U.S. Department
Of Transportation

Federal Railroad Administration

Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents from 1994 to 2003

Office of Research
and Development
Washington, D.C. 20590

DOT/FRA/ORD-09/05 April 2009

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		Final Report July 2005 – June 2006

4. TITLE AND SUBTITLE
Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents from 1994 to 2003

5. FUNDING NUMBERS
RR-03/EB013

6. AUTHOR(S)
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8.PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FRA-09-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Research and Development
1120 Vermont Avenue, SW
Washington. DC 20590

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FRA/ORD-09/05

11. SUPPLEMENTARY NOTES
Safety of Highway-Railroad Grade Crossings series

12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Between the years 1994 and 2003, incidents at highway-rail grade crossings declined by 41.2 percent. The reasons for this decline were unknown. The John A. Volpe National Transportation Systems Center was tasked by the Federal Railroad Administration to identify the salient success factors in highway-rail grade crossing incident reduction. The success factors were analyzed and investigated using various qualitative and quantitative methods. Ten factors were identified as the most influential safety factors. The ten factors are: Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Crossing Closure and Grade Separation, Sight Lines Clearance, Warning Device Upgrades, the Grade Crossing Maintenance Rule, the Section 130 Program, Operation Lifesaver, and Railroad Mergers. Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, and the Grade Crossing Maintenance Rule were quantitatively analyzed with data from the Railroad Accident Incident Reporting System; they impacted 54 percent of the incidents and accounted for 79 percent of the reduction in incidents.

14. SUBJECT TERMS
Accident reduction, highway-rail intersections, safety

15. NUMBER OF PAGES
114

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Acknowledgements

The U.S. Department of Transportation (USDOT) Federal Railroad Administration (FRA) Office of Research and Development sponsored the work leading to this report, "Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents from 1994 to 2003." The authors would like to extend special appreciation to James Smailes, Program Manager of High-Speed Rail and Grade Crossings, Track Research Division, FRA, for his guidance and support.

The authors would also like to acknowledge John Choros and Michael Coltman, Structures and Dynamics Division, USDOT John A. Volpe National Transportation Systems Center (Volpe Center), as the task managers for this work. This project was conducted under the auspices of the Highway-Rail Grade Crossing Safety Research Program, Rail and Transit Systems Division, Volpe Center.

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Executive Summary

Between the years 1994 and 2003, incidents at highway-rail grade crossings in the United States declined by 41.2 percent. This decline was likely in response to the variety of highway-rail grade crossing safety improvement programs that were conducted during that time period. The United States Department of Transportation (USDOT) Federal Railroad Administration (FRA) Office of Research and Development tasked the USDOT Research and Innovative Technology Administration John A. Volpe National Transportation Systems Center (Volpe Center) with determining the most influential safety factors responsible for the reduction of incidents from 1994 to 2003.

During the first phase of the project, the research team began to identify all of the possible factors that may have influenced safety at highway-rail grade crossings during the study period. This was done through extensive literature reviews and group discussions. The team then categorized the comprehensive list of success factors by the projected impact on incident reduction and perceived difficulty to analyze. At the conclusion of Phase I, the factors that rated a high projected impact were selected for further analysis. Those factors were Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, Grade Crossing Maintenance Rule, Crossing Closure and Grade Separation, Warning Device Upgrades, Traffic Signal Preemption, Operation Lifesaver, and the Section 130 Program.

The second phase of the project was a quantitative analysis of the factors that were rated easy or moderate for perceived difficulty to analyze (Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, Grade Crossing Maintenance Rule, Crossing Closure and Grade Separation, Warning Device Upgrades, and Traffic Signal Preemption). The research team used two metrics to determine each factor's contribution to incident reduction. The percent impact is the percentage of incidents, from 1994 to 2003, that can be attributed to behaviors that the factor was attempting to change. The percent reduction is the percentage of incidents reduced, from 1994 to 2003, that can be attributed to the safety countermeasures for a factor. At the conclusion of project's phase, the team elected to pursue seven of the eight quantitatively analyzed factors in the next phase. The eighth, Traffic Signal Preemption, did not reflect a strong influence on reducing highway-rail grade crossing incidents.

