SUCCESS FACTORS IN THE REDUCTION OF HIGHWAY-RAIL GRADE CROSSING INCIDENTS

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ABSTRACT

Between the years 1994 and 2007, incidents at highway-rail grade crossings declined by 44.7 percent. The reasons for this decline were unidentified. The U.S. Department of Transportation's (USDOT) Research & Innovative Technology Administration's (RITA) John A. Volpe National Transportation Systems Center (Volpe Center), under the direction of the USDOT Federal Railroad Administration's (FRA) Office of Research and Development (R&D), conducted a study to identify the salient success factors in highway-rail grade crossing incident reduction. The study was conducted in two parts. In the first part of the study, an examination of the reduction of highway-rail grade crossing incidents during the 1994 to 2003 time period was completed. In the second part of the study, an analysis of success factors for the 2003 through 2007 time period was completed.

The first part of the study identified five factors as major contributors to the reduction in highway-rail grade crossing incidents from 1994 to 2003. These five factors (Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, and the Grade Crossing Maintenance Rule) impacted 54 percent of the incidents and accounted for 79 percent of the reduction in incidents. The second part of the study analyzed the effects of those factors on grade crossing safety from 2003 to 2007 and identified any factors whose impact began after 2003. This effort revealed that regulations and rulemakings had a positive effect on the number of incidents, but the benefit diminished over time. By 2007, the number of incidents attributed to the major factors from 1994 to 2003 had leveled off. The study also unveiled positive impacts from the passing of the final rule on freight car reflectorization in 2005.

INTRODUCTION

Incidents at highway-rail grade crossings in the United States declined 44.7 percent from 1994 to 2007. This decline was likely a result of various crossing safety improvement programs conducted during that time period. The U.S. Department of Transportation (USDOT) Federal Railroad Administration (FRA) tasked the USDOT Research and Innovative Technology Administration's John A. Volpe National Transportation Systems Center (Volpe Center) to determine the safety factors that were responsible for the reduction of highway-rail grade crossing incidents. The study was conducted in two parts. In the first part of the study, an examination of the reduction of highway-rail grade crossing incidents during the 1994 to 2003 time period was completed (1). In the second part of the study, an analysis of success factors for the 2003 through 2007 time period was completed.

Through literature reviews, discussions, and consultation with subject matter experts, a comprehensive list of success factors was developed. The list was prioritized and narrowed to the factors that were assumed to have a high projected impact on incident reduction. The factors were then separated into those that could be approximated by fields in the Railroad Accident Incident Reporting System (RAIRS) Highway-Rail Grade Crossing database and those that would be analyzed without the RAIRS fields.

- The analysis revealed five factors with RAIRS field equivalents that influenced highway-rail grade crossing safety from 1994 to 2003, and an additional two factors that had potential influence from 2003 to 2007. Those seven factors were the following:Commercial Driver Safety – an emphasis on commercial driver safety at highway-rail grade crossings, including the Motor Carrier Safety Improvement Act of 1999
- Locomotive Conspicuity – the final rule on Locomotive Safety Standards (49CFR229) states that all locomotives exceeding 20 miles per hour must have auxiliary alerting lights in addition to the headlight
- More Reliable Motor Vehicles – improvements have been made in automobiles to be safer and more reliable, reducing the likelihood of stalling on the tracks
- Sight Lines Clearance – the clearance of vegetation and removal of obstructions surrounding the grade crossing provides highway-users adequate sight distance to stop safely and make informed judgments
- Grade Crossing Maintenance Rule – the final rule on Grade Crossing Signal System Safety (49CFR234) stated that railroads must implement specific maintenance, inspection , and testing requirements for active crossing warning systems
- Freight Car Reflectorization – the final rule on Reflectorization of Rail Freight Rolling Stock (49CFR224) mandated the application of retroreflectivesheeting to the sides of freight cars and locomotives
- Pedestrian Safety – new devices and technologies are being installed at grade crossings that specifically target pedestrian traffic

In addition, other factors were analyzed separately:

- Crossing Consolidation/Grade Separation - consolidation and grade separation reduce the risk of a collision to nearly zero because the vehicle and train paths no longer intercept at that location
- Warning Device Upgrades – the risk of a collision at a crossing is reduced when the warning devices are upgraded to devices with a higher effectiveness value
- Education & Enforcement – highway-rail grade crossing education and enforcement are options to supplement safety and increase public awareness of the dangers at crossings
- Crossing Improvement Programs - federal funding has been designated to improve safety measures at highway-rail grade crossings (this includes the Highway Safety Improvement Program and "Section 130" funds).

