Causal Analysis of Passenger Train Accidents on Freight Rail Corridors

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Abstract

A number of economic, technical and political factors have limited the development of new, dedicated, very-high-speed rail systems in North America. Consequently, most, near-term development of improved or expanded passenger rail service in the U.S. will involve use of existing railroad infrastructure or rights of way. Comprehensive understanding of train accidents on shared-use corridors is critical for rational allocation of resources to reduce train accident risk. Nevertheless, little research has been undertaken to quantify the risk of a passenger train operating on or next to a freight train in a shared track or shared-use corridor setting. The research described in this paper presents the initial results of a study intended to understand what the most important contributors to the risk of train accidents on shared-used rail corridors are. This work can be used to better understand how to most efficiently and effectively manage the risk on shared-use rail corridors. Although developed in the context of the railroad operation in the U.S., this research can also be applied to other countries by adapting to their safety standards and risk management strategies.

Introduction

Demand for regional and intercity passenger transport in the United States is increasing, resulting in the need to expand transportation network capacity. For the past half century most of this demand has been met by U.S. highway and air transportation systems; however, these are becoming increasingly congested and adding capacity is more and more constrained. Furthermore, rising fuel costs have added further pressure to both of these modes because of their relatively high energy intensity. Railroads are being viewed as a promising alternative because of their ability to provide, safe, economical, comfortable and reliable passenger transport [1, 2]. A number of economic, technical and political factors have limited the development of new, dedicated, very-high-speed rail systems in North America. Consequently, most, proposed, near-term development of improved or expanded passenger rail service in the U.S. will involve use of existing railroad infrastructure or rights of way [3, 4, 5].

Shared or mixed use corridors refer to different types of passenger and/or freight trains using common infrastructure in some way or another. The U.S. Department of Transportation, Federal Railroad Administration (FRA) defines three types of shared use: shared track, shared right-of-way (ROW), and shared corridor [6] (Figure 1).

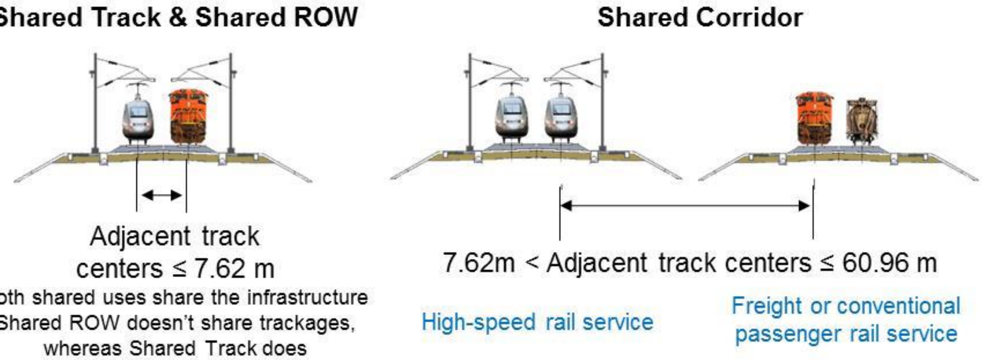


Figure 1. FRA Definition of Shared-Use Corridor [7]

