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Light Rail and Heavy Rail Shared Corridor Risk and Safety Management

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Agenda

- **Context**
- Adjacent Track Accident (ATA) Risk Index methodology
- Scenario analysis
- Methodology advantages

Context

Key transit corridors under pressure to accommodate greater volume of traffic and to share corridor with different modes of transit.

FRA defines shared corridor as:

- **Shared track:** tracks shared between light rail passenger and freight or other service (Time separation no simultaneous operation)
- **Shared right of way (ROW):** dedicated passenger tracks separated from freight or other service tracks up to 25’
- **Shared corridor:** dedicated passenger tracks separated from freight or other service tracks by 25-200’

Context

– Due to differences in **mass** between **heavy rail** and **light rail** vehicles, **consequences** of an accident would be **extreme**. **FRA crashworthiness** requirement in place to **ensure suitability** of railway vehicles to operate on shared lines and to **reduce consequences** of **accident.**

– November 2018, FRA Passenger Equipment Safety Standards updated to include "**Standards for Alternative Compliance and High-Speed Trainsets**" and facilitate the **safe implementation** of **interoperable** high-speed passenger rail service at speeds **up to 220 mph.**

Context

No regulation in Canada for the proximity of heavy rail and light rail.

A few applicable regulations:

- **TC E-05:** Heavy rail static railway clearance envelope and track center to center clearance distances.
- **2011 AECOM report to Transport Canada**: Recommending common corridor practices, including minimum track center distances.
- **AREMA Section 1.1.5.1**: Pier protection requirements for structures adjacent to railroad Tracks.
- **NURAIL** (University of Illinois, 2013): Shared Rail Corridor Adjacent Track Accident (ATA) Risk Analysis.

Context

The following criteria were identified as applicable:

- **Adjacent track centers distances** for conventional track is 14’ with a **13’ minimum** and allowance for curvature.

- Conventional distance from **Center Line to Center Line of an adjacent Track** is considered **14’**, and the conventional distance from **Center Line to Face of Structure to an adjacent Structure** is 18’ but can be as low as **12’**.

- Adjacent track center distances between heavy and light rail at which **no special protective measures** are required is **25’**.

How to **assess** the **risks** associated with **varying** track **conditions**, adjacent track distances, and mitigation measures?

National University Rail Center

US DOT OST-R Tier 1 University Transportation Center

NURail Center

USDOT Tier 1 University Transportation Center Final Report

NURail Project ID: NURail2013-UIUC-R08

Shared Rail Corridor Adjacent Track Accident Risk Analysis

Semi-quantitative risk assessment of adjacent track accidents on shared-use rail corridors

Chen-Yu Lin, Mohd Rapik Saat

ARTICLE INFO

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Shared-Use Corridor

ABSTRACT

Safety is a high priority for any rail system. There are several safety concerns associated with operating passenger and freight trains on shared-use rail corridors. Adjacent track accident (ATA) is one of the most important concerns. ATA mainly refers to a train accident scenario where a derailed 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), turnouts and railroad crossings. Limited literature is available that addresses the risk of ATA for shared-use rail corridors. The research described in this paper presents a comprehensive risk assessment to identify and quantify the effect of factors affecting the likelihood and consequence of ATA. A discussion on how these factors affect the probability and consequence is provided. A semi-quantitative risk analysis model is developed to evaluate the ATA risk incorporating various factors affecting train accident rate, intrusion rate, train presence rate, and accident consequences. A case study with a hypothetical railroad network is presented to illustrate the potential application of the risk model. This research intends to depict a high-level overview of adjacent track accident risk and provides a basis for future quantitative risk analyses and risk mitigation.

