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| 13. ABSTRACT (Maximum 200 words) The Federal Railroad Administration (FRA) set out to develop a best practices document which provides information on the design considerations and potential risk mitigations for high-speed rail (HSR) systems adjacent to and sharing corridors with existing conventional railway operations. The objective of this project is to provide input to and support the development of the best practices document by conducting a comprehensive literature review of the 11 hazards associated with HSR operations adjacent to conventional tracks that were identified by FRA. This report is the first part of the three-part project that defines the scope of the literature review and summarizes the results from the literature review. Causal analysis was conducted for mainline passenger and freight train accidents to understand major factors leading to passenger and freight train accidents and identify accident causes that are more relevant to HSR systems adjacent to and sharing corridors with existing conventional railway operations. | | | | | | |
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Executive Summary

Booz Allen Hamilton (Booz Allen) and the Rail Transportation and Engineering Center (RailTEC) in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign (UIUC) were requested by the Federal Railroad Administration (FRA) to assist in the development of a best practices document which provides information on the design considerations and potential risk mitigations for high-speed rail (HSR) systems adjacent to and sharing corridors with existing conventional railway operations. With the increasing demand for HSR operations, the potential hazards between HSR tracks and adjacent conventional tracks became more pronounced and needed to be considered. The objective of this project is to provide input to and support the development of the best practices document by conducting a comprehensive literature review of the following hazards associated with HSR operations adjacent to conventional tracks:

- Derailment on adjacent tracks
- Shifted load on adjacent tracks
- Aerodynamic interaction between trains on adjacent tracks
- Ground-borne vibration and its effect on HSR track geometry
- Intrusion of maintenance-of-way (MOW) 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

The initial literature review was enhanced by an additional, detailed literature review on specific hazards that FRA deems as requiring more information as well as train accident analyses to identify accident causes that are relevant to shared corridor operations. Booz Allen and RailTEC then developed a draft best practices document based on the enhanced literature review and additional risk analyses. The project consists of three parts: (1) a summary report that defines the scope of the literature review and summarizes the results from the comprehensive literature review; (2) a draft best practices document for understanding, addressing, and mitigating the risk of HSR systems adjacent to and sharing corridors with existing conventional railway operations using qualitative and quantitative risk management approaches; and (3) a complete and enhanced literature review of mitigating the risk of HSR systems adjacent to and sharing corridors with existing c

This report presents the first part of the project. An overview of the literature review and a comparison of the literature review and an enhanced literature review were presented. Results from the enhanced literature review were summarized, including eminent location where the aforementioned hazards may occur, key influencing factors of these hazards, and potential risk mitigation strategies for these hazards. Causal analysis was conducted for mainline passenger and freight train accidents to understand major factors leading to passenger and freight train accident causes that are more relevant to HSR systems adjacent to and sharing corridors with existing conventional railway operations.

1. Introduction

The following paragraphs give the overview of this summary report, including the background and objective of the literature review, approaches used to conduct the literature review, scope of this study, and the organization of the report.

1.1 Background

To address the existing gap between the literature review and the best practices document, Booz Allen Hamilton proposed the second phase of this effort, the development of an enhanced literature review. As demonstrated in Figure 1.1, the enhanced literature review will bridge the gap between these two major efforts and result in a somewhat lower effort required to develop the best practices document. The enhanced literature review will be designed and developed to resemble the best practices document but with more technical detail to evaluate and prioritize the importance of hazards, while the objective of the best practices document is still to provide information on the design considerations, potential risk mitigations for hazards related to the operation of high-speed rail (HSR) systems adjacent to and sharing corridors with existing conventional railway operations. The enhanced literature review will therefore include a risk quantification component.



Figure 1.1 Relative Level of Effort

1.2 Objectives

The primary objectives of the enhanced literature review include the following:

- 1. Conduct a detailed analysis to define and/or refine and describe in enhanced detail the hazards associated with HSR and conventional rail operations.
- 2. Implement screening procedures to identify locations where each hazard is eminent.
- 3. Add influencing factors or precursors of each hazard which can be used as potential metrics to assess the hazard.
- 4. Propose mitigation strategies to address the hazard.

1.3 Overall Approach

Table 1.1 is a comparison of the first two phases, the literature review and enhanced literature review.

| | Literature Review (Phase I) | Enhanced Literature Review (Phase II) | | |
|--|--|--|--|--|
| Hazards Focus | The following hazards were researched: 1. Derailment on adjacent tracks 2. Shifted load on an adjacent track | A secondary, more thorough, review of the 11 hazards will occur, but will focus on those FRA deems as requiring more information. The team will synthesize the literature review to identify: | | |
| | 3. Aerodynamic interaction between trains on adjacent tracks | 1. Potential locations on a typical HSR system where each hazard is eminent | | |
| 4. Ground-borne vibration and its effect on HSR track geometry | | 2. Influencing factors or precursors of each hazard that can be used as potential metrics to | | |
| | 5. Intrusion of maintenance-of-way MOW staff and equipment working on the adjacent track | assess the hazard3. Mitigation strategies to address each hazard. | | |
| | 6. Obstruction hazard resulting from an adjacent track (non-derailment and grade-crossing collisions) | 4. Input from Class I railroads, state agencies (especially in CA and IL), and international railway operators will be gathered and evaluated. | | |
| | 7. Drainage problem affecting either the HSR track or the adjacent track, | | | |
| | 8. Evacuation of passengers from trains on the adjacent track | | | |
| | 9. Hazardous materials on the adjacent track | | | |
| | 10. Fire on the adjacent track | | | |
| | 11. Electromagnetic interference (EMI) between trains and wayside equipment on adjacent tracks | | | |
| Research Methodology | A standard literature search methodology, using a combination of academic journal subscriptions (owned by UI) as well as Internet research, was performed. | A combination of standard literature search methodology, fault tree analysis, and other risk assessment techniques, interviews, and surveys will be implemented. | | |
| | Literature Review (Phase I) | Enhanced Literature Review (Phase II) | | |
| FRA Rail Equipment Accident/ Incident Database Review | No review of the database was performed. | A thorough analysis of the database will be conducted to identify conventional train accident causes which may be relevant to future HSR operations adjacent to conventional tracks. The intention of the analysis is to deduce high-priority accident causes of conventional passenger and freight train operations on multiple-track or shared corridors. | | |
| Risk Identification | A risk identification phase was performed with some initial risk mitigations identified in an overall risk management framework. Limited quantitative analysis was performed for the defined hazards. However, an appendix was added to the literature review to include a semi- quantitative risk model developed by the | The identification of influencing factors and precursors of hazards will be performed to assist in the development of risk metrics and, ultimately, the best practices document. Additional risk mitigations will be identified and evaluated. Guidelines to create risk inventory or risk register to record HSR-project-specific hazards, assessments of the associated | | |

Table 1.1 Comparison of Literature Review and Enhanced Literature Review

| | Literature Review (Phase I) | Enhanced Literature Review (Phase II) |
|--|---|--|
| | RailTEC team. This analytical model can be used to prioritize and mitigate the risk focusing on adjacent-track accidents. | influencing factors or precursors, and planned/completed risk mitigation strategies will be developed. |
| Human Factors (HF) | Limited recommendations on HF training was developed. HF training focused on the loading/unloading and MOW worker hazard. | Recommendations of training to improve overall HF performance will be included. |
| Domestic Stakeholder Outreach | Limited domestic stakeholder outreach occurred. | In this phase, the team will reach out to Class I railroads and state agencies (especially in CA and IL) to gather and review existing practices to manage associated risks. The team will incorporate their relevance to achieve the objective of this phase. |
| International Stakeholder Outreach | Limited international research was considered. Only publicly-available literature on the international experience was performed. | The initiation of a new survey and interviews will be performed involving rail operators and industry stakeholders in Europe (e.g., Société nationale des chemins de fer français in France, Administrador de Infraestructuras Ferroviarias in Spain, and/or ItaliaRail in Italy), and in Asia (rail operators in China, Taiwan, and/or Thailand). The purpose will be to obtain and review internal reports, manuals, or experiences they can share. To address this component fully, however, would require the development of new surveys and interviews with rail operators in those countries. |

1.4 Scope

The scope of this research focuses on identifying locations with higher risk influencing factors and risk mitigation strategies related to the safety issues of operating HSR adjacent to conventional railroad corridors.

1.5 Organization of the Report

After the Introduction, Section 2 summarizes high-risk locations, influencing factors, and potential risk mitigation strategies for the 11 hazards related to HSR operations adjacent to conventional railroad systems. Section 3 presents a passenger train accident analysis on shared-use rail corridors and identified major train accident causes. Section 4 presents conclusions based on previous analyses.

2. Literature Review Summary

The previously completed literature review report from Phase III of this project was synthesized and an additional literature review was completed to identify (1) potential locations on a typical HSR system where each hazard is eminent, (2) the influencing factors or precursors of each hazard that can be used as potential metrics to assess the hazard, and (3) mitigation strategies to address the hazard. The following sub-sections summarize the key results from the literature review.