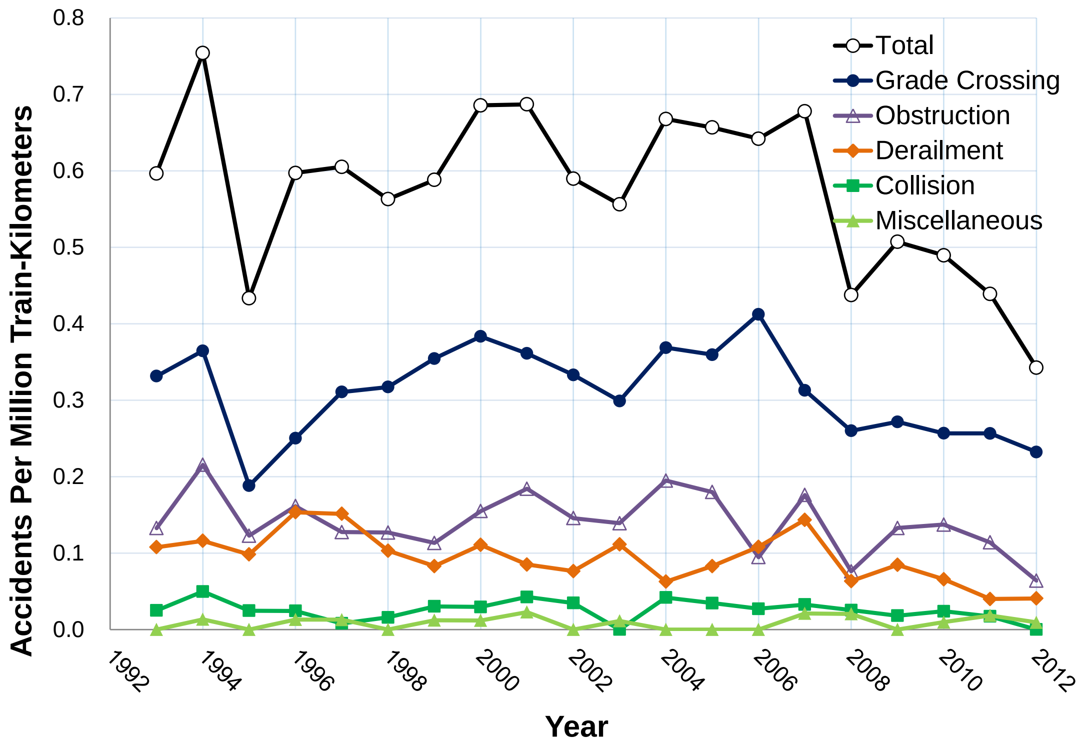
Each type of shared-use system has associated advantages and disadvantages. Among the advantages are potentially lower capital costs, less environmental impact, and potentially easier access to urban cores. Among the potential disadvantages include: safety and risk concerns due to more frequent, higher speed operation of passenger trains in close proximity to freight trains and maintenance of way personnel, reduced line capacity due to more heterogeneous operating characteristics, longer travel time compared to very-high-speed rail, tradeoffs in infrastructure and vehicle designs due to differing characteristics of passenger and freight trains as well as other technical and institutional challenges [1, 7].

A high priority for any rail system is operating safety and there are several concerns associated with operating more frequent, higher-speed passenger trains on shared-use corridors [7]. Among these are, the consequences of a collision between a passenger train and derailed equipment from an adjacent track. Higher passenger train operating speed increases the likely severity of an accident if another train derails and fouls the track on which a passenger train is operating, or alternatively, if a passenger train derails and collides with a freight train on a nearby track [7]. The U.S. approach to this has been to develop robust crash-worthiness standards for passenger equipment that operate in mixed-used circumstances [8]. An alternative approach used in most other countries has been to invest heavily in prevention of such accidents. Both approaches are beneficial, but although the U.S. railroad accident rate has been declining for decades, reaching its lowest level ever in 2012 [9], the latter approach is more difficult in the North American heavy-haul, freight environment because of the 1.5 million railcars owned by hundreds of owners operating over hundreds of thousands of kilometers throughout the continent. Under a system such as this, optimized for highly efficient freight transport, it is difficult to maintain all these railcars in a sufficiently high condition such that components never fail and cause a derailment. Furthermore, the very high axle loads, commonly ranging from 29.8 to 35.7 metric tons put enormous stress on the infrastructure. Although the infrastructure is designed for these heavy loads, components occasionally develop problems that go undetected until they fail and cause an accident. Besides mechanical and infrastructure related causes, a third major cause of accidents are those due to human factors, in which an individual involved in operating or controlling a train's movement, makes an error.

Although not necessarily related to heavy-axle-load freight, these accidents also contribute to the risk of shared corridor operations. Another important factor is grade (level) crossing accidents. Although nearly all of the world's dedicated HSR lines have complete grade separation between rail and highway lines, shared uses of existing freight infrastructure makes elimination of all grade crossings infeasible.
Analysis of train accident causes is critical for rational allocation of resources to reduce accident occurrence and consequences. However, very little research has been undertaken to quantify the risk of a passenger train operating on or next to a freight line in shared-use corridors. The research described in this paper presents the initial results of a study intended to understand and quantify the most important contributors to the risk of train accidents on shared-used rail corridors. The ultimate objective of this work is to understand and quantify the most effective means of preventing accidents and reducing the risk associated with shared-used corridors.