Agenda

- Context
- **Adjacent Track Accident (ATA) Risk Index methodology**
- Scenario analysis
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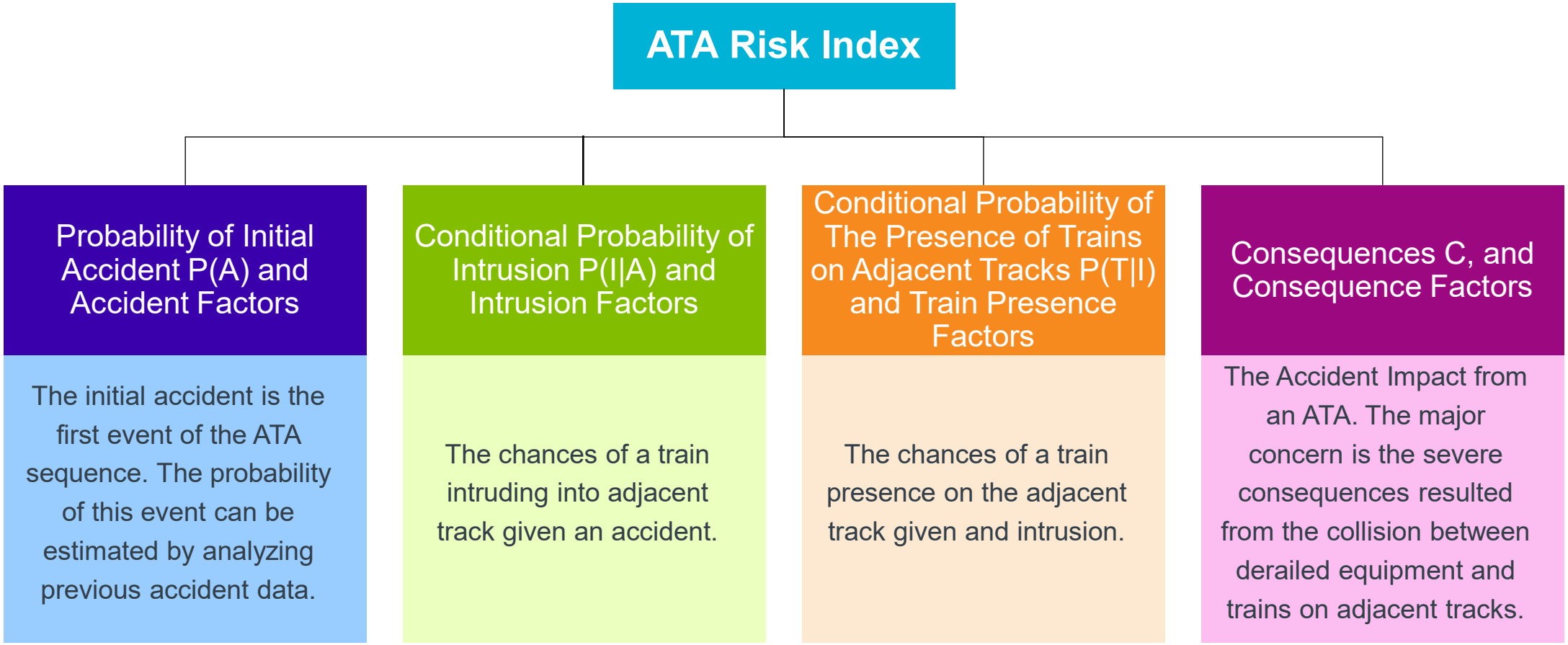
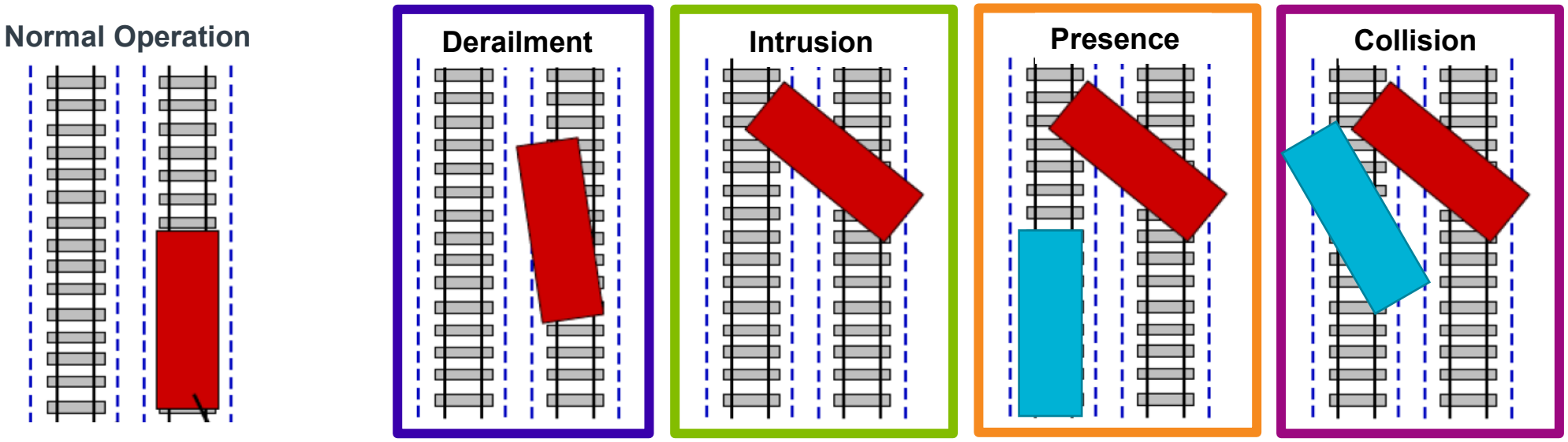
University of Illinois Adjacent Track Accident (ATA) Risk Analysis



NURail ATA Risk Index– Adjacent Track Accident

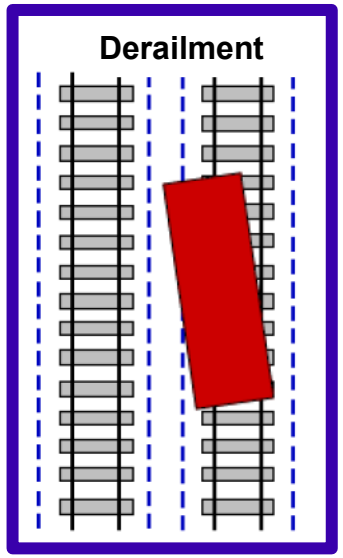
$$R = P(A) \times P(I|A) \times P(T|I) \times C$$