2.1 Locations Where Each Hazard Is Eminent

Different hazards occur at different places, and understanding where each hazard may occur is important for engineers and planners to appropriately address the potential risk when designing or planning a shared-use rail operation. Table 2.1 summarizes the general locations along a shared-use rail corridor where each hazard is eminent.

| | Hazard | Location |
|----|---|---|
| 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) |
| 5 | Intrusion of MOW staff and equipment working on adjacent tracks | Along a shared-use rail corridor where track maintenance activities frequently take place and locations with limited clearances (e.g., bridges, tunnels) |
| 6 | Obstruction hazard resulting from adjacent tracks (non-derailment collisions) | Along a shared-use rail corridor close to other rail or highway vehicles (e.g., yards, grade crossings) |
| 7 | Drainage problem affecting either the HSR track or adjacent tracks | Along a shared-use rail corridor especially with areas of high precipitation/snow, vegetation, or 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 | EMI between trains and wayside equipment on adjacent tracks | Along a shared-use rail corridor where the high-voltage overhead catenary wires present |

Table 2.1 General Locations Where Each Hazard is Eminent

2.2 Influencing Factors or Precursors of Each Hazard

There are different factors that could affect the individual hazard. Identifying these factors help to quantify and evaluate the risk of the hazard. Identified major factors include track center spacing between HSR tracks and conventional tracks, train speed (the maximum authorized speed for HSR and conventional rail systems), track geometry (curvature, elevation, maintenance standard, etc.), train equipment design, rail infrastructure, and human factors. A specific influencing factor may affect multiple hazards. Table 2.2 summarizes the key influencing factors for each hazard.

| | Hazard | Key Influencing Factors | | |
|----|---|--|--|--|
| 1 | Derailment on adjacent tracks | Track center spacing, train speed, human factors, track geometry, type of rail infrastructure, train control systems | | |
| 2 | Shifted load on adjacent tracks | Track center spacing, train speed, human factors, 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 geometry | Track center spacing, train speed, track geometry, type of rail infrastructure, soil foundation/subgrade characteristics | | |
| 5 | Intrusion of MOW staff and equipment working on adjacent tracks | Track center spacing, train speed, human factors | | |
| 6 | Obstruction hazard resulting from adjacent tracks (non-derailment collisions) | Track center spacing, train speed, human factors, track geometry, 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 factors | | |
| 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 factors, flammable product traffic volume | | |
| 11 | EMI between trains and wayside equipment on adjacent tracks | Train equipment design, type of rail infrastructure, train control systems | | |

Table 2.2 Key Influencing Factors for Each Hazard

2.3 Mitigation Strategies to Address Each Hazard

The ultimate goal of assessing the risk of each hazard is to be able to prevent or reduce the risk of each hazard in the shared-use rail operation. Based on the literature review, identified general locations where each hazard is eminent and the associated influencing factors, several risk mitigation strategies are proposed. Table 2.3 summarizes the potential risk mitigation strategies for each hazard.

| | 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, temporal separation |
| 2 | Shifted load on adjacent tracks | Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training on cargo securement, temporal separation |
| 3 | Aerodynamic interaction between trains on adjacent tracks | Proper track center spacing, installation of intrusion detection systems, building physical barriers, reduced train speed, temporal separation |
| 4 | Ground-borne vibration and its effect on HSR track geometry | Proper track center spacing, reduced train speed |
| 5 | Intrusion of MOW staff and equipment working on adjacent tracks | Proper track center spacing, installation of intrusion detection systems, building physical barriers, improved employee training, reduced train speed, temporal separation |
| 6 | Obstruction hazard resulting from 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, temporal separation |
| 10 | Fire on adjacent tracks | Proper track center spacing, building physical barriers, temporal separation, enhanced rail equipment design |
| 11 | EMI between trains and wayside equipment on adjacent tracks | Improved employee training, better rail equipment design to prevent or reduce electromagnetic field effect |

Table 2.3 Potential Risk Mitigation Strategies for Each Hazard

3. Train Accident Data Analysis

A thorough analysis of the FRA rail equipment accident/incident <u>database</u> was conducted to identify conventional train accident causes that may be relevant to future HSR operations adjacent to conventional tracks. The identified key accident causes can serve as more detailed, lower-level influencing factors or accident precursors to the high-level ones described in Section 2.2. In addition, results from the train accident data analysis can be used in future risk assessments of HSR operations adjacent to conventional tracks. In particular, the passenger train accident analysis would be applicable to HSR operations adjacent to tracks with conventional passenger train operations. Similarly, the freight train accident analysis would be applicable to HSR operations adjacent to tracks with freight passenger train operations.

3.1 Causal Analysis of Passenger and Freight Train Accident Analyses

Train accident data between 1999 and 2013 from the FRA rail equipment accident/incident database were analyzed to examine the effects of different accident causes on conventional passenger and freight train accidents. The FRA database does not have sufficient information regarding accident locations to identify shared-use corridors. However, the majority of passenger trains run on freight-owned infrastructures, and most of them are on shared trackage. Therefore, it is reasonable to assume that all the mainline passenger train accidents are on shared-use rail corridors. Although not all freight train accidents occur on shared-use rail corridors, due to large sample size of accidents, analyzing all them still help to identify more relevant accident causes (the relatively more frequent and/or more severe causes).

In these analyses the frequency of an accident is represented by the accident rate per unit distance traveled. While several metrics could be used to represent the severity of an accident (e.g., cost, casualty, number of cars derailed), number of cars derailed was selected, as it is expected to affect the cars' dispersion distance away from a track to potentially intrude other tracks on a shared rail corridor. The multiplication of the frequency and severity of an accident was used to represent the risk.

Over the 15-year interval from 1999 to 2013, there were 907 mainline passenger train accidents, including 441 grade crossing accidents, 264 obstruction accidents, 141 derailments, 49 collisions, and 12 miscellaneous accidents. Figure 3.1 shows the mainline passenger train accident rate over the 15-year interval sorted by five types of accidents: grade crossing accidents have been the most frequent type of passenger train accident, followed by obstructions and then derailments. On freight side, there were 8,947 mainline accidents, including 6,286 derailments, 1,876 grade crossing accidents, 379 collisions, 265 obstructions, and 141 miscellaneous accidents. Figure 3.2 shows mainline freight train accident rate over the 15-year interval sorted by five types of accidents: grade crossing accidents and collisions. Passenger train accident rates have been consistently lower than freight train accident rates.



Figure 3.1 Mainline Passenger Train Accident Rates by Type of Accidents, 1999–2013



Figure 3.2 Mainline Freight Train Accident Rates by Type of Accidents, 1999–2013

To measure the risk from different types of accidents, researchers plotted the number of accidents per unit train travel to represent the accident frequency versus the average severity of

mainline passenger train accidents (Figure 3.3) and freight train accidents (Figure 3.4) by accident type. The graph is divided into four quadrants on the basis of the average frequency and severity along each axis. It enables easy comparison of the relative frequency and severity of different accident types. Accident types in the upper-right quadrant would be the most likely to pose the greatest risk because they are both more frequent and more severe than the average. The data indicate that the types of train accident most likely to result in high-number-of-cars-derailed incidents are derailments and collisions. Although they account for only about 21 percent of all passenger train accidents, derailments and collision combined resulted in about 68 percent of the total number of cars derailed (Table 3.1). For freight train accidents, derailments are both frequent and severe and thus fall in the upper-right quadrant of the graph. Collisions and derailments are still the most severe accidents among all accident types. Although grade crossing accidents are the most common type of accident, they are among the least severe in their consequences. Collisions and derailments are caused by the interaction of two or more trains and motivate concern in shared-use corridors regarding passenger train collisions with a derailed freight train, or vice versa. Therefore, the next section of this report examines mainline passenger and freight derailments and collisions in more detail.



Figure 3.3 Frequency and Severity Graph of Mainline Passenger Train Accidents by Type of Accident, 1999–2013



Figure 3.4 Frequency and Severity Graph of Mainline Freight Train Accidents by Type of Accident, 1999–2013

| Table 3.1 Mainline Passenger | Accident Frequency | and Severity by | Type of Accident, |
|-------------------------------------|--|-----------------|-------------------|
| | Sorted by Frequer | ncy | |

| | Frequency | Percentage | Average Accident Rate | Total Cars Derailed | Percentage | Average Cars Derailed |
|----------------|-----------|------------|-----------------------|---------------------|------------|-----------------------|
| Grade Crossing | 441 | 48.6% | 0.306 | 114 | 17.6% | 0.26 |
| Obstruction | 264 | 29.1% | 0.183 | 68 | 10.5% | 0.26 |
| Derailment | 141 | 15.5% | 0.098 | 362 | 56.0% | 2.57 |
| Collision | 49 | 5.4% | 0.034 | 78 | 12.1% | 1.59 |
| Miscellaneous | 12 | 1.3% | 0.008 | 25 | 3.9% | 2.08 |
| Total | 907 | 100.0% | 0.629 | 647 | 100.0% | 0.71 |

Table 3.2 Mainline Freight Accident Frequency and Severity by Type of Accident, Sortedby Frequency

| | Frequency | Percentage | Average Accident Rate | Total Cars Derailed | Percentage | Average Cars Derailed |
|----------------|-----------|------------|-----------------------|---------------------|------------|-----------------------|
| Derailment | 6,286 | 70.3% | 0.795 | 57,350 | 92.5% | 9.12 |
| Grade Crossing | 1,876 | 21.0% | 0.237 | 1,323 | 2.1% | 0.71 |
| Collision | 379 | 4.2% | 0.048 | 2,600 | 4.2% | 6.86 |
| Obstruction | 265 | 3.0% | 0.034 | 387 | 0.6% | 1.46 |
| Miscellaneous | 141 | 1.6% | 0.018 | 329 | 0.5% | 2.33 |
| Total | 8,947 | 100.0% | 1.132 | 61,989 | 100.0% | 6.93 |

3.1.1 Passenger Train Derailment and Collision Accident Cause Analysis

FRA train accident cause codes are hierarchically organized and categorized into major cause groups—track, equipment, human factors, signal, and miscellaneous. Each of these major cause

groups has subgroups that include individual cause codes of related causes, such as roadbed, track geometry, etc. within the track group, and similar subgroups within the other major cause groups. In this Section, alternative FRA subgroups developed by Arthur D. Little (ADL) are used in which similar cause codes were grouped based on experts' opinions (Arthur D. Little, 1996). Table 3.3 shows the ADL's groupings of FRA accident cause codes.