The trend in incidents assigned to one of the seven factors and the overall grade crossing incident trend from 1994 to 2007 is shown in Figure 1. The success factor line closely mimics the overall trend.

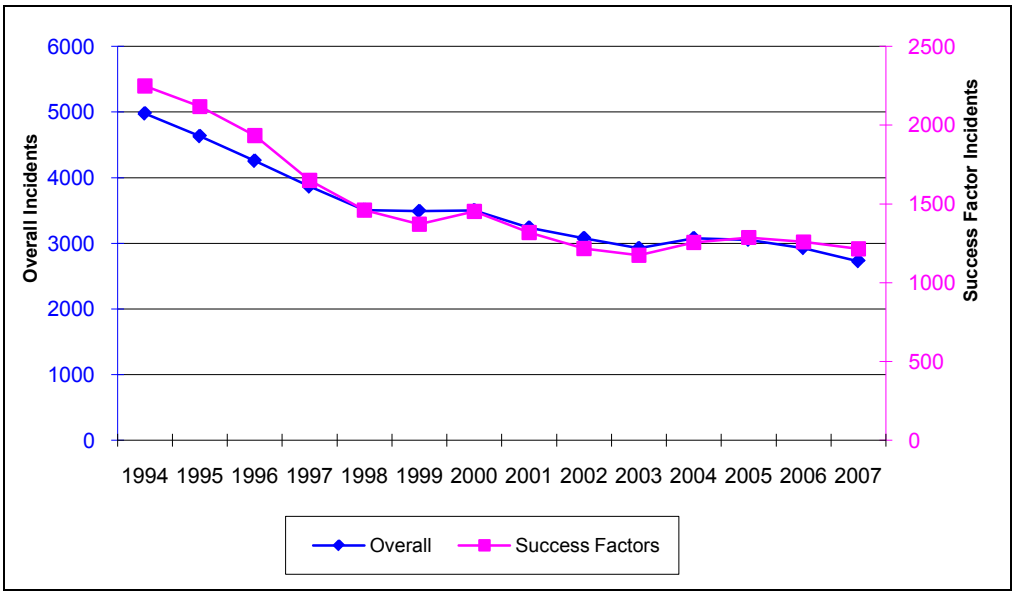

Figure 1. Highway-Rail Grade Crossing Incident Trends

BACKGROUND

The 1994 USDOT Secretary's Rail-Highway Crossing Safety Action Plan suggested initiatives and actions to reduce highway-rail grade crossing incidents over a ten-year period (2). The plan set a goal to reduce incidents by 50 percent. During those ten years, incidents declined 41.2 percent. Although this was short of the 50 percent goal, it was a significant decrease that suggested safety was improving in the grade crossing environment

In 2004, the USDOT Secretary issued an updated Action Plan for Highway-Rail Grade Crossing Safety and Trespass Prevention (3). This plan superseded the 1994 plan to improve safety at grade crossings across the nation. From 2003 to 2007, incidents declined an additional 7.5 percent. The reasons for the declines in both time periods were not attributed to particular safety initiatives.

A study on a similar topic area to this research was conducted by Mok and Savage entitled *Why Has Safety Improved at Highway-Rail Grade Crossings?* (4). The Mok and Savage study identifies and investigates possible factors that are influential in the reduction of incidents and fatalities at grade crossings. The focus of the study was the reduction in grade crossing incidents and fatalities from 1975 to 2001.The methodology used was a negative binomial regression. The greatest influence on safety was attributed to highway safety improvements such as drunk driving, enforcement, and improved emergency response. Other influential factors identified in the study were warning device upgrades, Operation Lifesaver, locomotive alerting lights and crossing closure. The main difference between the Mok and Savage study and this study is that this research does not attempt to develop a regression model for incidents. It makes the assumption that certain factors can be approximated by data fields in the RAIRS Grade Crossing database. The data fields were examined for reductions in incidents and those reductions were attributed to a particular factor.

RESEARCH OBJECTIVES

There were two objectives to this research. The first objective was to develop a methodology to evaluate the impact of highway-rail grade crossing safety programs on trends in incidents.

