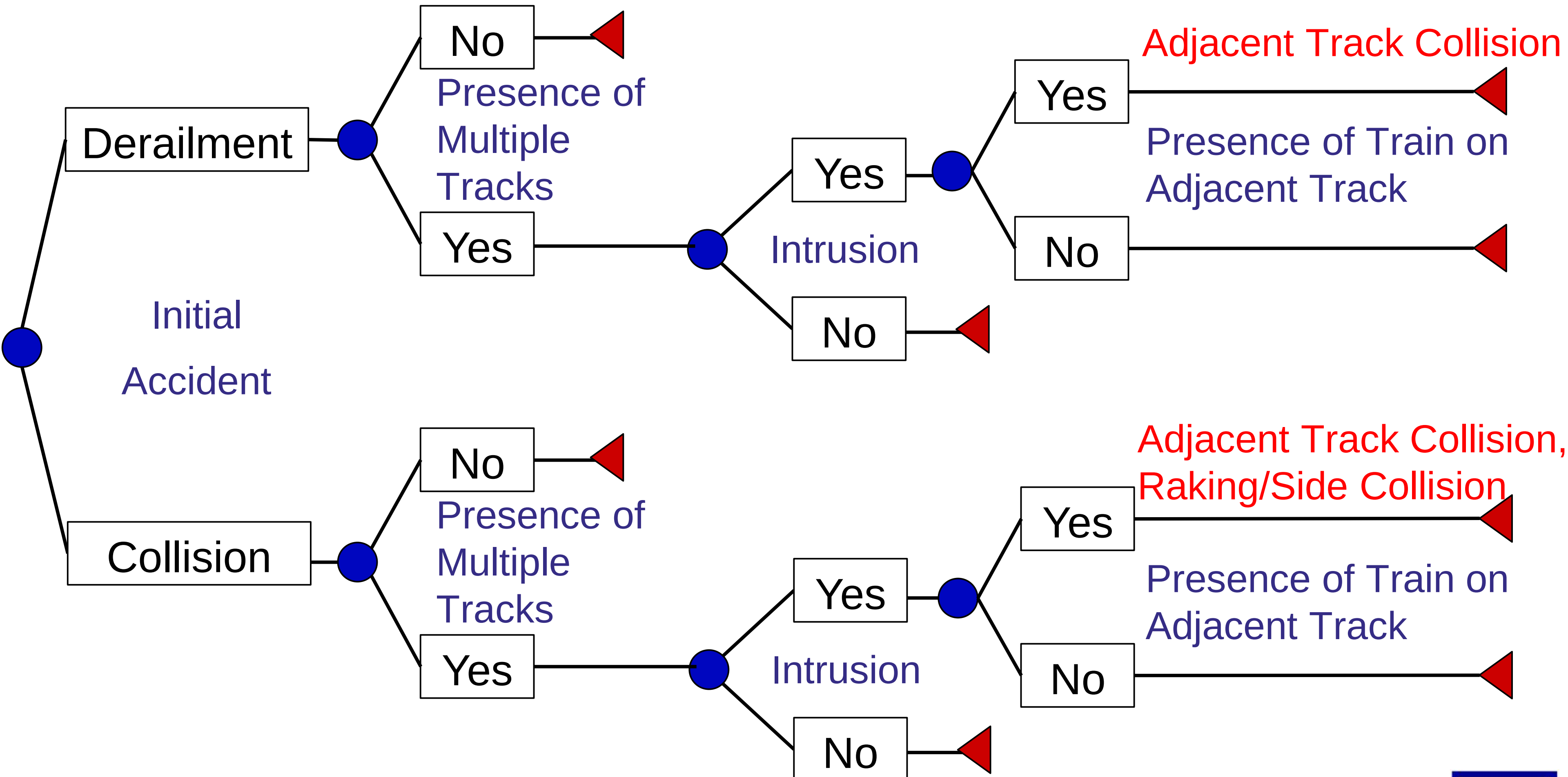


Adjacent Track Accident

- 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



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) X	P(I|A) X	P(T|I) X	C
	Derailment Collision	Intrusion	Train Presence	Consequence
	-Infrastructure Quality -Method of Operation -Traffic Density -Train Defect Detector	-Track Center spacing -Train Speed -Track Alignment -Geographic Condition -Elevation Differential -Containment -Adjacent Structure -Derailment Mechanism	-Traffic Density -Method of Operation -Train Speed -Intrusion Detection	-Train Speed -Equipment Damage Resistance -Containment -Hazmat