The quantitative analysis in the second phase of this study was based on data available from the Railroad Accident Incident Reporting System–Highway-Rail Grade Crossing (RAIRS Grade Crossing) database. Because the data fields from the database were used to categorize the incidents by success factor, one incident could be assigned to more than one factor. This resulted in an overestimation of the factor effects and an overlap of incidents among factors. Phase III of the study focused on isolating the effects of each success factor, where possible, and analyzing the factors that were labeled difficult or very difficult to analyze in Phase I.

The factor isolation was applied to five of the seven remaining factors that were analyzed in Phase II (Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor

Vehicles, Sight Lines Clearance, and Grade Crossing Maintenance Rule). Each incident was assigned to a single factor, some combination or interaction of factors, or a category of other factors. The other factors category included the identified factors that were not able to be isolated. The percent impact and percent reduction were recalculated to more accurately reflect the influence that each factor had on the reduction in incidents. The cumulative percent impact was 55 percent, and the cumulative percent reduction was 80 percent.

Table 1: Final Percent Impact and Percent Reduction

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 Interactions	12.8%	21.9%
Other Factors	44.7%	20.0%

The two factors from phase II that could not be isolated were Crossing Closure and Grade Separation and Warning Device Upgrades. The team tested for correlation between the number of closed, separated, and upgraded crossings and the number of incidents. The test revealed a positive correlation, indicating that closing, separating, or upgrading crossings affected the frequency of incidents.

Two of the factors identified in Phase I were rated very difficult to analyze. The researchers collected little data on Operation Lifesaver and the Section 130 Program. Both are broad reaching programs that encompass the effects of the other identified success factors. However, related studies and reports have been published, and these served as the basis for a qualitative analysis of these two factors. The qualitative analysis unveiled positive impacts from both factors on incident reduction.

Data mining efforts during the course of the study revealed an additional potential success factor. Railroad mergers appeared to have an impact on safety along the rail lines. As major mergers occurred in the mid-1990s, railroad operations expanded, but the number of incidents dropped dramatically. This indicated some safety benefit or efficiency of operation as a result of the merger activity.

The analyses conducted in this study identified ten success factors in highway-rail grade crossing incident reduction. These 10 factors can account for the majority of the reduction in incidents. The 10 success factors are:

- Commercial Driver Safety
- Locomotive Conspicuity
- More Reliable Motor Vehicles
- Sight Lines Clearance
- Grade Crossing Maintenance Rule
- Crossing Closure and Grade Separation

- Warning Device Upgrades
- Operation Lifesaver
- The Section 130 Program
- Railroad Mergers

Of the factors that were quantitatively analyzed, Commercial Driver Safety and Locomotive Conspicuity were responsible for the largest reductions in incidents from 1994 to 2003.

1.0 Introduction

1.1 Background

In 1994, the USDOT's *Rail-Highway Crossing Safety Action Plan* [1] set a goal to reduce incidents and fatalities nationwide by at least 50 percent over 10 years. From 1994 to 2003, incidents between trains and highway-users at highway-rail grade crossings were reduced by 41.2 percent, from 4,979 to 2,924. Fatalities during the same time period were reduced by 48 percent, from 617 to 324. The varied efforts to improve safety yielded positive results. During the April 2003 meeting of the National Academy of Sciences Transportation Research Board's Committee for Review of the FRA's Research and Development Program, the Committee requested that the FRA review the incident statistics for the Action Plan time period (1994 – 2003) and identify the salient success factors for the reduction in those incidents. Success factors are the safety initiatives that were the most successful in reducing incidents at highway-rail grade crossings during the years 1994 through 2003.

FRA tasked the Volpe Center to determine which success factors had the greatest influence on highway-rail grade crossing safety during the period 1994-2003. It is important to know what factors yielded the greatest reduction in grade crossing incidents. This enables future initiatives to be planned to maximize safety.

1.2 Research Methodology

The approach to this problem involved three phases of analysis. Phase I was a qualitative screening of information. In this phase, brainstorming, literature reviews and data mining were used to develop a comprehensive list of potential success factors. The projected impact of the factors on incident reduction was used to identify the major contributors to incident reduction.

Phase II was an analysis of the top success factors. This phase was a preliminary analysis of the incident data. The team used two metrics to determine the benefit of each success factor. The percent impact is the percentage of incidents, from 1994 to 2003, that can be attributed to behaviors that the factor was attempting to change. The percent reduction is the percentage of incidents reduced, from 1994 to 2003, that can be attributed to the safety countermeasures for a factor. The percentages were used to determine which success factors should be further analyzed. The database used for this analysis may have attributed grade crossing incidents to multiple factors. This overlap of incidents may have resulted in inflated impact and reduction percentages for the factors. Isolating the factors was the focus of Phase III.