The second objective was to use the methodology to determine the most influential safety factors responsible for the reduction of highway-rail grade crossing incidents from 1994 to 2003 and from 2003 to 2007.

RESEARCH METHODS

The first step in determining which safety factors had the largest influence on the reduction of incidents was to identify all possible factors during the study period. This was done through extensive literature reviews and group discussions. Brief data analysis, a literature search and discussions with subject-matter experts was conducted for each potential factor. This information was used to prioritize the potential factors based on the perceived impact on highway-rail grade crossing safety during the study time-period. The team then narrowed the list of success factors to those with a high projected impact on the number of incidents. The success factors that were considered in both phases of this study were the following:

- Commercial Driver Safety
- Locomotive Conspicuity
- Grade Crossing Maintenance
- More Reliable Motor Vehicles
- Sight Lines Clearance
- Crossing Consolidation/Grade Separation
- Warning Device Upgrades
- Education and Enforcement
- Crossing Improvement Programs
- Freight Car Reflectorization
- Pedestrian Safety

Of the factors that were selected, some factors could be approximated by fields within the RAIRS Grade Crossing database. The data fields were selected that specifically related to the factors. For example, incidents involving commercial vehicles were selected to represent Commercial Driver Safety. Table 1 shows a complete list of the fields from the RAIRS Grade Crossing database that were used to identify incidents related to the factors. Other factors were

difficult to analyze using RAIRS Grade Crossing data and were therefore evaluated by other means.

For the factors analyzed using RAIRS Grade Crossing data, incidents that matched the RAIRS fields identified in Table 1 were assigned to the appropriate factor. The change in the number or distribution of incidents over time was used to approximate the effects of each factor. One constraint in this analysis was that the quality of the results is only as a good as the quality of the data. Incomplete or inaccurate accident/incident forms could affect the robustness of the results.

The factors analyzed using Grade Crossing data from RAIRS were measured using two metrics: percent impact and percent reduction. The metrics were designed to determine each factor's contribution to incident reduction. The percent impact is the percentage of incidents that can be attributed to behaviors that the factor was attempting to change. The percent impact was calculated by dividing the number of incidents attributed to the factor by the total number of grade crossing incidents. The percent reduction is the percentage of incidents reduced that can be attributed to the safety countermeasures for a factor. The percent reduction was calculated by dividing the change in the number of incidents for a factor from the first year of the study to the last by the change in the total number of grade crossing incidents from the first year of the study to the last. Together, these two metrics provide a complete picture of the factors' contribution to incident reduction.

Table 1: Fields Used to Identify Incidents in RAIRS Grade Crossing Database

Factor	Description	RAIRS Field Identifiers
Commercial Driver Safety	Incidents involving commercial vehicles	TYPVEH (Truck, Truck-trailer, Bus, School Bus)
Locomotive Conspicuity	Incidents that may have involved reduced visibility of an oncoming train	TYPACC (Rail equipment struck highway user) VISIBILTY (Dawn, Dusk, Dark) RREQUIP (Train - units pulling, Train - units pushing)
More Reliable Vehicles	Incidents that involved highway vehicles that encountered a mechanical problem	POSITION (Stalled on the crossing)
Sight Line Clearance	Incidents that involved a visual obstruction of the right-of-way	VIEW (Permanent structure, standing railroad equipment, topography, vegetation)
Grade Crossing Maintenance Rule	Incidents involving a signal malfunction	SIGNAL (Alleged warning time > 60 sec, Alleged warning time < 20 sec, Alleged no warning, Confirmed warning time > 60 sec, Confirmed warning time < 20 sec, Confirmed no warning)
Freight Car Reflectorization	Incidents that may have involved reduced visibility of a train occupying the crossing	TYPACC (Highway user struck rail equipment) VISIBILTY (Dawn, Dusk, Dark) RREQUIP (Train - units pulling, Train - units pushing) LIGHTS (No)
Pedestrian Safety	Incidents involving pedestrians	TYPVEH (Pedestrian)

Data fields from the RAIRS Grade Crossing database were used to categorize the incidents by success factor. Because of this, one incident could be assigned to more than one factor. For example, an accident report could cite a commercial vehicle involved, the vehicle stalled on the tracks, and an obstruction blocked the sight line. This would mean that this incident would be attributed to all three of the following factors: Commercial Driver Safety, More Reliable Motor Vehicles, and Sight Lines Clearance. In reality, either one factor alone or some combination of the three factors was related to the incident. This resulted in an overlap of incidents among factors and inflated the estimate of the factors' effects. The methodology for isolating the incidents used the concept of a Venn Diagram. Each incident in the database was assigned to a single factor, some combination of factors, or a category of unidentified factors. The combined factors were incidents that could be mapped to more than one factor. The factor isolation provided a more accurate measure of the factors' effect on incident reduction.