Source: C. Lin/ M. Saat - Semi-quantitative Risk Assessment Of Adjacent Track Accidents On Shared-use Rail Corridors

$$\text{Risk} = \underset{\text{Derailment}}{\text{Probability of}} \times \underset{\text{Intrtusion}}{\text{Probability of}} \times \underset{\text{Train Prescence}}{\text{Probability of}} \times \text{Consequence}$$

Probability of Initial Accident P(A) and Accident Factors



Conditional Probability of Intrusion P(I|A) and Intrusion Factors

Conditional Probability of The Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

Consequences C, and Consequence Factors

Accident Factor	Criteria	Accident Factor Score
Track Class ▪ **Track quality** ▪ **Inspection frequency**	6 or above	1.0
	5	2.0
	4	4.0
	2, 3	8.0
	X, 1	16.0
Traffic Density ▪ **Type of rolling stock**	*Freight train only or shared freight and passenger tracks*	
	More than 60 MGT	1.0
	40 - 60 MGT	1.4
	20 - 40 MGT	2.0
	Less than 20 MGT	4.0
	Passenger train only lines	
	Dedicated passenger lane	1.0
Method of Operation ▪ **Signaling system**	Signaled	1.0
	Non-signaled	1.5

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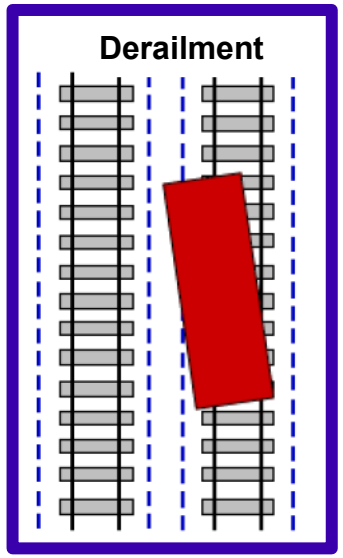
Probability of Initial Accident P(A) and Accident Factors



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Total Accident Factor Score (AFS)	Level of P(A)
AFS ≤ 3	1.0
3 < AFS ≤ 10	2.0
10 < AFS ≤ 20	3.0
20 < AFS ≤ 45	4.0
AFS > 45	5.0

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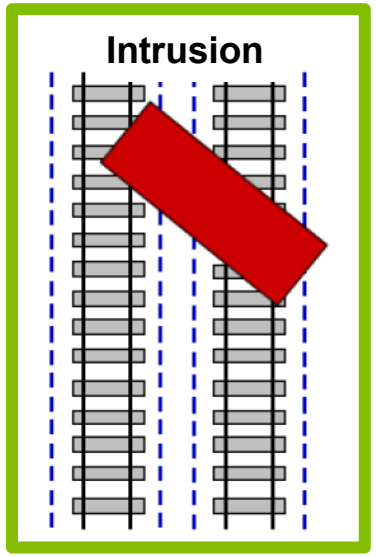

Conditional Probability of the Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

Consequences C, and Consequence Factors

Intrusion Factor	Criteria	Intrusion Factor Score (IFS)
▪ **Distance Between Track Centers, X in ft. (meters)**	X > 80 (24.4)	1.0
	55 (16.7) < X ≤ 80 (24.4)	1.5
	30 (9.1) < X ≤55 (16.7)	2.0
	15 (4.5) < X ≤ 30 (9.1)	3.0
	X ≤ 15 (4.5)	5.0
▪ **Track Alignment**	Tangent and level	1.0
	Tangent and on gradient	1.1
	Curve and level	1.5
	Curve and on gradient	1.7
▪ **Track Elevation Differential**	Adjacent track is 10 ft. higher	0.7
	Adjacent track is level	1.0
	Adjacent track is 10 ft. lower	1.3
▪ **Adjacent Structure**	No adjacent structure	1.0
	Single structure	1.1
	Discrete structure	1.2
	Continuous structure	1.3
▪ **Containment**	All containments installed	0.5
	Physical barrier and Guard Rail or Parapet installed	0.6
	Physical barrier installed only	0.7
	Parapet and Guard Rail installed	0.8
	Parapet or Guard Rail installed only	0.9
	No containment installed	1.0
▪ **Train Speed**	Low (less than 40 mph)	1.0
	Medium (40 mph to 70 mph)	1.2
	High (more than 70 mph)	1.4

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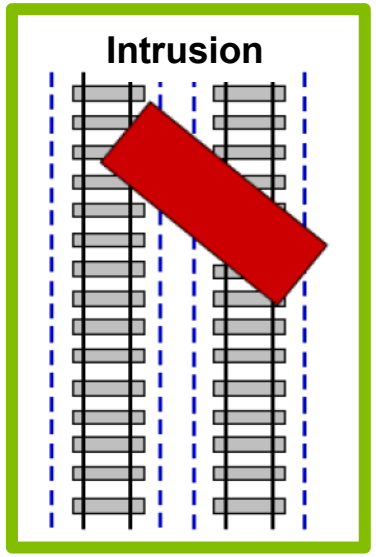

Conditional Probability of the Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

Consequences C, and Consequence Factors

Total Intrusion Factor Score (IFS)	Level of CPI
IFS ≤ 2	1.0
2 < IFS ≤ 3	2.0
3 < IFS ≤ 5	3.0
5 < IFS ≤ 10	4.0
IFS > 10	5.0