Phase III involved addressing the overestimation of the factors' effects by isolating each factor and the interactions among factors. It was important to assign each incident, from 1994 to 2003, to one of the three following categories: a single factor, a combination of factors, or no identified factor. This method validated that the factors found were indeed success factors for incident reduction. The percent impact and percent reduction were refined to more accurately reflect the effect of selected factors on incident reduction. The limitations of the data necessitated that other factors be analyzed using other methods. For some of the factors that required a different methodology, a measure of correlation between the factor and the reduction in incidents was performed. Other factors could only be analyzed qualitatively.

1.3 Summary of Results

The results of each project phase fed into the analyses conducted in subsequent phases. At the end of Phase I, the projected impact on incident reduction filtered out the ten most likely success factors. Eight were analyzed quantitatively in Phase II: Commercial Driver Safety, Locomotive Conspicuity, More Reliable Motor Vehicles, Sight Lines Clearance, Grade Crossing Maintenance Rule, Crossing Closure and Grade Separation, Warning Device Upgrades, and Traffic Signal Preemption. Two were analyzed qualitatively in Phase III: Operation Lifesaver and the Section 130 Program. Additional research revealed another potential success factor, Railroad Mergers.

Table 2 lists the percent impact and percent reduction of the eight factors analyzed in Phase II are listed in Table 2. Two numbers are associated with Commercial Driver Safety and the Grade Crossing Maintenance Rule because database changes occurred in 1997 that affected the analyses of these factors. On the basis of these numbers, Traffic Signal Preemption was not pursued in Phase III.

Table 2. Phase II Percent Impact and Percent Reduction

Factor	% Impact	% Reduction
Commercial Driver Safety	30.04/26.25	52.99/51.75
Crossing Closure and Grade Separation	4.73	16.22
Grade Crossing Maintenance Rule	2.23/3.41	3.07/13.92
Locomotive Conspicuity	24.7	30.3
More Reliable Motor Vehicles	7.54	11.19
Sight Lines Clearance	5.13	8.81
Traffic Signal Preemption	1.82	0
Warning Device Upgrades	3.01	8.25

In Phase III, the effects of five success factors were isolated. The other five factors were unable to be isolated and were analyzed separately. These analyses indicated that they also contributed to the reduction in incidents. The five factors that were analyzed separately were Crossing Closure and Grade Separation, Warning Device Upgrades, Operation Lifesaver, the Section 130 Program, and Railroad Mergers.

The five isolated factors were attributed a percent impact and reduction. The Pareto charts, shown below in Figure 1 and Figure 2, illustrate the results. The key is found in Table 3. The five factors and the interactions between them impacted 54 percent of the incidents from 1994-2003. Nearly 80 percent of the reduction in incidents, from 1994-2003, can be attributed to the five selected factors or interaction of those factors.

Table 3: Factor Key for Pareto Charts

Factor Type	Description*
A	Unidentified Factors
B	Commercial Driver Safety
C	Locomotive Conspicuity
D	Sight Lines Clearance
E	Grade Crossing Maintenance Rule
F	More Reliable Motor Vehicles
G	Combined Interactions