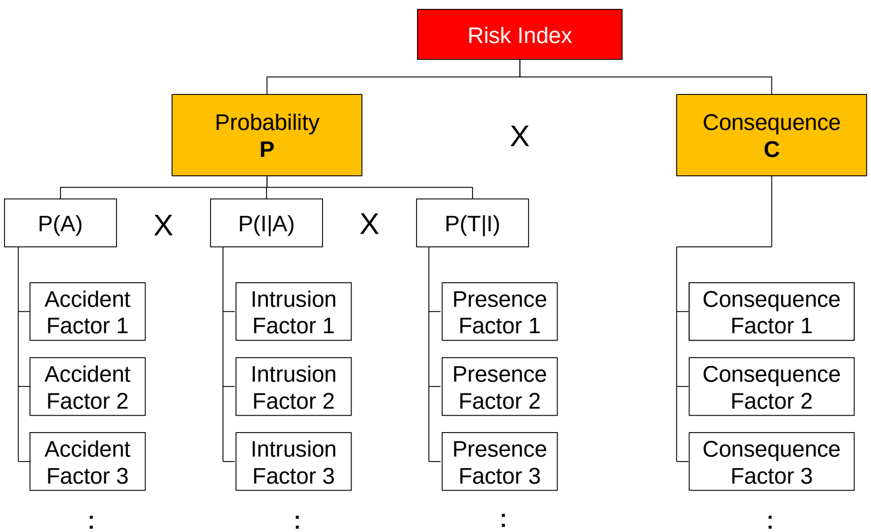
Train Accident Analysis

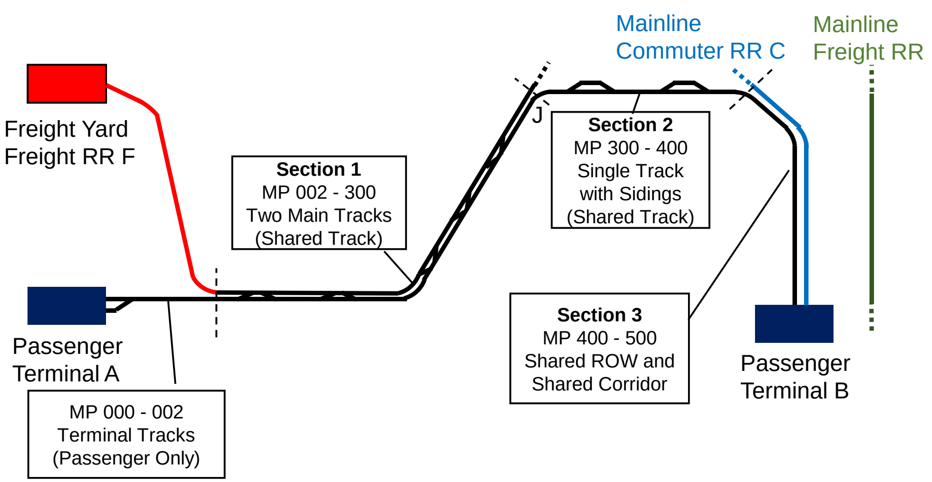
Precursor Analysis

Potential Application of the Risk Model

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