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Probability of Initial Accident P(A) and Accident Factors

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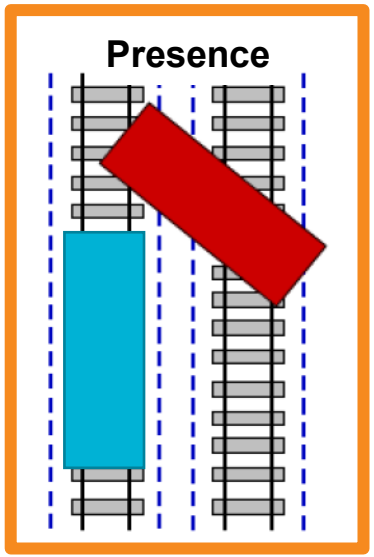

Consequences C, and Consequence Factors

Train Prescence Factor	Criteria	Train Prescence Factor Score
Intrusion Detection and Warning System	Present	1.0
	Absent	2.0
▪ **Traffic Density**	*Freight train only or shared freight and passenger tracks*	
	More than 60 MGT	1.0
	40 - 60 MGT	1.4
	20 - 40 MGT	2.0
	Less than 20 MGT	4.0
	Passenger train only lines	
	Dedicated passenger lane	1.0
▪ **Method of Operation**	Advanced train control	1.0
	Typical train control	2.0
	Dark territory	3.0
▪ **Train Speed**	Low (less than 40 mph)	1.0
	Medium (40 mph and 70 mph)	2.0
	High (more than 70 mph)	3.0

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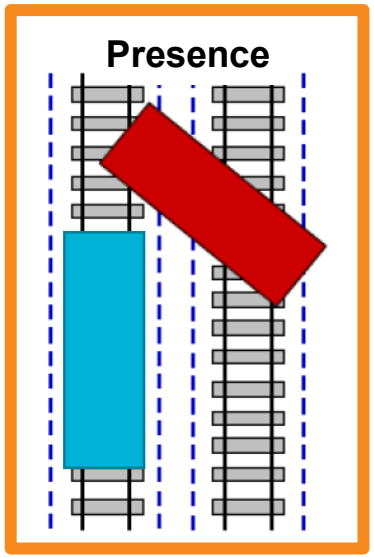

Consequences C, and Consequence Factors

Train Presence Factor Score (TPS)	Level of P(T|I)
TPS ≤ 3	1.0
3 < TPS ≤ 6	2.0
6 < TPS ≤ 12	3.0
12 < TPS ≤ 24	4.0
TPS > 24	5.0

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Probability of Initial Accident P(A) and Accident Factors

Conditional Probability of Intrusion P(I/A) and Intrusion Factors

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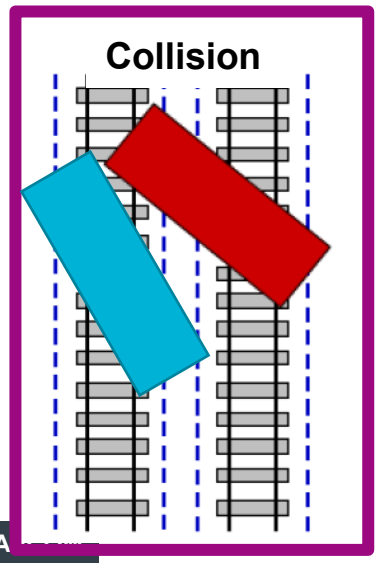
Consequences C, and Consequence Factors



Consequence Factor	Criteria	Consequence Factor Score
▪ **Equipment Strength**	Reinforced equipment	1.0
	Traditional equipment	2.0
▪ **Speed**	Low (Less than 40 mph)	1.0
	Medium (40 mph and 70 mph)	2.0
	High (More than 70 mph)	3.0
▪ **Containment**	Present	1.0
	Absent	2.0
▪ **Product Being Transported**	Non-hazardous material	1.0
	Hazardous material	2.0

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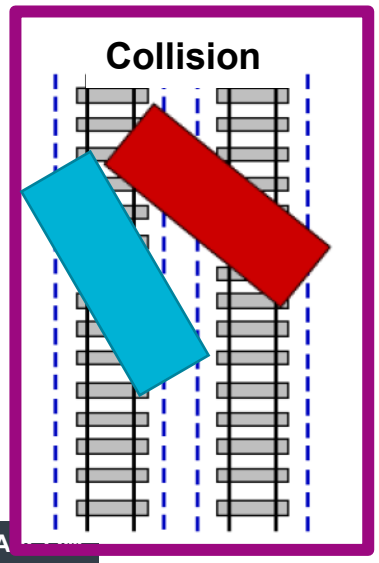

Consequence Factor Score (CFS)	Level of Consequence
CFS ≤ 3	1.0
3 < CFS ≤ 6	2.0
6 < CFS ≤ 10	3.0
10 < CFS ≤ 15	4.0
CFS > 15	5.0