ADL's groupings enable greater resolution for certain causes. For example, FRA combines broken rails, joint bars, and rail anchors in the same subgroup, whereas the ADL grouping distinguishes between broken rail and joint bar defects. Figure 3.5 shows the frequency and severity graphs by the major accident cause categories, namely infrastructure-related, human factor related, mechanical related, signal and communication related, and miscellaneous. The graph is also divided into four quadrants to enable easy comparison of the relative frequency and severity of different accident cause groups. The infrastructure-related cause category was identified as the most severe group, and the human factor-related cause category had higher frequency but lower severity. Both human factor-related and infrastructure-related accident cause categories consistently represented the most frequent or severe accident cause categories and therefore were analyzed in more detail.

| Table 3.3 ADL's Group | ing for FRA Accide | ent Cause Group (| Cause Codes |
|-----------------------|---------------------|-------------------|-------------|
| | ma for i fui ficera | ine Cause Group | cuase coues |

| Cause Group | Description | CM/TM | | | | | FRA | Cause Co | odes | | | | |
|-------------|---------------------------------------|-------------|--------------|--------------|-------|-------|-------|----------|--------------|-------|-------------|------|-------|
| 01T | RoadbedDefects | CM | T001 | T099 | | | | | | | | | |
| 02T | Non-Traffic, Weather Causes | TM | T002 | T401 | T402 | T403 | | | | | | | |
| 03T | Wide Gauge | CM | T110 | T111 | T112 | T113 | | | | | | | |
| 04T | Track Geometry (excl. Wide Gauge) | CM | T101 | T102 | T103 | T104 | T105 | T106 | T107 | T108 | T199 | | |
| 05T | BuckledTrack | CM | T109 | | | | | | | | | | |
| 057 | Pail Defects at Polted Inist | CM | T101 | T211 | | | | | | | | | |
| 077 | Init Defects an Defects | CM | T201 | T211 T214 | T215 | T216 | | | | | | | |
| 0/1 | Donin Bai Delects | CM | 1215 | 1214 | 1215 | 1210 | 7000 | 7210 | 7010 | 7210 | 7210 | 7000 | 7221 |
| 081 | Broken Railsor Welds | СМ | 1202 | 1205 | 1204 | 1207 | 1208 | 1210 | 1212 | 1218 | 1219 | 1220 | 1221 |
| 09T | Other Rail and Joint Defects | CM | T299 | | | | | | | | | | |
| 10T | Turnout Defects-Switches | CM | T307 | T308 | T309 | T310 | T311 | T312 | T313 | T314 | T315 | T319 | |
| 11T | Tumout Defects-Frogs | CM | T304 | T316 | T317 | T318 | | | | | | | |
| 12T | Misc. Track and Structure Defects | CM | T205 | T206 | T217 | T222 | T301 | T302 | T303 | T305 | T306 | T399 | T499 |
| | | | S001 | S002 | S003 | S004 | S005 | S006 | S007 | S008 | S009 | S010 | S011 |
| 01S | Signal Failures | TM | S012 | S013 | S099 | | | | | | | | |
| 01E | AirHose Defect (Car) | CM | E00C | | | | | | | | | | |
| 02E | Broke Rigging Defact (Car) | CM | E07C | | | | | | | | | | |
| 03E | Handhraka Dafacts (Car) | CM | FORC | FOHC | | | | | | | | | |
| ME | IDE (Carari and) | CM | POSC | FOST | | | | | | | | | |
| 045 | ODE(Cardination) | CM | EUSC | EUCL | | TOUC | - | - | | | | | |
| UDE | Other Brake Detect (Car) | СМ | EOIC | E02C | E05C | E04C | E00C | EU9C | | | | | |
| 06E | Centerplate/Carbody Defects(Car) | CM | E20C | E21C | E22C | E23C | E24C | E25C | E26C | E27C | E29C | | |
| 07E | CouplerDefects(Car) | CM | E30C | E31C | E32C | E33C | E34C | E35C | E36C | E37C | E39C | | |
| 08E | Truck Structure Defects (Car) | CM | E44C | E45C | | | | | | | | | |
| 09E | Sidebearing, Suspension Defects (Car) | CM | E40C | E41C | E42C | E43C | E47C | E48C | | | | | |
| 10E | BearingFailure (Car) | CM | E52C | E53C | | | | | | | | | |
| 11E | Other Axle/Journal Defects(Car) | CM | E51C | E54C | E55C | E59C | | | | | | | |
| 12E | Broken Wheels (Car) | CM | E60C | E61C | E62C | E63C | E6AC | | | | | | |
| 13E | Other Wheel Defects(Car) | CM | E64C | E65C | E66C | E67C | E68C | E69C | | | | | |
| 14E | TOFC/COFC Defects | CM | ELIC | E12C | E13C | E19C | | | | | | | |
| | | | E07 | E40T | FAIT | F47 | F43 | F44 | F45T | E46I | E47I | F491 | E4TT |
| | | | TAOT | Dent | Dent | Dent | 75.0 | Dent | TCOL | Dent | Delt | Dent | Dett |
| 160 | Less Trucks/Reasonry (Milasola | C 14 | E49L E64L | LOIL | E52L | ESSL | E34L | DEAL | E39L E60L | EOUL | E0IL E77 | E0/L | E05L |
| 136 | Loco marks Beamings wheels | CM | EOHL | EOOL | FOOL | E0/L | EUGL | EOAL | E09L | E/UL | E//L | | |
| 10E | Loco Electrical and Fires | СМ | E/IL | E/2L | E/3L | E/4L | E/OL | | | | | | |
| | | | EOOL | E01L | E02L | E03L | E04L | E06L | EOSL | EOHL | E09L | E20L | E21L |
| | | | E22L | E23L | E24L | E25L | E26L | E27L | E29L | E30L | E31L | E32L | E33L |
| 17E | All Other Locomotive Defects | CM | E34L | E35L | E36L | E37L | E39L | E79L | E99L | | | | |
| 18E | AllOtherCarDefects | CM | E49C | E80C | E81C | E82C | E83C | E84C | E85C | E86C | E89C | E99C | |
| 19E | StiffTruck(Car) | CM | E46C | | | | | | | | | | |
| 20E | Track/TrainInteraction(Hunting)(Car) | CM | E4TC | | | | | | | | | | |
| 21E | Current Collection Equipment (Loco) | CM | E75L | | | | | | | | | | |
| | | | H510 | H511 | H512 | H513 | H514 | H515 | H516 | H517 | H518 | H510 | H520 |
| 01H | Brake Operation (Main Line) | TM | H521 | H525 | H526 | | | | | | | | |
| 07H | Handbrake Operations | TM | H017 | H018 | H010 | H020 | H021 | H022 | H025 | M504 | | | |
| 0211 | Brake Operations (Other) | TM | 11000 | 11010 | 11015 | 11020 | 11021 | 11022 | 11020 | 11100 | | | |
| OF | Englane Operations (Other) | TM | 11006 | 11099 | 11102 | 11104 | 11100 | | | | | | |
| 0481 | Employee Physical Condition | 154 | 1101 | H102 | 1105 | 1104 | 1199 | | | ***** | ****** | | |
| | | | H201 | H202 | H203 | H204 | H205 | H200 | H207 | H208 | H209 | H215 | H210 |
| 05H | Failure to Obey/Display Signals | TM | H217 | H299 | | | | | | | | | |
| 06H | Radio Communications Error | TM | H210 | H211 | H212 | H405 | | | | | | | |
| | | | H301 | H302 | H303 | H304 | H305 | H306 | H307 | H308 | H309 | H310 | H311 |
| 07H | SwitchingRules | TM | H312 | H313 | H314 | H315 | H399 | | | | | | |
| 08H | Mainline Rules | TM | H401 | H402 | H403 | H404 | H406 | H499 | | | | | |
| | | | H501 | H502 | H503 | H504 | H505 | H506 | H507 | H508 | H509 | H522 | H523 |
| 09H | TrainHandling (excl. Brakes) | TM | H524 | H599 | | | | | | | | | |
| 104 | Train Sneed | TM | H601 | H602 | H603 | H604 | H605 | H606 | H600 | | | | |
| 1111 | Use of Switches | TM | H201 | H202 | H203 | H704 | H705 | H700 | 11099 | | | | |
| 1111 | Man Harry Paster | 101 | TICOL | 11000 | 11000 | 11004 | 11000 | 11001 | 11000 | 11000 | 1100.4 | TIME | 11000 |
| 12H | MISC HUMAN PACTORS | IM | Hazl | H822 | H823 | H824 | H899 | H991 | H992 | H993 | 11994 | H990 | 11999 |
| 01M | Obstructions | TM | M101 | M102 | M103 | M104 | M105 | M199 | M402 | M403 | M404 | | |
| 02M | Grade Crossing Collisions | TM | M301 | M302 | M303 | M304 | M305 | M306 | M307 | M399 | | | |
| 03M | LadingProblems | CM | M201 | M202 | M203 | M204 | M205 | M206 | M207 | M299 | M409 | M410 | |
| 04M | Track-Train Interaction | CM | M405 | | | | | | | | | | |
| 05M | OtherMiscellaneous | TM | M401 | M406 | M407 | M408 | M501 | M502 | M503 | M505 | M599 | | |



Figure 3.5 Frequency and Severity Graph of Mainline Passenger Derailments and Collisions, 1999–2013, by Accident Cause Category, with Average Cars Derailed as Severity Indicator

In order to gain insights on what specific accident causes would result in high frequency or severity, accident cause categories were broken down to accident cause groups. Table 3.4 shows the accident frequency and severity for individual accident cause groups. The accident cause groups are categorized into infrastructure related (T), human-factor related (H), mechanical related (E), signal and communication related (S), and miscellaneous (M). The risk of each accident cause group was calculated by multiplying its accident rate by its severity. Overall, 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)

Most of the top ten accident cause groups are infrastructure related or human-factor related. Table 3.5 shows the top ten high-risk accident groups in infrastructure, human factors, and mechanical categories, respectively.