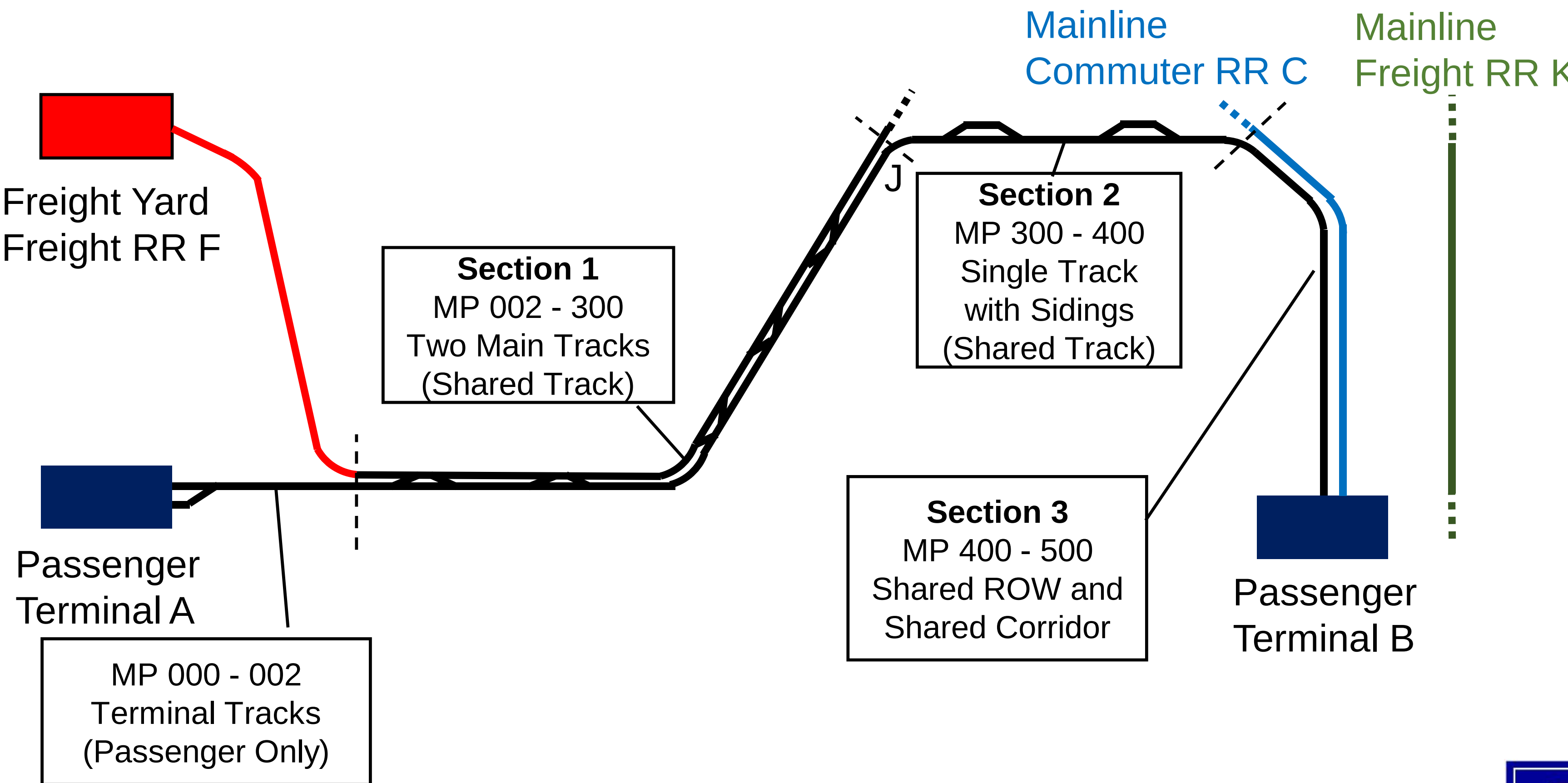
- Calculate and compare ATA risk of different segment on the shared-rail corridor network.
- Identify the “risk hotspot” of the network
- Evaluate the implementation of risk mitigation strategies.