Factors that were rated difficult to analyze were examined in other ways. Two factors, for which data was available but could not be isolated, were analyzed using a predicted number of incidents avoided. These were also tested for correlation between the factor and the number of incidents. Factors for which no data was readily available were analyzed qualitatively using relevant studies.

RESULTS - 1994 to 2003

The original assessment of highway-rail grade crossing safety initiatives revealed nine factors that were rated high on projected impact. Of these nine factors, five could be approximated using fields in the RAIRS Grade Crossing Database. Those five factors were Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, and the Grade Crossing Maintenance Rule. Four other factors were analyzed separately: Crossing Consolidation and Grade Separation, Warning Device Upgrades, Education and Enforcement (e.g. Operation Lifesaver) and Crossing Improvement Programs (e.g. Section 130 Program).

The five factors analyzed using RAIRS Grade Crossing data and the interactions between them had a combined percent impact of 55 percent. In addition, 80 percent of the reduction in incidents, from 1994 to 2003, can be attributed to the five selected factors. The two isolated factors with the largest effects on incident reduction during these years were Commercial Driver Safety and Locomotive Conspicuity. These results are shown in Table 2 and in Figure 2.

Percent impact and percent reduction values were also calculated for Crossing Closure and Grade Separation and Warning Device Upgrades using the predicted number of incidents avoided. The number of crossings consolidated or upgraded was derived from the USDOT National Highway-Rail Crossing Inventory. From 1984 to the year a crossing was closed or separated, the accident history was used to obtain an average number of incidents per year. The average number of incidents was then extrapolated to obtain a probable number of incidents per year. The probable number of incidents for a particular year was the number of incidents that would have occurred in that year if the crossings closed or separated between 1994 and that year had not been closed or separated. This methodology estimated the percent impact for Crossing Consolidations and Warning Device Upgrades at 4.73 and 3.01, respectively, and the percent reduction were calculated as 16.22 and 8.25. Because these factors could not be isolated, a

separate analysis was performed. A test for correlation between the number of crossings closed/upgraded and the number of incidents showed a strong correlation in some years and low correlation in others.

The Education and Enforcement and Crossing Improvement Programs factors were evaluated qualitatively. Both of these factors encompass other factors, therefore making them difficult to isolate and approximate using RAIRS or inventory data. These factors have widely been accepted as influential factors in highway-rail grade crossing safety. *Accidents That Shouldn't Happen; A Report of the Grade Crossing Safety Task Force to Secretary Federico Pena* (5) estimates that since the inception of the Section 130 Program, 40,000 injuries have been prevented and 9,000 lives saved. Case studies and evaluations of education and enforcement programs at a state or local level have indicated positive changes in behavior following the implementation of such programs. Although the effects of these factors could not be quantitatively estimated using this methodology, the positive influences on safety are acknowledged.

Table 2. Success Factor Results, 1994 to 2003

Factor	Percent Impact	Percent Reduction
Commercial Driver Safety	21.8%	34.6%
Locomotive Conspicuity	15.0%	13.6%
Sight Lines Clearance	2.6%	3.6%
Grade Crossing Maintenance Rule	1.1%	3.1%
More Reliable Motor Vehicles	1.9%	3.1%
Combined Factors	12.8%	21.9%
Total	**55.2%**	**79.9%**