Table 3.4 Passenger Train Derailment and Collision Frequency and Severity by Accident Cause Subgroup, Sorted by Risk

| Accident Carly Braine Accident Million Frainmile Carls Derailed Derailed PrAcedent Number of Carls Derailed 031 Wird Gauge 17 0.0022 59 3.4706 0.0075 011 Truin Speed 14 0.0018 4.33 3.0714 0.0054 011 Truin Carlebets 21 0.0027 40 1.9048 0.0051 011 Hore Alls of Welds 7 0.0009 36 5.1429 0.0046 011 Hore Alls of Welds 7 0.0009 36 5.1429 0.0046 011 Hore Alls of Welds 3 0.0004 22 7.333 0.0028 021 Most Trake And Structure Defects 8 0.0010 14 1.7500 0.0018 021 Most Trake And Structure Defects 8 0.0004 13 4.3333 0.0013 021 Most Trake And Structure Defects 8 0.0008 10 1.8667 0.0013 021 Most Trake Reading/Wheels 6 0.0008 1 2.0000 0.0011 021 Most Trake Reading/Wheels 6 0.0006 | | | Number of | Accident Rate (per | Number of | Average Number of Cars | Risk = Rate x Average |
|--|------|---|-----------|--------------------|---------------|------------------------|-------------------------|
| Instruction Control Control Control Control 10th Train Speed 14 0.0022 59 3.4706 0.0075 10th Train Speed 14 0.0018 43 3.0714 0.0054 10th Train Speed 15 0.0002 36 5.1429 0.0046 10th Valid Score 3 0.0004 22 7.3335 0.0003 10th Unit Score 3 0.0004 22 7.3335 0.0001 10th Unit Score 3 0.0004 14 4.553 0.0015 10th Unit Score 3 0.0004 1 4.333 0.0015 10th Score 3 0.0006 1 1.4365 0.0013 11th Unit Score 5 0.0006 1 2.0000 0.0013 11th Maine Radics 8 0.0006 8 1.0000 0.0013 11th Mainine Radics 8 0.00 | 0511 | Accident Cause Groups | Accident | million train-mile | Cars Derailed | Derailed Per Accident | Number of Cars Derailed |
| US1 Wild Subge 17 0.1022 59 3.4706 0.0075 UTT Tuncy Detects - Switches 14 0.007 40 1.948 0.0051 OTT Prock Tables of Welds 7 0.0009 36 5.1429 0.0044 OTT Joint Bar Defects 3 0.0004 22 7.0333 0.0022 OTM Thin Scrutz Defects 3 0.0004 13 4.3333 0.0016 OTM Switching Rules 7 0.0009 10 1.4245 0.0021 OTM Switching Rules 7 0.0004 13 4.3333 0.0016 OTM Switching Rules 7 0.0008 10 1.6667 0.0013 OTM Switching Rules 6 0.0006 10 2.0000 0.0011 OTM Switching Rules 8 0.0001 8 1.0000 0.0010 OTM Switching Rules 8 0.0005 6 1.2000 0.0006 OTM Switching Rules 8 0.0005 5 1.2500 0.0006 Otm Sw | USH | Failure to Obey/Display Signals | 22 | 0.0028 | 60 | 2.1213 | 0.0076 |
| 1011 111 <td>031</td> <td>Wide Gauge</td> <td>17</td> <td>0.0022</td> <td>59</td> <td>3.4706</td> <td>0.0075</td> | 031 | Wide Gauge | 17 | 0.0022 | 59 | 3.4706 | 0.0075 |
| 101 Lumout Detects 21 0.0027 40 19,443 0.0051 011 Broken Rails or Welds 7 0.0009 36 5,1429 0.0004 011 Broken Rails or Welds 3 0.0004 22 7,333 0.0002 05M Other Miscellaneous 11 0.0014 16 1,4545 0.0020 12T Miss. Trak and Structure Detects 8 0.0004 13 4,3333 0.0016 14T Miss. Thum Factors 5 0.0006 10 1,6667 0.0013 15E Loco Trucks/Dearings/Wheels 6 0.0006 6 1,5000 0.0011 15E Miss. Thum Factors 5 0.0006 6 1,5000 0.0010 15E Hird Structure 8 0.0005 8 2,0000 0.0006 15E Other Wheel Detects 4 0.0005 5 1,5000 0.0006 15E Other Wheel Detects 4 0.0005 5 2,5000 | 10H | Irain Speed | 14 | 0.0018 | 43 | 3.0714 | 0.0054 |
| Unit Unit <thunit< th=""> Unit Unit <thu< td=""><td>101</td><td>Turnout Defects - Switches</td><td>21</td><td>0.0027</td><td>40</td><td>1.9048</td><td>0.0051</td></thu<></thunit<> | 101 | Turnout Defects - Switches | 21 | 0.0027 | 40 | 1.9048 | 0.0051 |
| 11H Use of Switches 15 0.0019 24 1.6000 0.0008 0FM Other Miscellaneous 11 0.0014 16 1.4545 0.0020 12T Misc. Trakk and Structure Defects 8 0.0010 14 1.7500 0.0018 02T Non-Traffic, Weather Causes 3 0.0004 13 4.3333 0.0016 01F Noticiting Rules 7 0.0009 10 1.2486 0.0013 15E Loco Trucks/Bearings/Wheels 6 0.0008 9 1.5000 0.0011 15H Misc. Human Factors 5 0.0006 10 2.0000 0.0011 16H Mainife Rules 8 0.0005 8 1.0000 0.0006 15E Al Other Car Defects 4 0.0005 6 1.5000 0.0006 15E Other Wheel Defects (Car) 4 0.0005 5 1.5000 0.0006 15E Other Wheel Defects (Car) 3 0.0004 4 1.3333 0.0005 15E Locomotive Defects 4 0.0003 4 2.0000 | 08T | Broken Rails or Welds | 7 | 0.0009 | 36 | 5.1429 | 0.0046 |
| 071 Jont Bar Defects 3 0.0004 22 7.3333 0.0002 06M Other Misse Classes 3 0.0011 14 1.7500 0.0018 12T Miss. Track and Structure Defects 8 0.0010 14 1.7500 0.0018 02T Non-Trafic, Weather Causes 3 0.0004 13 4.3333 0.0016 02T Non-Trafic, Weather Causes 6 0.0008 10 1.4286 0.0013 12H Misc, Human Factors 6 0.0008 9 1.5000 0.0011 08H Singla Failures 6 0.0005 6 1.2000 0.0008 13E Al Other Car Defects 4 0.0005 6 1.5000 0.0006 13E Cher Wheel Defects (Car) 4 0.0005 5 1.2500 0.0006 13E Cher Wheel Defects (Car) 3 0.0004 4 1.3333 0.0005 13E Cher Wheel Defects (Car) 3 0.0003 4 2.0000 0.0006 13E Cher Wheel Defects (Car) 3 | 11H | Use of Switches | 15 | 0.0019 | 24 | 1.6000 | 0.0030 |
| 05M Other Miscellaneous 11 0.0014 16 1.4545 0.0020 12T Misc. Track and Structure Defects 8 0.0004 13 4.3333 0.0018 02T Non-Traffic, Weather Causes 3 0.0004 13 4.3333 0.0013 15E Loco Trucks/Bearings/Wheels 6 0.0008 10 1.6667 0.0013 15E Lico Trucks/Bearings/Wheels 6 0.0008 9 1.5000 0.0011 0H Mainine Rules 8 0.0010 8 1.0000 0.0010 15E All Other Car Defects 4 0.0005 6 1.2000 0.0008 12E Other Wheel Defects (Car) 4 0.0005 5 1.2500 0.0006 12E Other Wheel Defects (Car) 3 0.0004 4 1.3333 0.0005 12E Toper Uncorrentive Defects 4 0.0003 4 2.0000 0.0005 12E Toper Uncorrentive Defects (Car) 3 0.0004 4 1.3333 0.0005 12E Toper Uncorrentrak 1 0.0001 | 07T | Joint Bar Defects | 3 | 0.0004 | 22 | 7.3333 | 0.0028 |
| 12T Misc. Track and Structure Defects 8 0.0010 14 1.7500 0.0018 OT Non-Traffic (Weather Causes 3 0.0004 13 4.3333 0.0016 OTH Synchring Rules 7 0.0009 10 1.4286 0.0013 15E Locs Trucks/Bearing/Wheels 6 0.0008 10 2.6000 0.0011 08H Mainine Rules 8 0.0010 8 1.0000 0.0010 08H Mainine Rules 8 0.0005 6 1.2000 0.0006 19E All Other Cace Defects (Car) 4 0.0005 6 1.2000 0.0006 19E Other Wheel Defects (Car) 4 0.0005 5 1.2500 0.0006 19E Loce Teleckic Car) 3 0.0004 4 1.3333 0.0006 19E Loce Teleckic Car) 3 0.0005 5 1.2500 0.0006 19E Loce Teleckic Car) 3 0.0004 4 1.3333 0.0006 19E Loce Teleckic Car) 1 0.0001 4 0.0005 | 05M | Other Miscellaneous | 11 | 0.0014 | 16 | 1.4545 | 0.0020 |
| O2T Non-Traffic, Weather Causes 3 0.0004 13 4.3333 0.0016 OTH Switching Rules 7 0.0009 10 1.4286 0.0013 15E Loco Trucks/Bearings/Wheels 6 0.0008 10 1.6667 0.0013 12H Misc. Human Factors 5 0.0006 10 2.0000 0.0011 08H Mainine Rules 8 0.0005 8 2.0000 0.0008 13E Chier Wheel Defects (Car) 4 0.0005 6 1.5000 0.0008 13E Chier Wheel Defects (Car) 4 0.0005 5 2.5000 0.0006 13E Chier Wheel Defects (Car) 3 0.0004 4 1.3333 0.0005 14E Tock/CoCPC Defects 1 0.0003 4 2.0000 0.0005 15E Loce Electrical and Fires 2 0.0003 4 2.0000 0.0005 15E Tock/CoCP Defects 1 0.0001 1 0. | 12T | Misc. Track and Structure Defects | 8 | 0.0010 | 14 | 1.7500 | 0.0018 |
| O'H Switching Rules 7 0.009 10 1.4286 0.0013 12H Misc: Human Factors 5 0.0006 10 2.0000 0.0013 12H Misc: Human Factors 5 0.0006 10 2.0000 0.0011 08H Mainline Rules 8 0.0010 8 1.0000 0.0010 18E All Other Car Defects 4 0.0005 6 1.2000 0.0008 17E All Other Vicel Defects 4 0.0005 5 1.2500 0.0006 17E All Other Locomotive Defects 4 0.0005 5 2.5000 0.0006 14E Other Misel Defects (Car) 3 0.0004 4 1.3333 0.0005 15E Loce Diredectrical and Fires 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0000 10H Thor Mission 1 0.0001 1 1.00001 | 02T | Non-Traffic, Weather Causes | 3 | 0.0004 | 13 | 4.3333 | 0.0016 |
| 15E Loco Trucks/Bearings/Wheels 6 0.0008 10 1.6667 0.0013 21H Misc, Human Factors 5 0.0008 9 1.5000 0.0011 01S Signal Failures 6 0.0008 9 1.5000 0.0010 08H Mainine Rules 8 0.0005 8 2.0000 0.0008 13E Chter Wheel Defects (Car) 4 0.0005 6 1.5000 0.0006 13E Chter Wheel Defects (Car) 4 0.0005 5 2.5000 0.0006 13E Loter Muck/Journal Defects (Car) 3 0.0004 4 1.3333 0.0005 13E Loter Muck/Journal Defects (Car) 3 0.0004 4 2.0000 0.0005 15E Loce Electrical and Fires 2 0.0003 4 2.0000 0.0005 14E TOC/C/CPC Defects 1 0.0001 4 4.0000 0.0000 14E TOC/C/CPC Defects (Car) 1 0.0001 0 | 07H | Switching Rules | 7 | 0.0009 | 10 | 1.4286 | 0.0013 |