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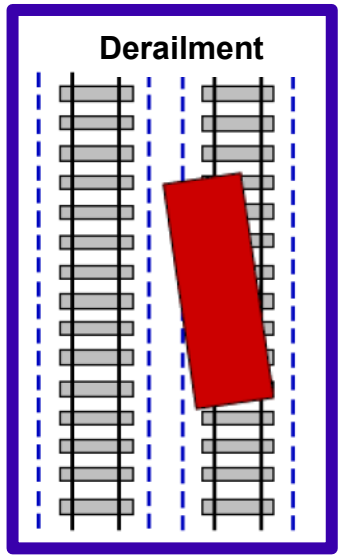

Conditional Probability of Intrusion P(I|A) and Intrusion Factors

Conditional Probability of The Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

Consequences C, and Consequence Factors

Accident Factor	Criteria	Accident Factor Score
Track Class	6 or above	1.0
▪ **Track quality**	5	2.0
	4	4.0
▪ **Inspection frequency**	2, 3	8.0
	X, 1	16.0
Traffic Density	*Freight train only or shared freight and passenger tracks*	
▪ **Type of rolling stock**	*More than* 60 MGT	1.0
	40 - 60 MGT	1.4
	20 - 40 MGT	2.0
	Less than 20 MGT	4.0
	Passenger train only lines	
	Dedicated passenger lane	1.0
Method of Operation	Signaled	1.0
▪ **Signaling system**	None-signaled	1.5

$$Total\ Accident\ Factor\ Score = Track\ Class \times Traffic\ Density \times Method\ of\ Operation$$

AFS = 3

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Probability of Initial Accident P(A) and Accident Factors

Total Accident Factor Score (AFS)	Level of P(A)
AFS ≤ 3	1.0
3 < AFS ≤ 10	2.0
10 < AFS ≤ 20	3.0
20 < AFS ≤ 45	4.0
AFS > 45	5.0

P(A) = 1

Conditional Probability of Intrusion P(I|A) and Intrusion Factors

Total Intrusion Factor Score (IFS)	Level of CPI
IFS ≤ 2	1.0
2 < IFS ≤ 3	2.0
3 < IFS ≤ 5	3.0
5 < IFS ≤ 10	4.0
IFS > 10	5.0

P(I|A) = 4

Conditional Probability of The Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

Train Presence Factor Score (TPS)	Level of P(T|I)
TPS ≤ 3	1.0
3 < TPS ≤ 6	2.0
6 < TPS ≤ 12	3.0
12 < TPS ≤ 24	4.0
TPS > 24	5.0

P(T|I) = 3

Consequences C, and Consequence Factors

Consequence Factor Score (CFS)	Level of Consequence
CFS ≤ 3	1.0
3 < CFS ≤ 6	2.0
6 < CFS ≤ 10	3.0
10 < CFS ≤ 15	4.0
CFS > 15	5.0

C = 3

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Probability of Initial Accident P(A) and Accident Factors

P(A) = 1

Conditional Probability of Intrusion P(I|A) and Intrusion Factors

P(I|A) = 4

Conditional Probability of The Presence of Trains on Adjacent Tracks P(T|I) and Train Presence Factors

P(T|I) = 3

Consequences C, and Consequence Factors

C = 3

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

$$= 1 \times 4 \times 3 = 12$$

$P(A) \times P(I\|\mathrm{A}) \times P(T\|\mathrm{I})$	**Overall Probability Level, P**
1 < P ≤ 10	1.0
10 < P ≤ 20	2.0
20 < P ≤ 30	3.0
30 < P ≤ 50	4.0
P > 50	5.0