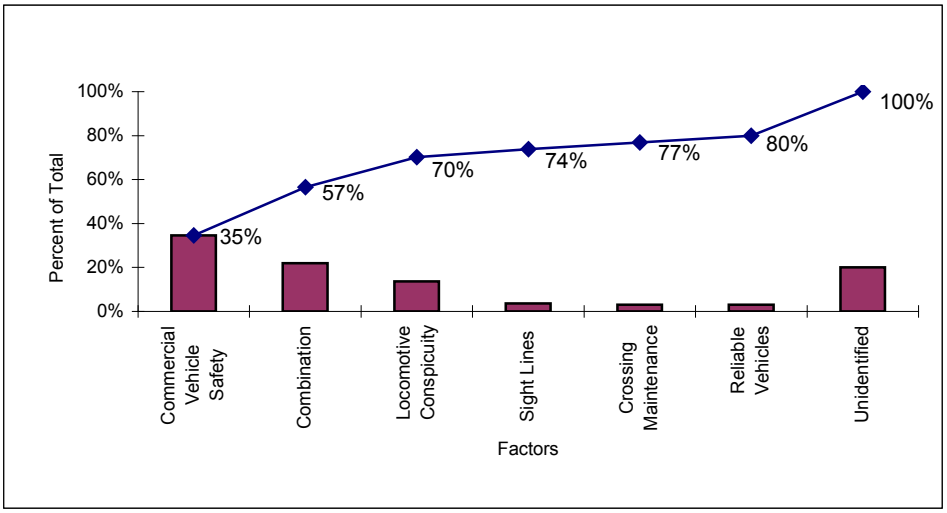

Figure 2. Percent Reduction Pareto Chart, 1994 to 2003

RESULTS - 2003 to 2007

The study of the success factors in the reduction of highway-rail grade crossing incidents was expanded to include the years 2003 through 2007. The purpose of this work was to investigate whether the previously identified success factors were continuing to contribute to crossing safety and to determine whether any new factors were responsible for the decline in incidents from 2003 to 2007.

The five factors that were evaluated using RAIRS Grade Crossing data for 1994 to 2003 were analyzed using the same methodology for the years 2003 through 2007. The results, shown in Table 3, indicate their effects were diminished by 2007.

Because the effects of the major factors identified from 1994 to 2003 had leveled off, it was necessary to identify additional factors that may have contributed to the decline in incidents. The additional factors selected were initiatives that began after 2003 and could be reasonably approximated by data fields within the RAIRS Grade Crossing database. Two additional factors were selected: Freight Car Reflectorization and Pedestrian Safety. The numbers of pedestrian incidents were mostly unchanged during the period. The number of incidents that approximated Freight Car Reflectorization incidents (incidents in which the motor vehicle struck the train) was relatively small. However, they showed a discernible downturn after the passing of the Reflectorization of Rail Freight Rolling Stock Final Rule (49CFR224) in 2005. A graph of Freight Car Reflectorization incidents versus Overall Incidents is shown in Figure 3.

Table 3. Success Factor Results, 2003 to 2007

Factor	Percent Impact	Percent Reduction
Commercial Driver Safety	18.7%	1.02%
Locomotive Conspicuity	15.5%	-5.1%
Sight Lines Clearance	1.8%	4.6%
Grade Crossing Maintenance Rule	1.4%	4.6%
More Reliable Motor Vehicles	1.6%	3.1%
Freight Car Reflectorization	1.0%	5.1%
Pedestrian Safety	1.8%	-8.7%