Mainline Passenger Train Accident Analysis

Train accident data from the FRA Rail Equipment Accident database were analyzed to examine the effects of different accident causes on the risk of passenger train accidents. The FRA publishes annual train accident statistic summaries [10] but the results are presented at a highly aggregated level [11]. More in-depth insights can be found by analyzing these data in more detail and considering other statistical approaches. Figure 2a shows mainline passenger train accident rate over the 20-year interval from 1993 to 2012 sorted by five types of accidents: grade crossing, derailment, collision, obstruction, and miscellaneous. Annual traffic data were obtained from the U.S. Bureau of Transportation Statistics [12] and the FRA Railroad Safety Statistics Annual Reports [13, 14]. The overall passenger train accident rate has decreased since 1993. Over this period, grade-crossing accidents have been the most frequent type of passenger train accident, followed by obstructions and then derailments.



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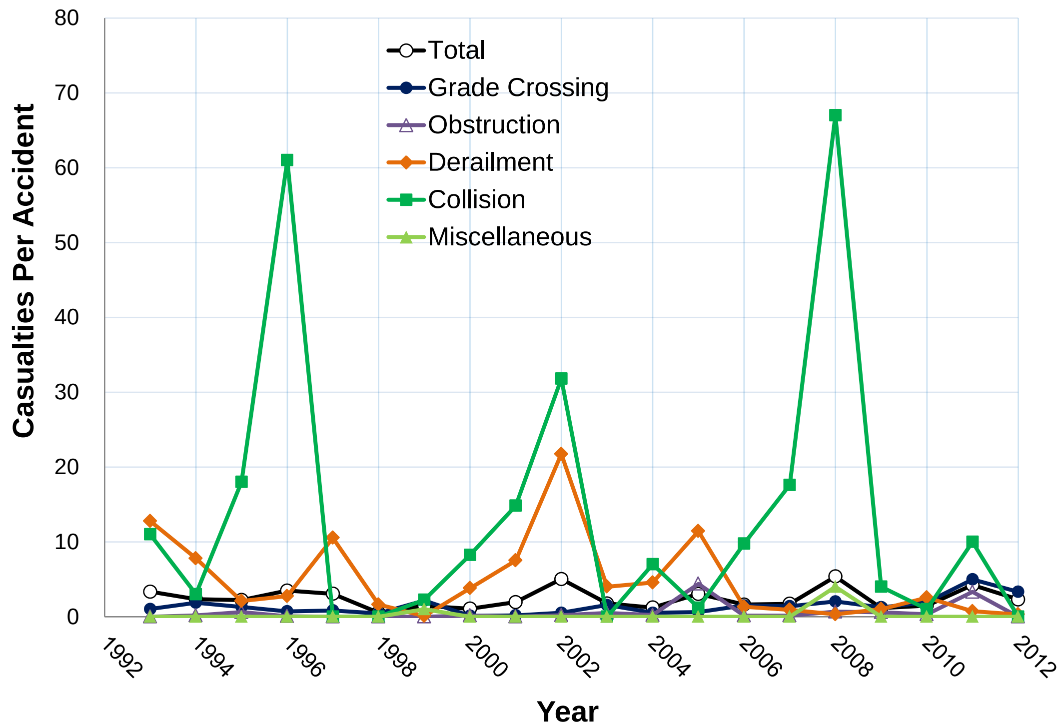


(b)

Figure 2. Mainline Passenger Train Accident Rates (2a) and Average Casualties (2b) by Type of Accidents, 1993 – 2012