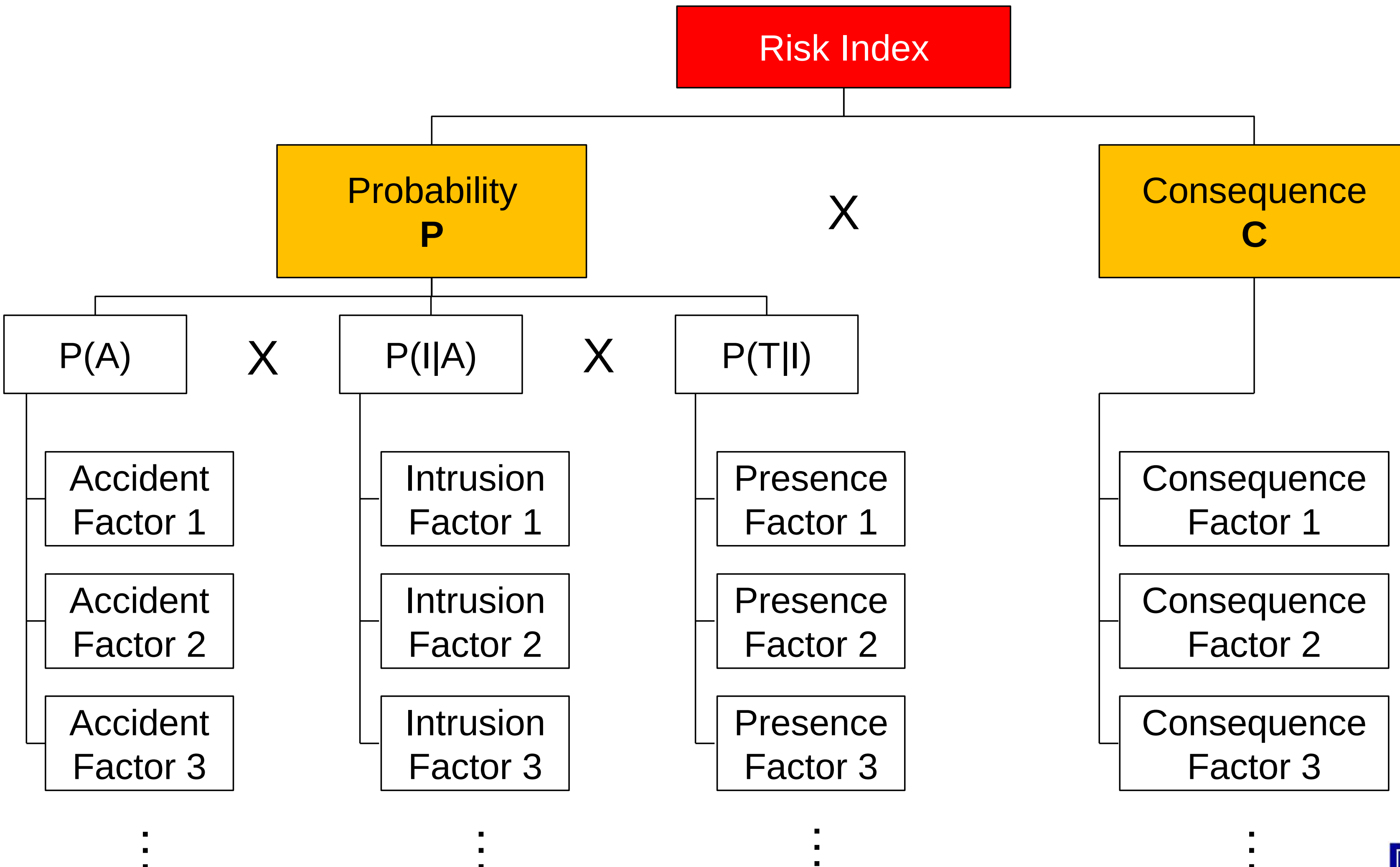


Case Study

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



Case Study


Risk Index
Probability
P
X
Consequence
C
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 Factor 1
Consequence Factor 2
Consequence Factor 3

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 Unites 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

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U.S. Department of Transportation
Federal Railroad Administration

Thank you!