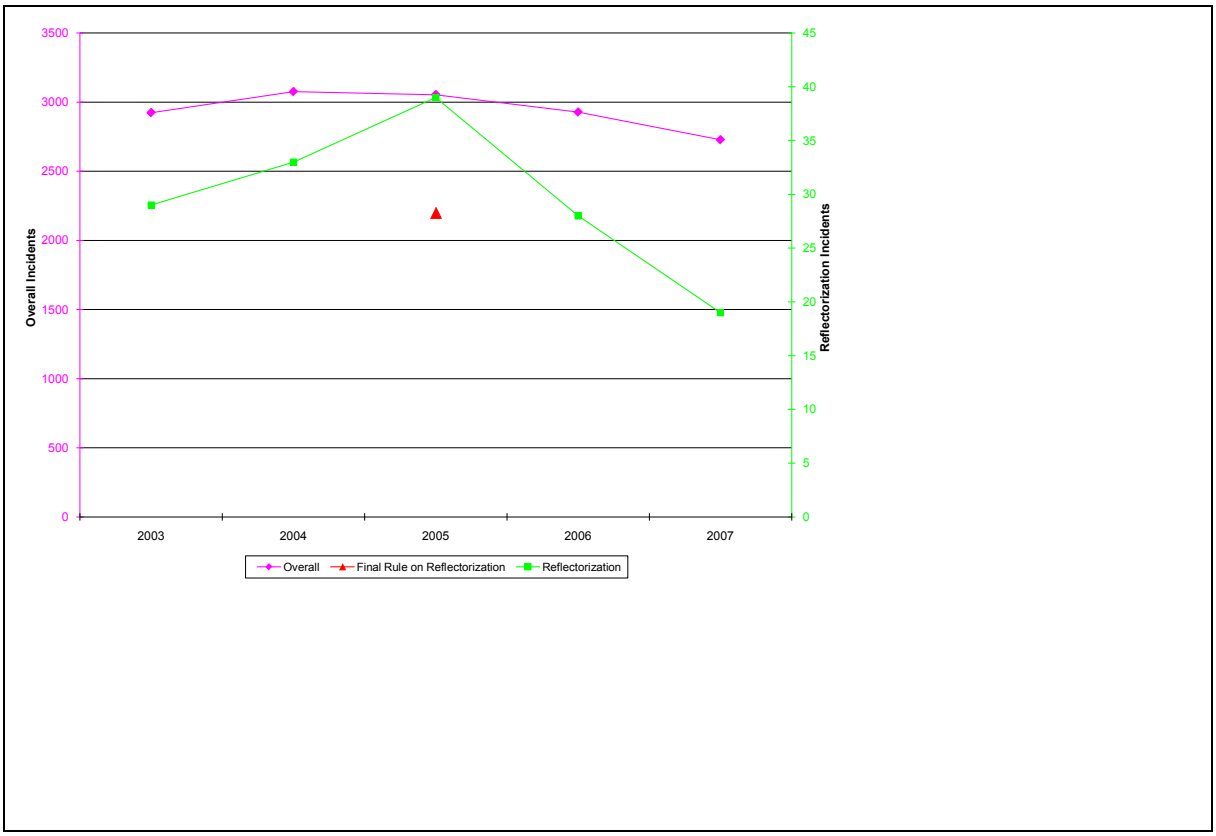

Figure 3. Reflectorization Incidents versus Overall Incidents, 2003 to 2007

CONCLUSIONS

During the study of success factors for 1994 to 2003, five factors were identified as major contributors to the reduction of highway-rail grade crossing incidents. The five factors were Commercial Driver Safety, Locomotive Conspicuity, Sight Lines Clearance, Grade Crossing Maintenance and More Reliable Motor Vehicles. These factors were analyzed using data from the RAIRS Grade Crossing database. These five factors impacted 55 percent of the incidents during the ten years. And 80 percent of the reduction in incidents, from 1994-2003, can be attributed to these five selected factors or the interaction of these factors. The two factors with the greatest success in reducing incidents were Commercial Driver Safety (34.6 percent) and Locomotive Conspicuity (13.6 percent).

At the conclusion of the first phase of the study, it was unknown whether those factors would continue to contribute to the declines in incidents. The analysis of those five factors from 2003 through 2007 revealed that their effects were diminished. The regulations and measures introduced during the 1990s had maximized their contributions to incident reduction by 2007. The two factors with the greatest success in reducing incidents, during 1994 to 2003, were Commercial Driver Safety (35.5 percent reduction) and Locomotive Conspicuity (13.6 percent reduction.) During the time period 2003 to 2007, the percent reduction for Commercial Driver Safety and Locomotive Conspicuity were 1.0 and -5.1 respectively. Although the small numbers

magnified any variability in the annual data, the results indicate that maximum reductions in incidents from these factors have been achieved.

Additional factors may have contributed to the declines from 2003 to 2007. Two factors were analyzed, Pedestrian Safety and Freight Car Reflectorization. These factors were selected because they were crossing safety initiatives that began after 2003 and they could be reasonably approximated by data fields within the RAIRS Grade Crossing database. The numbers of pedestrian incidents were mostly unchanged during the study period. This indicated that Pedestrian Safety measures need to be more widespread. The numbers of incidents that approximated Freight Car Reflectorization incidents were relatively small. However, they showed a discernible downturn after the passing of the final rule in 2005. The rulemaking had a positive effect on crossing safety. There are other factors that continue to impact the frequency of incidents at grade crossings but, cannot be analyzed using RAIRS Grade Crossing data. The percent impact and reduction for Crossing Closure and Warning Device Upgrades indicate they are effective strategies for improving safety at grade crossings. Education, Enforcement and Crossing Improvement Programs are also factors that impact the number of grade crossing incidents. These factors are difficult to quantitatively analyze, but other studies and reports indicate positive effects.

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