Both the probability of an event and the consequence of the event affect risk. The rate of accident was calculated as accidents per unit distance traveled (Figure 2a). Several different indices were considered to measure consequence (referred to as severity indicators). These included the cost of damage to rolling stock and infrastructure (referred to as damage), number of railcars derailed, and casualties. Casualties (the sum of injuries and fatalities) were chosen as the primary severity indicator, but other severity indicators will be discussed later in this paper. In Figure 2b, the average casualties in mainline passenger train accidents from 1993 to 2012 were plotted by the same five types of accidents as shown in Figure 2a. Annual passenger train casualties fluctuate widely. It is evident that although grade crossings are the most common causes of passenger train accidents (Figure 2b), they do not tend to result in large numbers of passenger casualties. Instead, derailments and collisions generally result in the highest rate of casualties, driven by a relatively small number of severe accidents that resulted in large casualties [15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25]. Although there were 1,631 passenger train accidents during the 20-year study period, 144 or less than 10%, resulted in 95% of the casualties.
To measure the risk from different types of accidents, we plotted the number of accidents per unit train traveled to represent the accident frequency versus the average severity of mainline passenger train accidents by type (Figure 3). 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 are most likely to pose the greatest risk because they are both more frequent and more severe than average. As mentioned above, derailments and collisions had the most severe consequences in terms of casualties. Although they were below average in terms of frequency, the total risk due to derailments and collisions are still the highest among the five types of accidents.

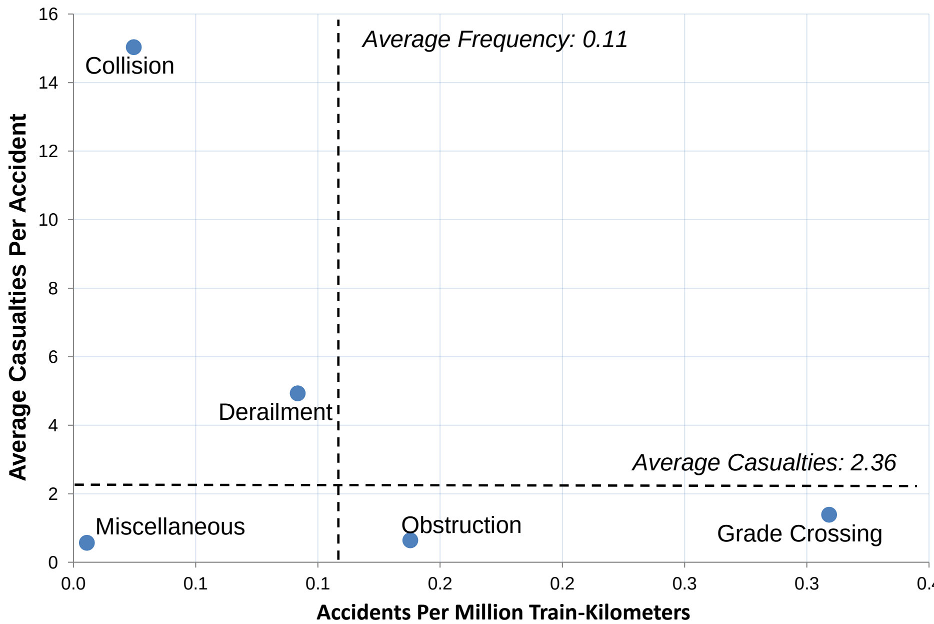


Figure 3. Frequency and Severity Graph of Mainline Passenger Train Accidents by Type of Accident