$$\textit{ATA Risk Index} = P \times C = 2 \times 3 = 6$$

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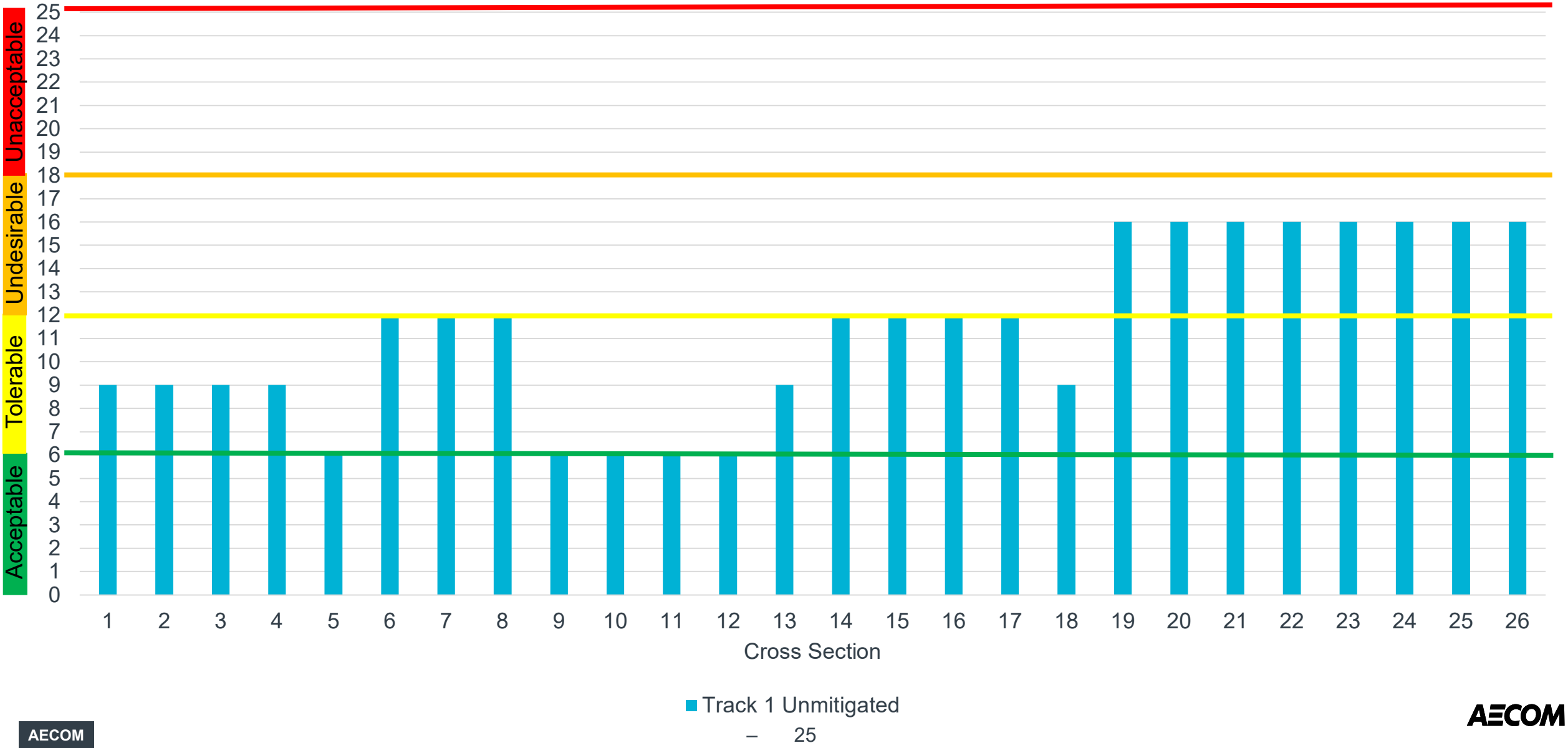
NURail ATA Risk Index Risk Acceptability Level Correspondence

– ATA Risk Index Conversion to European Committee for Electrotechnical Standardization (CENELEC)

		Severity Level (CENELEC) = Consequence, C (NURail)			
		Catastrophic	Critical	Marginal	Negligible
Frequency (CENELEC) = Probability, P (NURail) P = (P(A) × P(I|A) × P(T|I))	Frequent	19-25	Unacceptable	Unacceptable	Undesirable
	Probable	Unacceptable	Unacceptable	Undesirable	Tolerable
	Occasional	Unacceptable	13-18	Undesirable	Tolerable
	Rare	Undesirable	Undesirable	7-12	Acceptable
	Improbable	Tolerable	Tolerable	Acceptable	1-6
	Unlikely	Acceptable	Acceptable	Acceptable	Acceptable

Results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Cross Section
Track 1 Unmitigated
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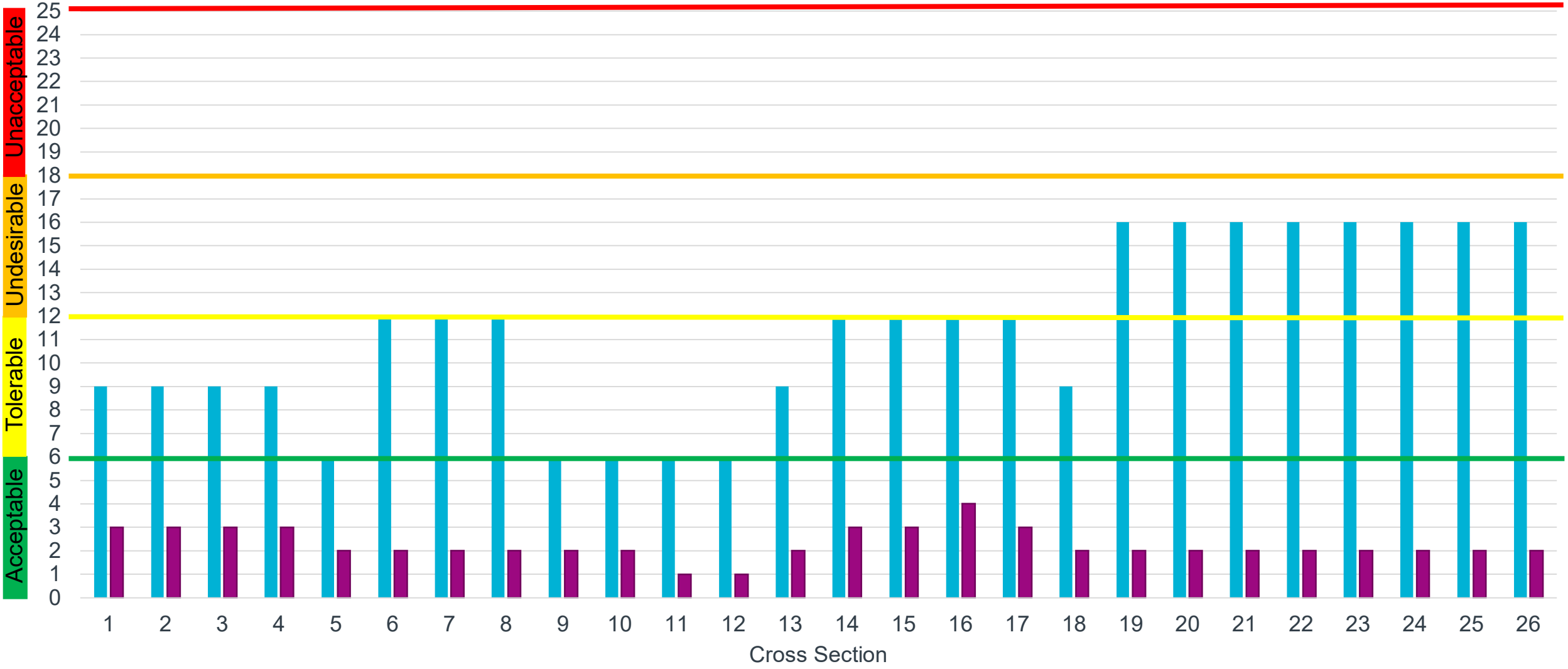
Results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Cross Section
Track 1 Unmitigated
Track 2 Unmitigated