| 12H Misc. Human Factors 5 0.0006 10 2,0000 0.0013 0S Signal Failures 6 0.0008 9 1,5000 0.0011 0BH Mainline Rules 8 0.0010 8 1,0000 0.0011 0BH Mainline Rules 8 0.0005 8 2,0000 0.0010 04T Track Geometry (excl. Wide Gauge) 5 0.0006 6 1,2000 0.0008 12E All Other Car Defects 4 0.0005 5 1,2000 0.0006 04M Track-Train Interaction 2 0.0003 5 2,5000 0.0006 04M Track-Train Interaction 2 0.0003 4 2,0000 0.0005 05T Buckled Track 2 0.0003 4 2,0000 0.0005 05T Buckled Track 1 0.0001 4 4,0000 0.0005 03M Lading Problems 3 0.0004 2 0.6667 0.0003 03T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 04H Handbrack Operations 1 0.0001 0 0.0000 <t< td=""><td>15E</td><td>Loco Trucks/Bearings/Wheels</td><td>6</td><td>0.0008</td><td>10</td><td>1.6667</td><td>0.0013</td></t<> | 15E | Loco Trucks/Bearings/Wheels | 6 | 0.0008 | 10 | 1.6667 | 0.0013 |
| 01S Signal Failures 6 0.0003 9 1.5000 0.0011 08H Mainine Rules 8 0.0010 8 1.0000 0.0010 18E All Other Car Defects 4 0.0005 8 2.0000 0.0008 18E Other Wheel Defects (Car) 4 0.0005 6 1.2000 0.0008 12E Other Wheel Defects (Car) 4 0.0005 5 1.2600 0.0006 04M Track-Train Interaction 2 0.0003 5 2.5000 0.0006 11E Other Axle/Journal Defects (Car) 3 0.0004 4 1.3333 0.0005 15E Loco Electrical and Fires 2 0.0003 4 2.0000 0.0005 16E Loco Electrical and Fires 1 0.0001 4 4.0000 0.0005 16E Conceptations 1 0.0001 1 1.0000 0.0000 0.0000 08T Asing Problems 3 0.0001 0 0.0000 0.0000 0.0000 08T Asing Problems 3 0.0001 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 | 12H | Misc. Human Factors | 5 | 0.0006 | 10 | 2.0000 | 0.0013 |
| 0BH Mainline Rules 8 0.0010 8 1.0000 0.0010 DBE All Other Car Defects 4 0.0005 8 2.0000 0.0008 13E Other Wheel Defects (Car) 4 0.0005 6 1.2000 0.0008 13E Other Mode Defects (Car) 4 0.0005 5 1.2500 0.0006 Odd Track-Train Interaction 2 0.0003 5 2.5000 0.0006 Other Wheel Defects (Car) 3 0.0004 4 1.3333 0.0005 OTE Luckled Track 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0001 OST Luckled Track 1 0.0001 1 1.0000 0.0001 OST Euckled Track 1 0.0001 0 0.0000 0.0000 OST Euckled Track 1 0.0001 0 0.0000 0.0000 OST | 01S | Signal Failures | 6 | 0.0008 | 9 | 1.5000 | 0.0011 |
| 18E All Other Car Defects 4 0.0005 8 2.0000 0.0010 13E Other Wheel Defects (Car) 4 0.0005 6 1.5000 0.0008 13E Other Wheel Defects (Car) 4 0.0005 5 1.2500 0.0006 VM Track-Train Interaction 2 0.0003 5 2.5000 0.0006 05T Buckled Track 2 0.0003 4 2.0000 0.0005 15E Loce Flectrical and Fires 2 0.0003 4 2.0000 0.0005 05T Buckled Track 2 0.0003 4 2.0000 0.0005 05T Lockled Track 2 0.0003 4 4.0000 0.0005 05T Deckled Track 0 0.0001 1 1.0000 0.0001 05T Deckled Track 0 0.0001 1 1.0000 0.0000 05T Deckled Track 0 0.0001 0.0000 0.0000 0.0000 | 08H | Mainline Rules | 8 | 0.0010 | 8 | 1.0000 | 0.0010 |
| OAT Track Geometry (excl. Wide Gauge) 5 0.0006 6 1.2000 0.0008 17E All Other Locomotive Defects 4 0.0005 5 1.2500 0.0006 17E All Other Locomotive Defects 4 0.0005 5 1.2500 0.0006 17E Other Acck-Train Interaction 2 0.0003 5 2.5000 0.0006 04M Track-Train Interaction 2 0.0003 4 2.0000 0.0005 05T Buckled Track 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0003 05T Buckled Track 0 0.0011 1 1.0000 0.0001 05T Buckled Carstondy Defects (Car) 4 0.0005 0 0.0000 0.0000 05E Centerplate/Carbody Defects (Car) 1 0.0001 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 | 18E | All Other Car Defects | 4 | 0.0005 | 8 | 2.0000 | 0.0010 |
| 13E Other Wheel Defects (Car) 4 0.0005 6 1.5000 0.0008 17E All Other Locomotive Defects 4 0.0005 5 1.2500 0.0006 MT Tack-Train Interaction 2 0.0003 5 2.5000 0.0006 05T Buckled Tack 2 0.0003 4 2.0000 0.0005 15E Loop Electical and Fires 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0005 05E Centerplate/Carbody Defects (Car) 3 0.0004 2 0.6667 0.0003 05E Centerplate/Carbody Defects (Car) 4 0.0001 0 0.0000 0.0000 05E Centerplate/Carbody Defects (Car) 1 0.0001 0 0.0000 0.0000 05E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 05E Sidebearing, Suspension Defects (Car) 0 0.0000 0 0.0000 0.0000 0.0000 0.00000 0.0000 <td>04T</td> <td>Track Geometry (excl. Wide Gauge)</td> <td>5</td> <td>0.0006</td> <td>6</td> <td>1.2000</td> <td>0.0008</td> | 04T | Track Geometry (excl. Wide Gauge) | 5 | 0.0006 | 6 | 1.2000 | 0.0008 |
| 17E All Other Loconolive Defects 4 0.0005 5 1.2500 0.0006 04M Track-Train Interaction 2 0.0003 5 2.5000 0.0006 11E Other Axlel/Journal Defects (Car) 3 0.0004 4 1.3333 0.0005 05T Buckled Track 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0005 05T Buckled Track 2 0.0001 4 4.0000 0.0005 05M Lading Problems 3 0.0004 2 0.6667 0.0003 05T Detects 1 0.0001 0 0.0000 0.0000 0.0000 05T Bardenting, Suspension Defects (Car) 1 0.0001 0 0.0000 0 | 13E | Other Wheel Defects (Car) | 4 | 0.0005 | 6 | 1.5000 | 0.0008 |
| 04M Track-Train Interaction 2 0.0003 5 2.5000 0.0006 11E Other Axie/Journal Defects (Car) 3 0.0004 4 1.3333 0.0005 5T Buckled Track 2 0.0003 4 2.0000 0.0005 16E Loco Electrical and Fires 2 0.0003 4 2.0000 0.0005 03M Lading Problems 3 0.0004 2 0.6667 0.0003 03T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 03H Lading Problems 3 0.0001 0 0.0000 0.0000 03H Defects of Carrel Jak/Carbody Defects 1 0.0001 0 0.0000 | 17E | All Other Locomotive Defects | 4 | 0.0005 | 5 | 1.2500 | 0.0006 |
| 11E Other Axle/Journal Defects (Car) 3 0.0004 4 1.3333 0.0005 05T Buckled Track 2 0.0003 4 2.0000 0.0005 15E Loco Electrical and Fires 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0003 03M Lading Problems 3 0.0004 2 0.6667 0.0003 05T Handbrake Operations 1 0.0001 1 1.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02H Handbrake Operations (Car) 1 0.0001 0 0.0000 0.0000 03H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 0.0000 0.0000 04H Handbrake Operations (Other) 0 0.0000 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 <td>04M</td> <td>Track-Train Interaction</td> <td>2</td> <td>0.0003</td> <td>5</td> <td>2.5000</td> <td>0.0006</td> | 04M | Track-Train Interaction | 2 | 0.0003 | 5 | 2.5000 | 0.0006 |
| 05T Buckled Track 2 0.0003 4 2.0000 0.0005 16E Loco Electrical and Fires 2 0.0003 4 2.0000 0.0005 16T TOFC/COFC Defects 1 0.0001 4 4.0000 0.0003 03M Lading Problems 3 0.0004 2 0.6667 0.0003 05T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.00000 0.0000 | 11E | Other Axle/Journal Defects (Car) | 3 | 0.0004 | 4 | 1.3333 | 0.0005 |
| 16E Loco Electrical and Fires 2 0.0003 4 2.0000 0.0005 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0005 3M Lading Problems 3 0.0004 2 0.66667 0.0003 09T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 04H Rail Defects 0 0.0000 0 0.0000 0.0000 04T Roadbed Defects 0 0.0000 0 0.0000 0.0000 01T Kaadbe Defects a Bolted Joint 0 0.0000 0 0.0000 0.0000 0.0000 01H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 | 05T | Buckled Track | 2 | 0.0003 | 4 | 2.0000 | 0.0005 |
| 14E TOFC/COFC Defects 1 0.0001 4 4.0000 0.0005 03M Lading Problems 3 0.0004 2 0.6667 0.0003 03F Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 06E Centerplate/Carbody Defects (Car) 4 0.0005 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 03T Tanout Defects - Frogs 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 04H Employee Defect (Car) 0 0.0000 0 0.0000 0.0000 04H Handbrake Defecti (Car) 0 0.0000 0 0.0000 0.0000 05H Radio Communications Error 0 <td>16E</td> <td>Loco Electrical and Fires</td> <td>2</td> <td>0.0003</td> <td>4</td> <td>2.0000</td> <td>0.0005</td> | 16E | Loco Electrical and Fires | 2 | 0.0003 | 4 | 2.0000 | 0.0005 |
| 03M Lading Problems 3 0.0004 2 0.6667 0.0003 09T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 06E Centerplate/Carbody Defects (Car) 4 0.0005 0 0.0000 0.0000 02E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 02F Rail Defects at Boited Joint 0 0.0000 0 0.0000 0.0000 01T Turnout Defects - Frogs 0 0.0000 0 0.0000 0.0000 0.0000 03H Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0 | 14E | TOFC/COFC Defects | 1 | 0.0001 | 4 | 4.0000 | 0.0005 |
| 09T Other Rail and Joint Defects 1 0.0001 1 1.0000 0.0000 09E Centerplate/Carbody Defects (Car) 4 0.0005 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 04F Rail Defects at Bolted Joint 0 0.0000 0 0.0000 0.0000 0.0000 01T Turout Defects - Frogs 0 0.0000 0 0.0000 <td< td=""><td>03M</td><td>Lading Problems</td><td>3</td><td>0.0004</td><td>2</td><td>0.6667</td><td>0.0003</td></td<> | 03M | Lading Problems | 3 | 0.0004 | 2 | 0.6667 | 0.0003 |