*Detailed description of factors available in the section on *Phase I*

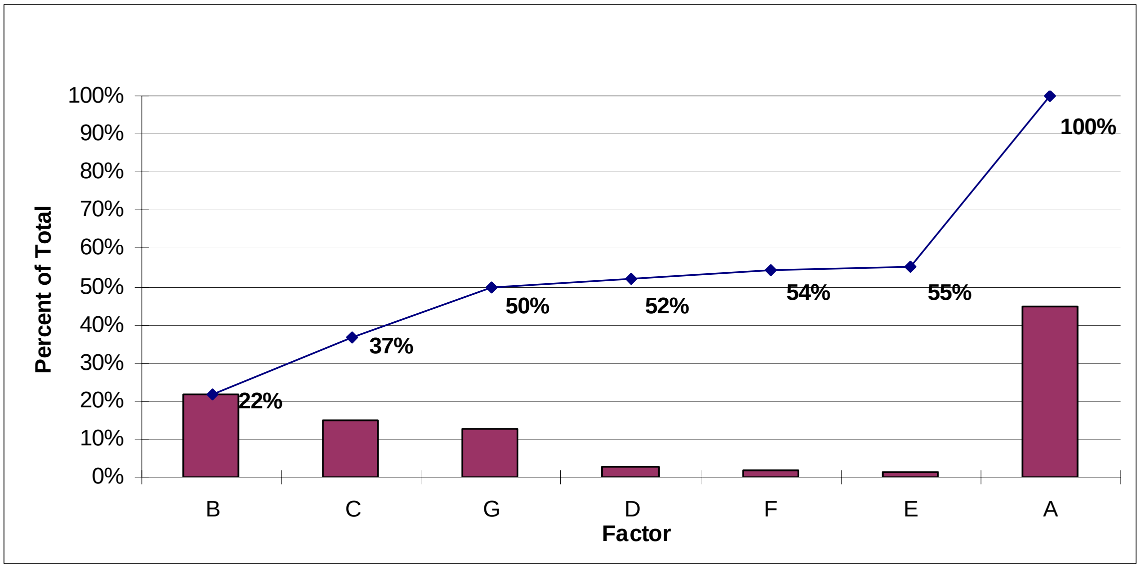


Figure 1: Pareto Chart of Factors Involved in Incidents (Percent Impact)

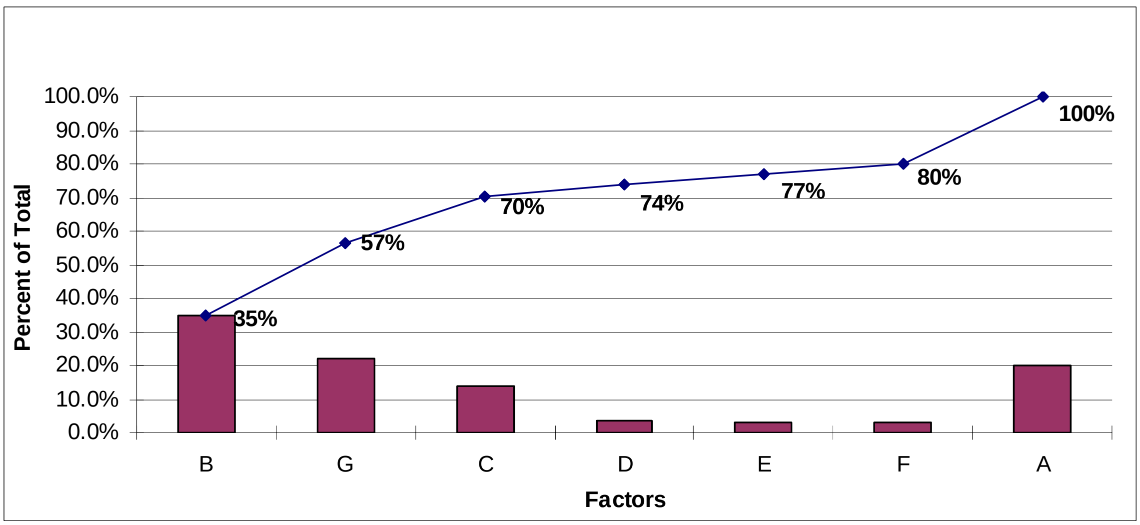


Figure 2: Pareto Chart of Factors that Contributed to a Reduction of Incidents (Percent Reduction)

1.4 Similar Research

A study on a similar topic area was conducted by Mok and Savage entitled "Why Has Safety Improved at Highway-Rail Grade Crossings?" [2]. 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 FRA research described in this report attempts to answer the same question of what is responsible for the reduction in grade crossing incidents. The FRA research study period was from 1994 to 2003. This is the period covered by the 1994 *Rail-Highway Crossing Safety Action Plan* [1]. By 1994, many of the major highway safety improvements had been realized and did not continue to yield the same safety benefits. From 1994 to 2003, many rules and safety initiatives specific to rail and grade crossing safety were enacted. In the FRA study, only incidents were examined. The decision to use incidents as the metric for safety is described in Section 3.3.

Similar to the Mok and Savage study, the FRA study conducted background literature reviews and research on grade crossing safety. The factors considered in both studies were Warning Device Upgrades, Operation Lifesaver, Locomotive Conspicuity and Crossing Closure. The main difference between the two studies is the FRA 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. For example, for the factor Commercial Driver Safety, incidents from the data field "type of vehicle" were analyzed from 1994 to 2003. Factors that were more complex and could potentially encompass the effects of other identified factors that were analyzed qualitatively.