Mitigation Measures

Physical protection:

- Physical separation through increased track centers
- Crash Protection Walls
- Guard Rails
- Restraining Rails
- Elimination of special trackwork


Restraint Rail


Guard Rails

Mitigation Measures

Control systems:

- Signal Systems
- Defect Detectors
- Derailment detection
- Intrusion protection
- Increased FRA Track Class


Restraint Rail


Guard Rails

Mitigation Measures

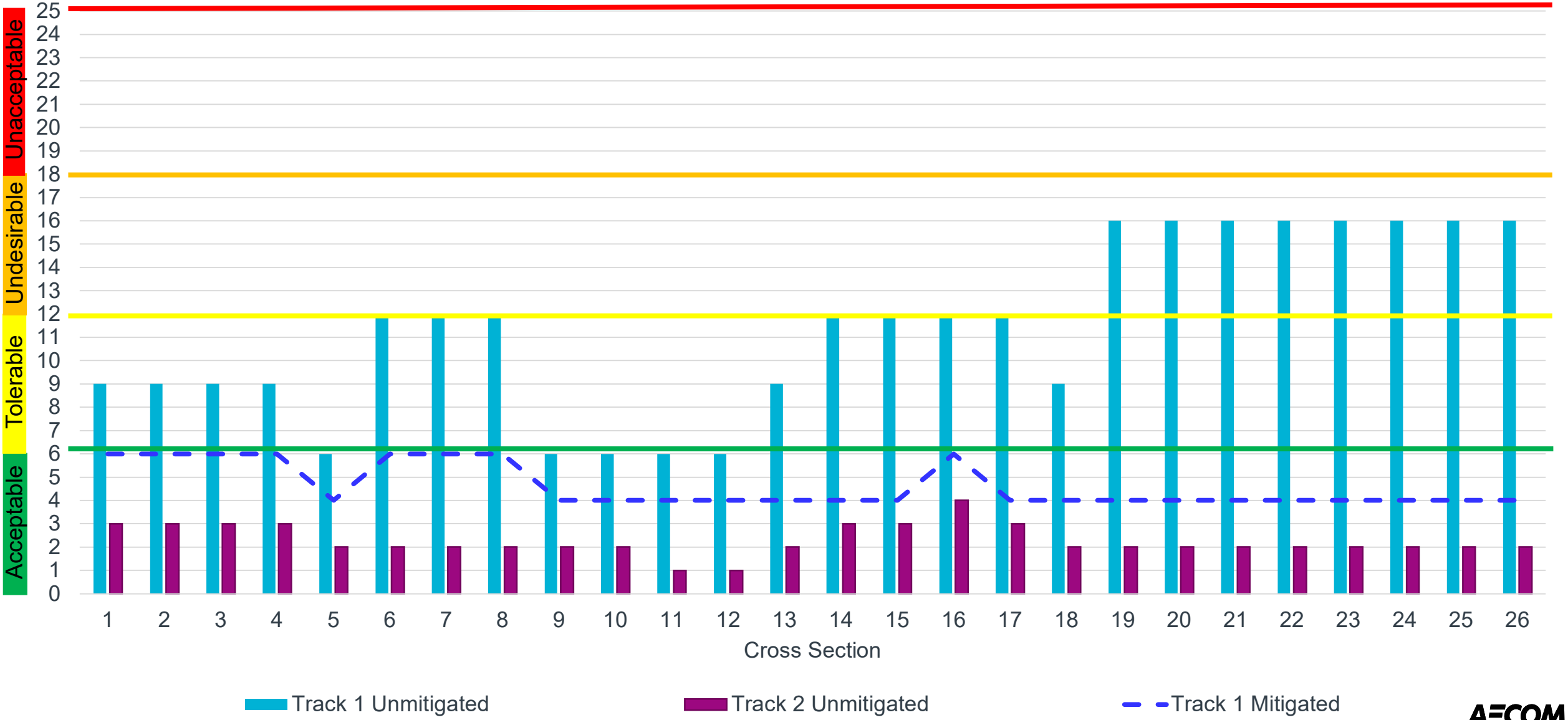
Operational measures:

- Exclusive passenger corridors
- Reduced operating speed


Restraint Rail


Guard Rails

Results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Cross Section
Track 1 Unmitigated
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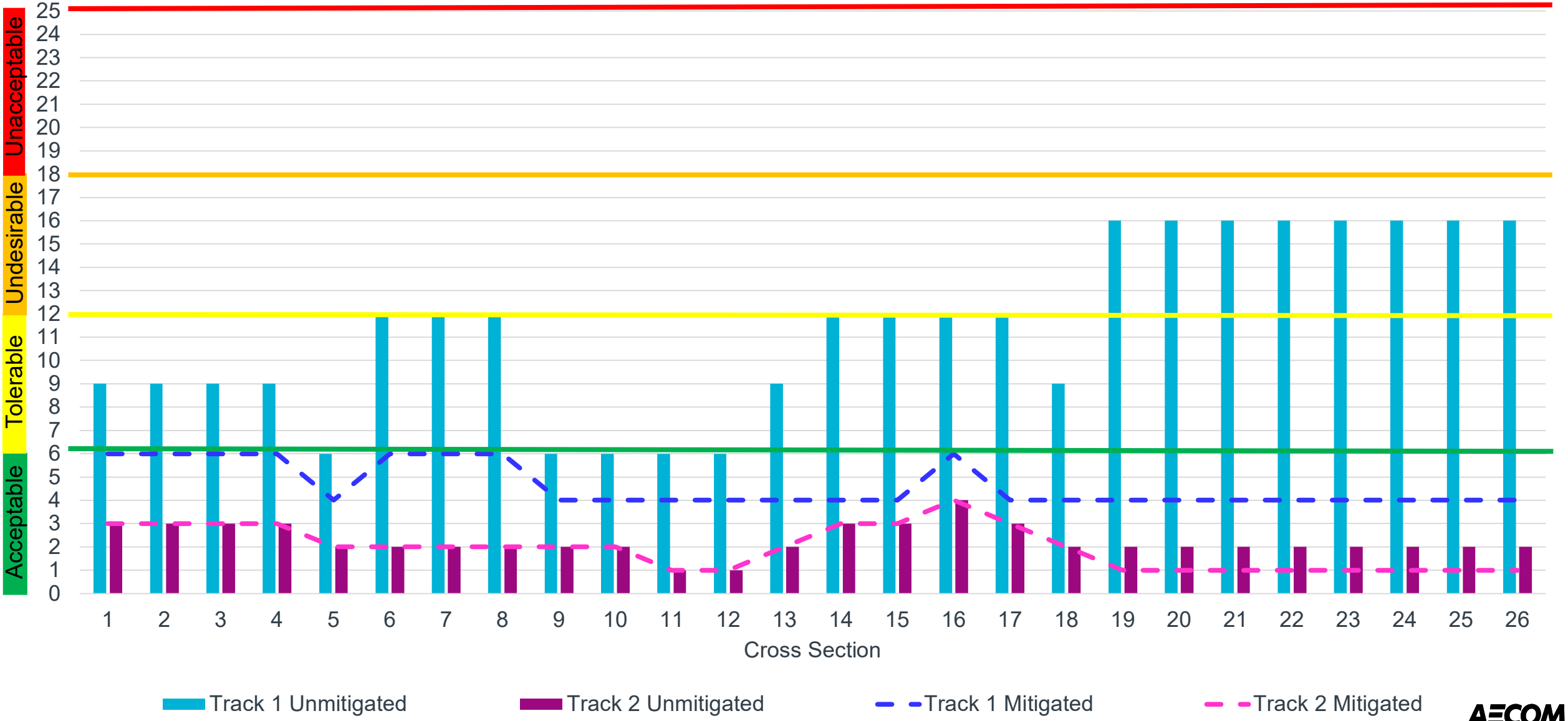
Track 1 Mitigated

Results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Cross Section
Track 1 Unmitigated
Track 2 Unmitigated
Track 1 Mitigated
Track 2 Mitigated

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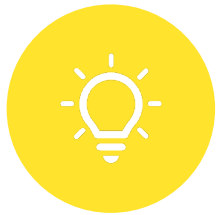
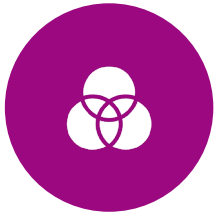
Adjacent Track Risk Analysis Benefits



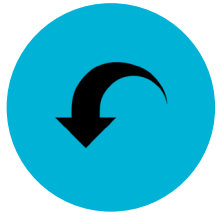
Allows for a **Unified Risk Rating Methodology** throughout shared corridors.

Comprehensible and comparable by **multidisciplinary teams** with multiple decision makers and stakeholders.

Assesses the **effectiveness** of **mitigation measures**.



Allows for the assessment of **multiple mitigation measures** and **alternative scenarios**.



Can be converted to **Standard Risk Acceptability Levels**.

Questions?

https://blogs.lt.vt.edu/yasamanshahtaheri/

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