Questions and comments are Welcomed!

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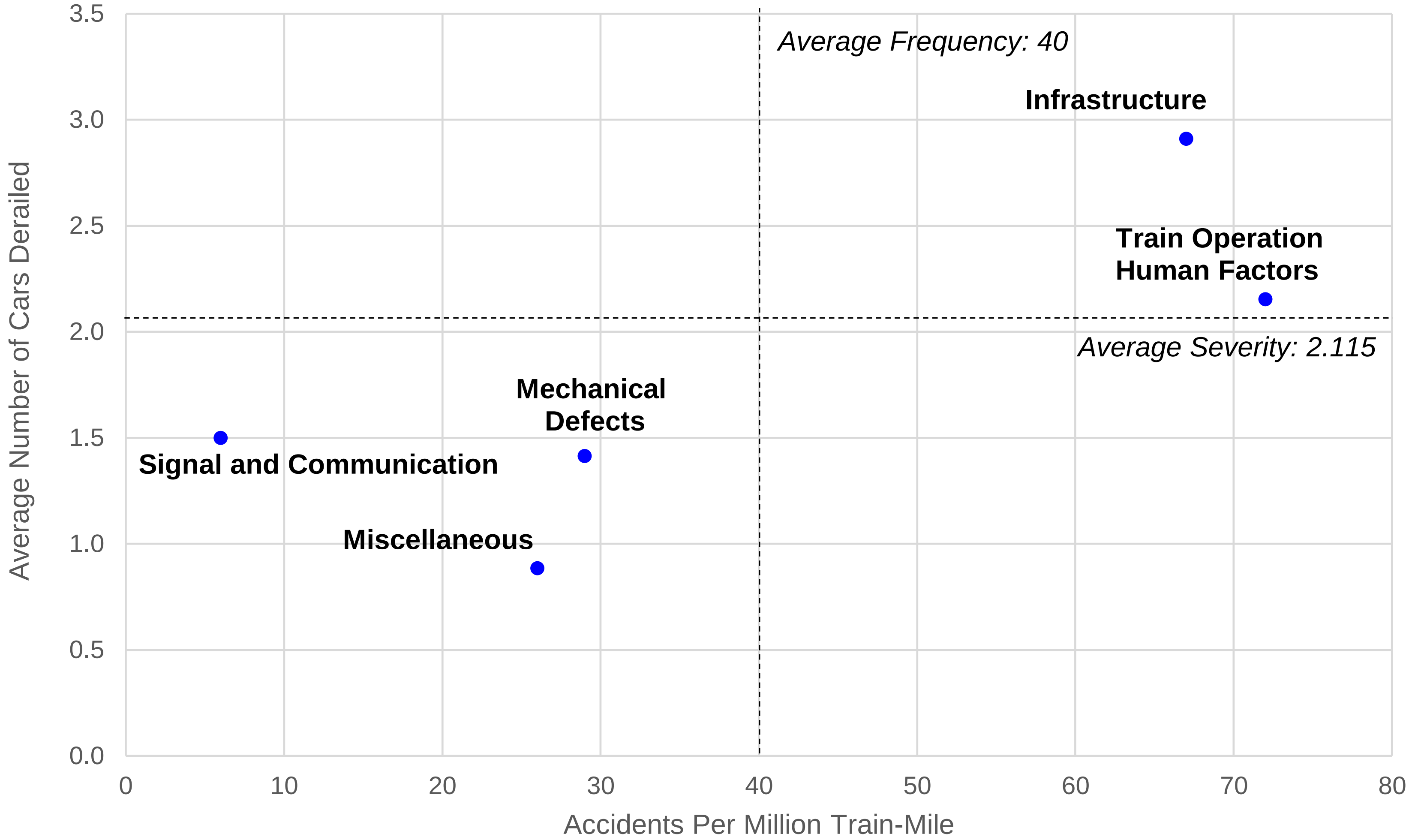
Mainline Passenger Train Accident Analysis