| 06E Centerplate/Carbody Defects (Car) 4 0.0005 0 0.0000 0.0000 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 09E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 09E Sidebearing, Suspension Defects (Car) 1 0.0000 0 0.0000 0.0000 00F Rail Defects Bolted Joint 0 0.0000 0 0.0000 0.0000 01T Turnout Defects - Frogs 0 0.0000 0 0.0000 0.0000 0.0000 01H Brake Operations (Other) 0 0.0000 0 0.0000 0. | 09T | Other Rail and Joint Defects | 1 | 0.0001 | 1 | 1.0000 | 0.0001 |
| 02H Handbrake Operations 1 0.0001 0 0.0000 0.0000 09E Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 01T Roadbed Defects 0 0.0000 0 0.0000 0.0000 01T Roadbed Defects at Bolted Joint 0 0.0000 0 0.0000 0.0000 01T Turnout Defects + Frogs 0 0.0000 0 0.0000 0.0000 0.0000 01H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 0.0000 01H Brake Operations (Other) 0 0.0000 0 0.00000 0.0000 0.0000 | 06E | Centerplate/Carbody Defects (Car) | 4 | 0.0005 | 0 | 0.0000 | 0.0000 |
| OSE Sidebearing, Suspension Defects (Car) 1 0.0001 0 0.0000 0.0000 01T Roadbed Defects 0 0.0000 0 0.0000 0.0000 06T Rail Defects at Bolted Joint 0 0.0000 0 0.0000 0.0000 01T Turmout Defects - Frogs 0 0.0000 0 0.0000 0.0000 01H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 0.0000 04H Employee Chrysical Condition 0 0.0000 0 0.0000 | 02H | Handbrake Operations | 1 | 0.0001 | 0 | 0.0000 | 0.0000 |
| Old Roadbed Defects 0 0.0000 0 0.0000 Off Rail Defects at Bolted Joint 0 0.0000 0 0.0000 0.0000 Off Rail Defects at Bolted Joint 0 0.0000 0 0.0000 0.0000 Off Raid Defects Frogs 0 0.0000 0 0.0000 0.0000 Off Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0000 0.0000 OHH Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0000 0.0000 OHH Brake Operations (Other) 0 0.0000 0 0.0000 <td>09F</td> <td>Sidebearing Suspension Defects (Car)</td> <td>1</td> <td>0.0001</td> <td>0</td> <td>0.0000</td> <td>0.0000</td> | 09F | Sidebearing Suspension Defects (Car) | 1 | 0.0001 | 0 | 0.0000 | 0.0000 |
| Off Rail Defects at Bolted Joint 0 0.0000 0.0000 0.0000 11T Turnout Defects - Frogs 0 0.0000 0 0.0000 0.0000 01H Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0000 03H Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0 | 01T | Roadbed Defects | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Of Transol Defects - Frogs 0 0.0000 0 0.0000 0.0000 01H Brake Operation (Main Line) 0 0.0000 0 0.0000 0.0000 03H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 03H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 06H Radio Communications Error 0 0.0000 0 0.0000 0.0000 09H Train Handling (excl. Brakes) 0 0.0000 0 0.0000 0.0000 01E Air Hose Defect (Car) 0 0.0000 0 0.0000 0.0000 02E Brake Rigging Defect (Car) 0 0.0000 0 0.0000 0.0000 03E Handbrake Defect (Car) 0 0.0000 0 0.0000 0.0000 04E UDE (Car or Loco) 0 0.0000 0 0.0000 0.0000 0.0000 05E Other Brake Defect (Car) 0 0.0000 </td <td>06T</td> <td>Rail Defects at Bolted Joint</td> <td>0</td> <td>0.0000</td> <td>Ő</td> <td>0,0000</td> <td>0.0000</td> | 06T | Rail Defects at Bolted Joint | 0 | 0.0000 | Ő | 0,0000 | 0.0000 |
| In Andrease Operation (Main Line) 0 0.0000 0 0.0000 0.0000 03H Brake Operations (Other) 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 04H Employee Physical Condition 0 0.0000 0 0.0000 0.0000 04H Endoco Communications Error 0 0.0000 0 0.0000 0.0000 0.0000 04H Tain Handling (excl. Brakes) 0 0.0000 0 0.0000 0 | 11T | Turnout Defects - Frogs | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Initial Deficiency Constraint Constraint <th< td=""><td>01H</td><td>Brake Operation (Main Line)</td><td>0</td><td>0.0000</td><td>0</td><td>0.0000</td><td>0.0000</td></th<> | 01H | Brake Operation (Main Line) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Och Data Group Constraint Constraint <td>03H</td> <td>Brake Operations (Other)</td> <td>0</td> <td>0.0000</td> <td>Ő</td> <td>0.0000</td> <td>0.0000</td> | 03H | Brake Operations (Other) | 0 | 0.0000 | Ő | 0.0000 | 0.0000 |
| Orth Employed infisition 0 0.0000 0 0.0000 | 04H | Employee Physical Condition | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Only Train Handling (excl. Brakes) 0 0.0000 0 0.0000 0.0000 09H Train Handling (excl. Brakes) 0 0.0000 0 0.0000 0.0000 01E Air Hose Defect (Car) 0 0.0000 0 0.0000 0.0000 02E Brake Rigging Defect (Car) 0 0.0000 0 0.0000 0.0000 03E Handbrake Defects (Car) 0 0.0000 0 0.0000 0.0000 03E Handbrake Defects (Car) 0 0.0000 0 0.0000 | 06H | Radio Communications Error | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Online Ham Hammang (exc) 0 0.0000 0 | nah | Train Handling (eycl. Brakes) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| OTE In Fise Detect (Car) 0 0.0000 0.0000 0.0000 02E Brake Rigging Defect (Car) 0 0.0000 0 0.0000 0.0000 03E Handbrake Defects (Car) 0 0.0000 0 0.0000 0.0000 03E Handbrake Defects (Car) 0 0.0000 0 0.0000 0.0000 04E UDE (Car or Loco) 0 0.0000 0 0.0000 0.0000 05E Other Brake Defect (Car) 0 0.0000 0 0.0000 0.0000 05E Other Brake Defects (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.00000 0.0000 0.0000 <td>01E</td> <td>Air Hose Defect (Car)</td> <td>0</td> <td>0.0000</td> <td>0</td> <td>0.0000</td> <td>0.0000</td> | 01E | Air Hose Defect (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Old Drake Rigging Detect (Car) 0 0.0000 0.0000 0.0000 03E Hand Rigging Detect (Car) 0 0.0000 0 0.0000 0.0000 04E UDE (Car or Loco) 0 0.0000 0 0.0000 0.0000 05E Other Brake Defect (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.0000 0.0000 07E Eventy Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0 | 025 | Brake Bigging Defect (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Obsc Handblake Delects (Car) 0 0.0000 0 0.0000 0.0000 04E UDE (Car or Loco) 0 0.0000 0 0.0000 0.0000 05E Other Brake Defect (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 10E Bearing Failure (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 </td <td></td> <td>Handbroke Defects (Car)</td> <td>0</td> <td>0.0000</td> <td>0</td> <td>0.0000</td> <td>0.0000</td> | | Handbroke Defects (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Ope (Carlo LOCO) 0 0.0000 0 0.0000 0.0000 05E Other Brake Defect (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 10E Bearing Failure (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | 04E | IDE (Car or Looo) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Other Brake Defect (Car) 0 0.0000 0 0.0000 0.0000 07E Coupler Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Fruck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 10E Bearing Failure (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | | Obe (Cal of Loco) Other Brake Defect (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Or L Couple: Defects (Car) 0 0.0000 0 0.0000 0.0000 08E Truck Structure Defects (Car) 0 0.0000 0 0.0000 0.0000 10E Bearing Failure (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | | Coupler Defects (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Operative Delects (Car) 0 0.0000 0 0.0000 0.0000 10E Bearing Failure (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | | Truck Structure Defects (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Tote beaming raine (Car) 0 0.0000 0 0.0000 0.0000 12E Broken Wheels (Car) 0 0.0000 0 0.0000 0.0000 19E Stiff Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | | Rearing Failure (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Instruction Image: View of the state of the | 10E | Deaning Failure (Car) | U | 0.0000 | U | 0.0000 | 0.0000 |
| Type Stim Truck (Car) 0 0.0000 0 0.0000 0.0000 20E Track/Train Interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | 12E | Broken wheels (Car) | U | 0.0000 | U | 0.0000 | 0.0000 |
| 20E Irack/ Irain interaction (Hunting) (Car) 0 0.0000 0 0.0000 0.0000 21E Current Collection Equipment (Loco) 0 0.0000 0 0.0000 0.0000 | 19E | | U | 0.0000 | U | 0.0000 | 0.0000 |
| | 20E | Irack/Irain Interaction (Hunting) (Car) | U | 0.0000 | U | 0.0000 | 0.0000 |
| | 21E | | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |

Table 3.5 Top Ten High-Risk Accident Causes of Mainline Passenger Train Accidents by Accident Cause Categories and Type of Accident, 1999–2013

| | | | | Number of | | |
|------------|---------------------------------------|-----------|--------------------|-----------|------------------------|-------------------------|
| | | Number of | Accident Rate (per | Cars | Average Number of Cars | Risk = Rate x Average |
| | Accident Cause Groups | Accident | million train-mile | Derailed | Derailed Per Accident | Number of Cars Derailed |
| Infrastruc | cture Related | | | | | |
| 03T | Wide Gauge | 17 | 0.0118 | 59 | 3.4706 | 0.0075 |
| 10T | Turnout Defects - Switches | 21 | 0.0146 | 40 | 1.9048 | 0.0051 |
| 08T | Broken Rails or Welds | 7 | 0.0049 | 36 | 5.1429 | 0.0046 |
| 07T | Joint Bar Defects | 3 | 0.0021 | 22 | 7.3333 | 0.0028 |
| 12T | Misc. Track and Structure Defects | 8 | 0.0055 | 14 | 1.7500 | 0.0018 |
| 02T | Non-Traffic, Weather Causes | 3 | 0.0021 | 13 | 4.3333 | 0.0016 |
| 04T | Track Geometry (excl. Wide Gauge) | 5 | 0.0035 | 6 | 1.2000 | 0.0008 |
| 05T | Buckled Track | 2 | 0.0014 | 4 | 2.0000 | 0.0005 |
| 09T | Other Rail and Joint Defects | 1 | 0.0007 | 1 | 1.0000 | 0.0001 |
| 01T | Roadbed Defects | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Human F | actor Related | | | | | |
| 05H | Failure to Obey/Display Signals | 22 | 0.0152 | 60 | 2.7273 | 0.0076 |
| 10H | Train Speed | 14 | 0.0097 | 43 | 3.0714 | 0.0054 |
| 11H | Use of Switches | 15 | 0.0104 | 24 | 1.6000 | 0.0030 |
| 07H | Switching Rules | 7 | 0.0049 | 10 | 1.4286 | 0.0013 |
| 12H | Misc. Human Factors | 5 | 0.0035 | 10 | 2.0000 | 0.0013 |
| 08H | Mainline Rules | 8 | 0.0055 | 8 | 1.0000 | 0.0010 |
| 02H | Handbrake Operations | 1 | 0.0007 | 0 | 0.0000 | 0.0000 |
| 01H | Brake Operation (Main Line) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| 03H | Brake Operations (Other) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| 04H | Employee Physical Condition | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| Mechani | cal Related | | | | | |
| 15E | Loco Trucks/Bearings/Wheels | 6 | 0.0042 | 10 | 1.6667 | 0.0013 |
| 18E | All Other Car Defects | 4 | 0.0028 | 8 | 2.0000 | 0.0010 |
| 13E | Other Wheel Defects (Car) | 4 | 0.0028 | 6 | 1.5000 | 0.0008 |
| 17E | All Other Locomotive Defects | 4 | 0.0028 | 5 | 1.2500 | 0.0006 |
| 11E | Other Axle/Journal Defects (Car) | 3 | 0.0021 | 4 | 1.3333 | 0.0005 |
| 16E | Loco Electrical and Fires | 2 | 0.0014 | 4 | 2.0000 | 0.0005 |
| 14E | TOFC/COFC Defects | 1 | 0.0007 | 4 | 4.0000 | 0.0005 |
| 06E | Centerplate/Carbody Defects (Car) | 4 | 0.0028 | 0 | 0.0000 | 0.0000 |
| 09E | Sidebearing, Suspension Defects (Car) | 1 | 0.0007 | 0 | 0.0000 | 0.0000 |
| 01E | Air Hose Defect (Car) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |

3.1.2 Freight Train Derailment and Collision Accident Cause Analysis

The accident causes of freight train derailments and collisions were analyzed in the same way as passenger train derailments and collisions. Figure 3.6 shows the frequency and severity graphs by the major accident cause categories. The graph is also divided into four quadrants to enable easy comparison of the relative frequency and severity of different accident cause groups. The infrastructure-related cause category was identified as the most severe and frequent one. The mechanical-related accident cause category has higher frequency but lower severity.



Figure 3.6 Frequency and Severity Graph of Mainline Freight Derailments and Collisions, 1999-2013, by Accident Cause Category, with Average Cars Derailed as Severity Indicator

Table 3.6 shows the accident frequency and severity for individual accident cause groups. The accident cause groups are categorized into infrastructure related (T), human-factor related (H), mechanical related (E), signal and communication related (S), and miscellaneous (M). The risk of each accident cause group was calculated by multiplying its accident rate by its severity. Overall, 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)

Most of the top ten accident cause groups are infrastructure-related and some of them are mechanical-related. Compared to passenger accident causes, more mechanical-related causes are

of higher risk in freight train derailments and collisions. Table 3.7 shows the top ten high-risk accident groups in infrastructure, human factors, and mechanical categories, respectively.

Table 3.6 Freight Train Derailment and Collision Frequency and Severity by Accident Cause Subgroup, Sorted by Risk