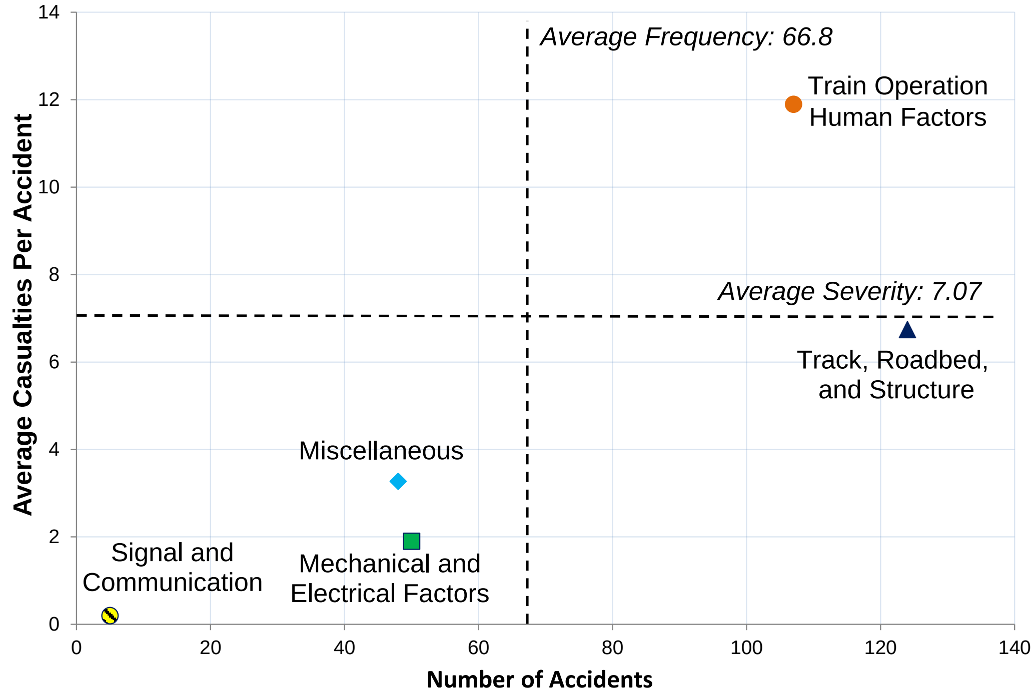
The data suggest that the train accidents most likely to result in high-casualty incidents are derailments and collisions. Although grade crossings are the most common type of accident they are among the least severe in their consequences. Collisions and derailments are caused by the interaction of two or more trains and thus a concern in shared-use corridors in which a passenger train may collide with a derailed freight train or vice versa. Therefore, the next section of this paper examines mainline passenger derailments and collisions in more detail.

Train Accident Cause

FRA train accident cause codes are hierarchically organized and categorized into major cause groups - track, equipment, human factors, signal and miscellaneous [26]. Within each of these major cause groups, FRA organizes individual cause codes into subgroups of related causes such as roadbed, track geometry, etc. within the track group, and similar subgroups within the other major cause groups. We used a variation on the FRA subgroups developed by Arthur D. Little (ADL) in which similar cause codes were combined into groups based on expert opinion [11, 27]. ADL's groupings are similar to FRA's subgroups but are more fine-grained thereby allowing 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. These groups were used to analyze cause-specific derailment frequency and severity.

Figure 4 shows the frequency and severity graphs by the major accident cause groups. The graph is also divided into four quadrants to enable easy comparison of the relative frequency and severity of different accident cause groups. Figure 4a uses average casualties as the severity indicator, while Figure 4b uses average cars derailed. In terms of average casualties (Figure 4a), the human factors accident cause group was identified as the most frequent and severe. The track accident cause group, as represented by Track, Roadbed, and Structure, was more frequent than the human factors accident cause group, but less severe. In terms of average cars derailed (Figure 4b), the track accident cause group was identified as the most frequent and severe group, and the human factors accident cause group had high frequency but low severity. Track-related causes led to more cars derailed than human factors accident causes did, whereas human factors accident causes resulted in more casualties than track-related causes.

Both human factors and track accident causes consistently represented the most frequent and severe accident cause groups and therefore were analyzed in more detail.