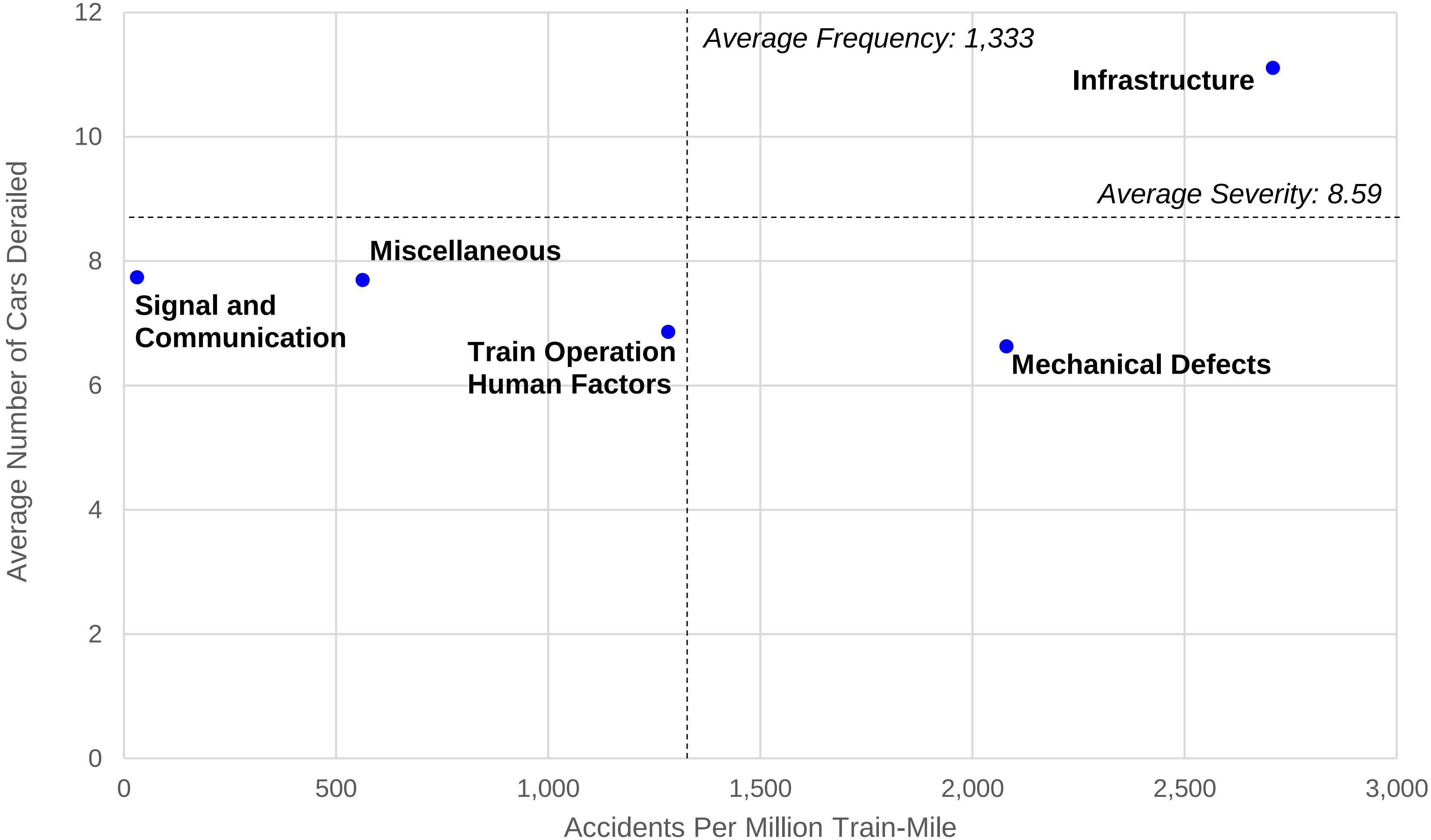


Mainline Passenger Train Accident Analysis

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



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)