| | Accident Cause Groups | Number of Accident | Accident Rate (per million train-mile | Number of Cars Derailed | Average Number of Cars Derailed Per Accident | Risk = Rate x Average Number of Cars Derailed |
|-----|---|-----------------------|--|----------------------------|---|--|
| 08T | Broken Rails or Welds | 984 | 0.1245 | 12,756 | 12.9634 | 1.6138 |
| 05T | Buckled Track | 238 | 0.0301 | 3,081 | 12.9454 | 0.3898 |
| 04T | Track Geometry (excl. Wide Gauge) | 454 | 0.0574 | 2,977 | 6.5573 | 0.3766 |
| 03T | Wide Gauge | 286 | 0.0362 | 2,691 | 9.4091 | 0.3404 |
| 12E | Méchanic Defects Broken Wheels (Car) | 312 | 0.0395 | 2,480 | 7.9487 | 0.3137 |
| 10E | Bearing Failure (Car) | 384 | 0.0486 | 2,399 | 6.2474 | 0.3035 |
| 09H | Train Handling (excl. Brakes) | 297 | 0.0376 | 2,170 | 7.3064 | 0.2745 |
| 07T | Joint Bar Defects | 96 | 0.0121 | 1,723 | 17.9479 | 0.2180 |
| 04M | Track-Train Interaction | 201 | 0.0254 | 1,643 | 8.1741 | 0.2079 |
| 05H | Failure to Obev/Display Signals | 154 | 0.0195 | 1.543 | 10.0195 | 0.1952 |
| 09T | Other Rail and Joint Defects | 74 | 0.0094 | 1,495 | 20.2027 | 0.1891 |
| 11E | Other Axle/Journal Defects (Car) | 175 | 0.0221 | 1.471 | 8.4057 | 0.1861 |
| 05M | Other Miscellaneous | 145 | 0.0183 | 1 466 | 10 1103 | 0 1855 |
| 09E | Sidebearing, Suspension Defects (Car) | 178 | 0.0225 | 1,273 | 7,1517 | 0.1610 |
| 01H | Brake Operation (Main Line) | 139 | 0.0176 | 1 247 | 8 9712 | 0 1578 |
| 06T | Rail Defects at Bolted Joint | 68 | 0.0086 | 1 235 | 18 1618 | 0 1562 |
| 03M | Lading Problems | 217 | 0.0275 | 1,200 | 5 6452 | 0.1550 |
| 10T | Turnout Defects Switches | 200 | 0.0273 | 1 101 | 5.0452 | 0.1507 |
| 01T | Poodbed Defects | 200 | 0.0233 | 1,151 | 10 4375 | 0.1479 |
| 13 | Other Wheel Defects (Car) | 103 | 0.0142 | 1,103 | 5 4249 | 0.1325 |
| 10L | Mise Track and Structure Defects | 113 | 0.0244 | 1,047 | 9 1062 | 0.1323 |
| 075 | Coupler Defects (Car) | 176 | 0.0143 | 1,025 | 5.1002 | 0.1362 |
| 110 | Lice of Switches | 101 | 0.0223 | 990 | 3.0705 | 0.1203 |
| 100 | Train Speed | 191 | 0.0242 | 930 | 4.9005 | 0.1164 |
| | Centernlete/Cerhedy/Defects (Cer) | 144 | 0.0102 | 915 | 0.3342 | 0.1156 |
| 100 | Miss Human Fasters | 138 | 0.0175 | 637 505 | 4.0159 | 0.0806 |
| | MISC. Human Factors | 73 | 0.0092 | 595 | 0.1507 | 0.0753 |
| 19E | | 81 | 0.0102 | 507 | 7.0000 | 0.0717 |
| ZUE | Track/Train Interaction (Hunting) (Car) | 54 | 0.0068 | 520 | 9.6296 | 0.0658 |
| 021 | Non-Tramc, Weather Causes | 60 | 0.0076 | 508 | 8.4667 | 0.0643 |
| 07H | Switching Rules | 118 | 0.0149 | 471 | 3.9915 | 0.0596 |
| 08E | Truck Structure Defects (Car) | 57 | 0.0072 | 418 | 7.3333 | 0.0529 |
| 18E | All Other Car Defects | 72 | 0.0091 | 413 | 5.7361 | 0.0522 |
| 08H | Mainline Rules | 61 | 0.0077 | 377 | 6.1803 | 0.0477 |
| 15E | Loco Trucks/Bearings/Wheels | 64 | 0.0081 | 333 | 5.2031 | 0.0421 |
| 05E | Other Brake Defect (Car) | 62 | 0.0078 | 327 | 5.2742 | 0.0414 |
| 02H | Handbrake Operations | 70 | 0.0089 | 309 | 4.4143 | 0.0391 |
| 02E | Brake Rigging Defect (Car) | 46 | 0.0058 | 259 | 5.6304 | 0.0328 |
| 01S | Signal Failures | 31 | 0.0039 | 240 | 7.7419 | 0.0304 |
| 11T | Turnout Defects - Frogs | 23 | 0.0029 | 239 | 10.3913 | 0.0302 |
| 17E | All Other Locomotive Defects | 25 | 0.0032 | 232 | 9.2800 | 0.0294 |
| 01E | Air Hose Defect (Car) | 23 | 0.0029 | 198 | 8.6087 | 0.0250 |
| 16E | Loco Electrical and Fires | 25 | 0.0032 | 128 | 5.1200 | 0.0162 |
| 04H | Employee Physical Condition | 8 | 0.0010 | 95 | 11.8750 | 0.0120 |
| 04E | UDE (Car or Loco) | 10 | 0.0013 | 88 | 8.8000 | 0.0111 |
| 06H | Radio Communications Error | 17 | 0.0022 | 76 | 4.4706 | 0.0096 |
| 03H | Brake Operations (Other) | 11 | 0.0014 | 72 | 6.5455 | 0.0091 |
| 14E | TOFC/COFC Defects | 3 | 0.0004 | 3 | 1.0000 | 0.0004 |
| 03E | Handbrake Defects (Car) | 2 | 0.0003 | 3 | 1.5000 | 0.0004 |
| 21E | Current Collection Equipment (Loco) | 0 | 0.0000 | 0 | 0.0000 | 0.0000 |
| | Total/Average | 6,665 | 0.8432 | 57,268 | 8.5923 | 7.2450 |

| | | | | Number of | | |
|-----------|---|-----------|--------------------|------------------|------------------------|-------------------------|
| | Assidant Causa Groups | Number of | Accident Rate (per | Cars Dorailod | Average Number of Cars | Risk = Rate x Average |
| Infrastru | Accident Cause Groups | Accident | inition transmite | Deralleu | Defailed Fel Accident | Number of Cars Defailed |
| 08T | Broken Bails or Welds | 984 | 0 1245 | 12 756 | 12 9634 | 1 6138 |
| 05T | Buckled Track | 238 | 0.0301 | 3 081 | 12.3004 | 0.3898 |
| 04T | Track Geometry (excl. Wide Gauge) | 454 | 0.0574 | 2 977 | 6 5573 | 0.3766 |
| 03T | Wide Gauge | 286 | 0.0362 | 2,691 | 9 4091 | 0.3404 |
| 07T | Joint Bar Defects | 96 | 0.0002 | 1 723 | 17 9479 | 0.2180 |
| 09T | Other Rail and Joint Defects | 74 | 0.0094 | 1,495 | 20.2027 | 0.1891 |
| 06T | Rail Defects at Bolted Joint | 68 | 0.0086 | 1,235 | 18,1618 | 0.1562 |
| 10T | Turnout Defects - Switches | 200 | 0.0253 | 1,191 | 5.9550 | 0.1507 |
| 01T | Roadbed Defects | 112 | 0.0142 | 1,169 | 10.4375 | 0.1479 |
| 12T | Misc. Track and Structure Defects | 113 | 0.0143 | 1.029 | 9.1062 | 0.1302 |
| Human F | actor Related | | | | | |
| 09H | Train Handling (excl. Brakes) | 297 | 0.0376 | 2,170 | 7.3064 | 0.2745 |
| 05H | Failure to Obey/Display Signals | 154 | 0.0195 | 1,543 | 10.0195 | 0.1952 |
| 01H | Brake Operation (Main Line) | 139 | 0.0176 | 1,247 | 8.9712 | 0.1578 |
| 11H | Use of Switches | 191 | 0.0242 | 936 | 4.9005 | 0.1184 |
| 10H | Train Speed | 144 | 0.0182 | 915 | 6.3542 | 0.1158 |
| 12H | Misc. Human Factors | 73 | 0.0092 | 595 | 8.1507 | 0.0753 |
| 07H | Switching Rules | 118 | 0.0149 | 471 | 3.9915 | 0.0596 |
| 08H | Mainline Rules | 61 | 0.0077 | 377 | 6.1803 | 0.0477 |
| 02H | Handbrake Operations | 70 | 0.0089 | 309 | 4.4143 | 0.0391 |
| 04H | Employee Physical Condition | 8 | 0.0010 | 95 | 11.8750 | 0.0120 |
| Mechani | cal Related | | | | | |
| 12E | Broken Wheels (Car) | 312 | 0.0395 | 2,480 | 7.9487 | 0.3137 |
| 10E | Bearing Failure (Car) | 384 | 0.0486 | 2,399 | 6.2474 | 0.3035 |
| 11E | Other Axle/Journal Defects (Car) | 175 | 0.0221 | 1,471 | 8.4057 | 0.1861 |
| 09E | Sidebearing, Suspension Defects (Car) | 178 | 0.0225 | 1,273 | 7.1517 | 0.1610 |
| 13E | Other Wheel Defects (Car) | 193 | 0.0244 | 1,047 | 5.4249 | 0.1325 |
| 07E | Coupler Defects (Car) | 176 | 0.0223 | 998 | 5.6705 | 0.1263 |
| 06E | Centerplate/Carbody Defects (Car) | 138 | 0.0175 | 637 | 4.6159 | 0.0806 |
| 19E | Stiff Truck (Car) | 81 | 0.0102 | 567 | 7.0000 | 0.0717 |
| 20E | Track/Train Interaction (Hunting) (Car) | 54 | 0.0068 | 520 | 9.6296 | 0.0658 |
| 08E | Truck Structure Defects (Car) | 57 | 0.0072 | 418 | 7.3333 | 0.0529 |

Table 3.7 Top Ten High-Risk Accident Causes of Mainline Freight Train Accidents byAccident Cause Categories and Type of Accident, 1999–2013

4. Conclusion

This report is Phase I of the three-part project that defines the scope of the literature review and summarizes the results from the literature review. Locations where each hazard is eminent, influencing factors of each hazard, and potential risk mitigation strategies for each hazard were identified and presented. Causal analysis was conducted for mainline passenger and freight train accidents to understand major factors leading to passenger and freight train accidents and identify accident causes that are more relevant to HSR systems adjacent to and sharing corridors with existing conventional railway operations.

5. References

Arthur D Little. (1996). *Risk Assessment for the Transportation of Hazardous Materials by Rail, Supplementary Report: Railroad Accident Rate and Risk Reduction Option Effectiveness Analysis and Data* (2nd ed.). Cambridge, Massachusetts.

Abbreviations and Acronyms

| Abbreviation or Acronym | Name |
|----------------------------|--|
| ADL | Arthur D. Little |
| FRA | Federal Railroad Administration |
| GD | Guidance Document |
| HSR | High-Speed Rail |
| HF | Human Factors |
| RailTEC | Rail Transportation and Engineering Center |
| UI | University of Illinois at Urbana-Champaign |