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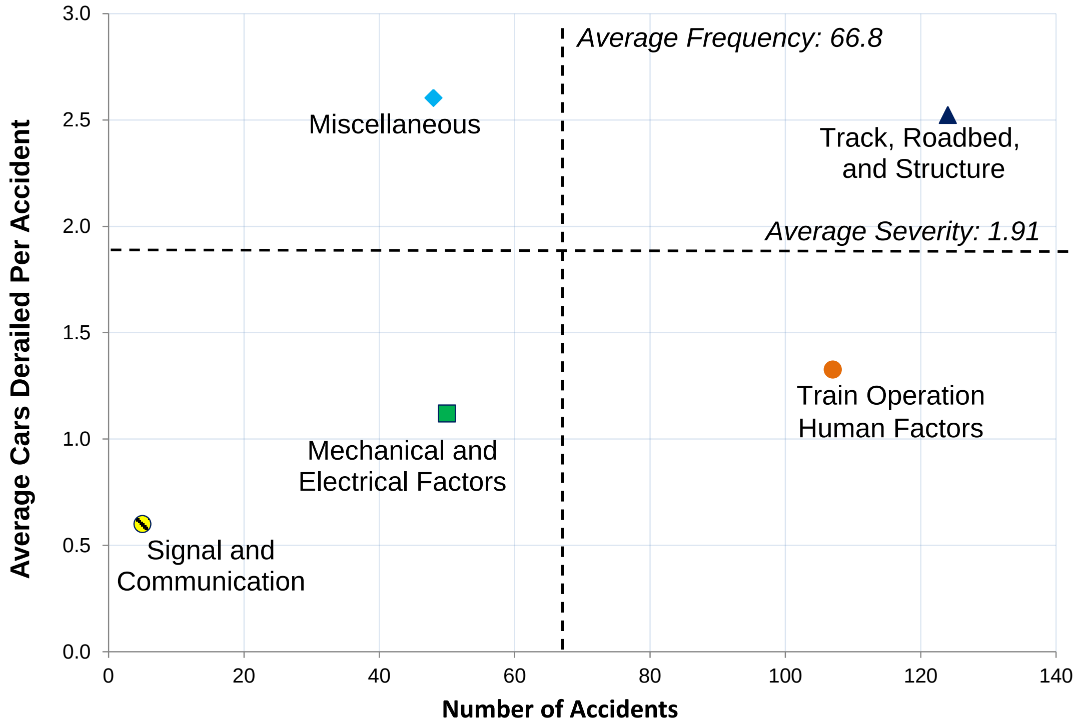


(b)

Figure 4. Frequency and Severity Graph of Mainline Passenger Derailments and Collisions, 1993-2012, by Accident Cause Category with Average Casualties (4a) and Average Cars Derailed (4b) as Severity Indicator.

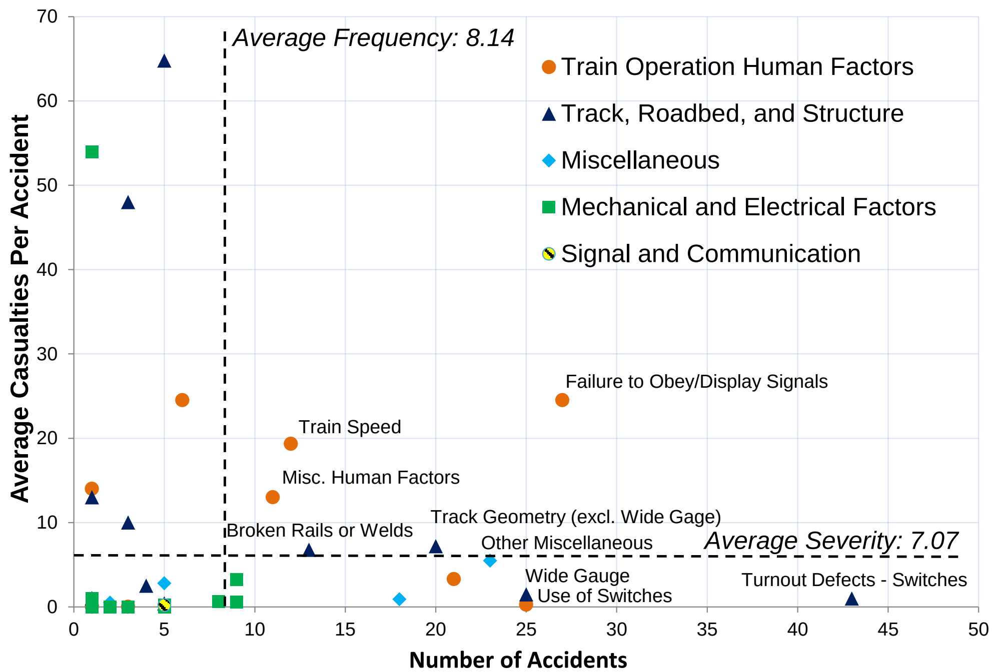
Figure 5 shows the frequency and severity of the more detailed accident cause subgroups for human factors and track accident cause groups. Similar to the approach shown in Figures 3 and 4, the graph is divided into four quadrants to enable easy comparison of the relative frequency and severity of different accident cause subgroups. In terms of average casualties, five accident cause subgroups were in the upper right quadrant in Figure 5a, which were most likely to pose the greatest risk due to their high frequency and severity. They include:

- Failure to Display/Obey Signals (Human Factors)
- Train Speed (Human Factors)
- Misc. Human Factors (Human Factors)
- Track Geometry excl. Wide Gauge (Track)
- Broken Rails or Welds (Track)

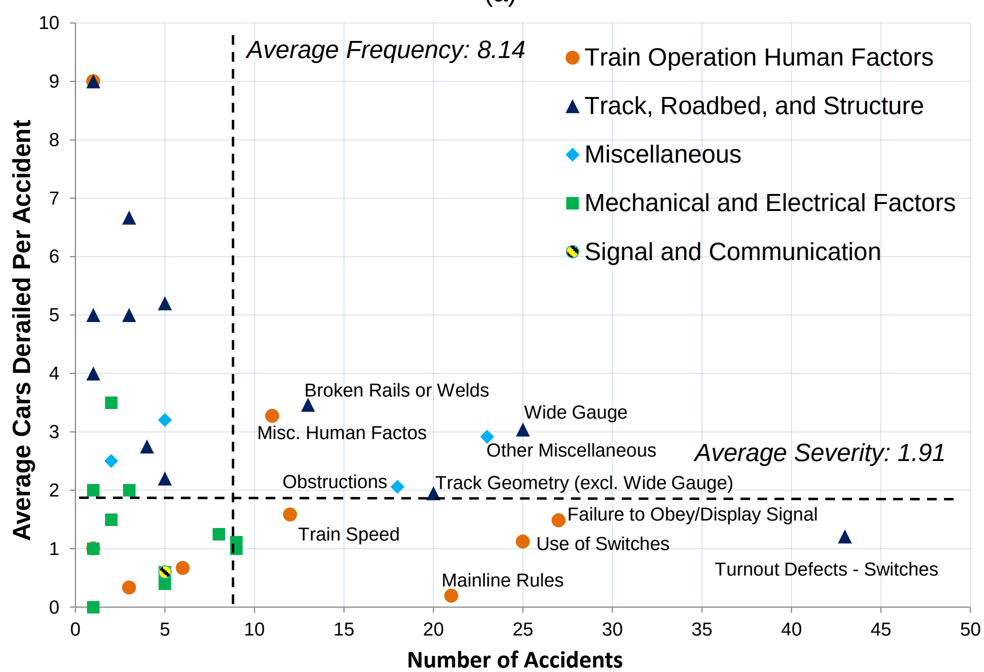
Similarly, in terms of average cars derailed, six accident cause groups were identified in the upper right quadrant in Figure 5b:

- Broken Rails or Welds (Track)
- Other Miscellaneous (Miscellaneous)
- Wide Gauge (Track)
- Misc. Human Factors (Human Factors)
- Obstructions (Miscellaneous)
- Track Geometry excluding Wide Gauge (Track)

Among all the subgroups identified in the top-right quadrant “Failure to Display/Obey Signals” had the highest average casualties per accident, while “Broken Rails or Welds” had the highest average cars derailed per accident. Note that “Broken Rails or Welds”, “Track Geometry excluding Wide Gauge”, and “Misc. Human Factors”, appeared on the upper right quadrant in both figures.



(a)



(b)

Figure 6. Frequency and Severity Graph of Mainline Passenger Derailments and Collisions, 1993-2012, by Accident Cause Groups with Average Casualties (5a) and Average Cars Derailed (5b) as Severity Indicator

Conclusion and Future Work

This paper presents the initial results of a study to identify the most important contributors to the risk of train accidents on shared-used rail corridors. Derailments and collisions were identified as the most potentially significant train accident types while human factors accidents and track failures were the primary causes of those accidents. Some accident causes related to human factors on train operations were identified to have high risk such as train speed violation and not obeying signals. Some high-risk infrastructure-related factors include track geometry defects and broken rails or welds. This analysis of train accident causes is critical for rational allocation of resources to reduce accident occurrence and consequences on shared-use corridors. Future work in this area will include comparisons of the major accident causes with those incurred by freight trains, how to quantitatively evaluate the risk from these causes and how these accident causes affect the likelihood of adjacent track derailments.

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