The results of the Mok and Savage study differed from the FRA study. The regression model approach derived weighted coefficients for each factor. The coefficients attributed a portion of the reduction in incidents to the factors. The FRA study examined each factor individually and tried to isolate each factor's effects. Although the methodologies and results differed, both studies identified Warning Device Upgrades, Operation Lifesaver, Locomotive Conspicuity and Crossing Closure as success factors.

2.0 Research Approach

2.1 Databases

The researchers identified six databases as resources for the analyses of grade crossing incidents from the paper, "Documenting the Strength and Weakness of Databases for Use in Analyzing Highway-Railroad Grade Crossings" [3]. These databases are as follows:

- National Highway-Rail Crossing Inventory (Crossing Inventory)
- Highway-Railroad Crossing Inventory Geographical Information System (GIS) Layer
- RAIRS Grade Crossing
- RAIRS Rail Equipment
- Fatal Accident Reporting System (FARS)
- National Automotive Sampling System General Estimate System

Of the six databases identified, the team only used two in the analyses of grade crossing incidents for this project: the Crossing Inventory and the RAIRS Grade Crossing databases. These two were selected because others were limited in the data available for grade crossing incidents or they did not contain complete data for the 10-year study period.

FRA developed the Crossing Inventory database in 1970 and the FRA Office of Safety manages the database. It contains all U.S. public and private highway-rail grade crossings, with detailed current and historical information on individual crossings. The railroad submits the crossing data and the States submit the highway information voluntarily. Crossing data should be submitted if a crossing is closed, opened, or the level of protection is changed. However, changes are voluntary, which could lead to outdated or incomplete data, as noted in the paper, "Grade Crossings of Northeastern Illinois: An Analysis of the FRA Grade Crossing and Grade Crossing Accident Inventories, and an Analysis of the Potential Impacts from the Horn Sounding Requirement of the Swift Rail Development Act" [4].

FRA developed the RAIRS Grade Crossing database in 1975 and the FRA Office of Safety manages the database. It contains all incidents involving a highway user and railroad equipment. Information on the train involved is available, as well as detailed information on crossing characteristics. Unlike the RAIRS Rail Equipment database, no dollar threshold exists for the reporting of an incident. The railroad reports all incidents that involve railroad on-track equipment and highway users of public and private highway-rail grade crossings to FRA. A copy of the current FRA Highway-Rail Grade Crossing Accident Incident Report Form is available in Appendix A.

2.2 Changes in Database Structures

The Crossing Inventory database underwent changes in the 10-year study period. The most notable change occurred in 1997 when the database was expanded to be Y2K compliant. A narrative field was added to the database, and additional information was collected on whistle bans and passenger trains. In addition in 2000, the category, four-quadrant gate warning devices, was added to the warning device field.

FRA added new fields and modified some of the existing fields in the RAIRS Grade Crossing database. Two new fields, driver gender and whistle ban, were added in 1997. The modified data fields that may have affected the analyses are type of vehicles, position, railroad equipment, type of equipment, and signal. All modifications to the above-mentioned fields were undertaken in 1997. Pickup truck, van, and other motor vehicles were added to the type of vehicle field; trapped was added to the position field; commuter train, single train, cut of cars, and maintenance/inspection equipment were added to the type of equipment field; alleged and confirmed warning signal greater than 60 seconds, less than 20 seconds, and confirmed no warning signal were added to the signal field.

2.3 Analytic Tools Used

The researchers used two different data mining tools, Accident Data Analytical Prospective Tool (ADAPT_X) Version 3.6 and SAS, Version 8.02, in the analyses of grade crossing incident data. They both utilized the same database, the RAIRS Grade Crossing database, but used different techniques to query the incident data.

Kenny Williams, formerly of the Structures and Dynamics Division of the Volpe Center, developed ADAPT_X. It is a front-end Microsoft Excel program that uses raw data extracted from the RAIRS Grade Crossing database. The data is filtered using selected criteria. The advantages of using this tool are that it is user friendly and it accounts for the multiple entries of a single incident in the database. Multiple entries may occur when two railroads are involved in the same incident, and both file reports with FRA. Instead of only one incident being listed, two incidents are recorded. In these cases, the integrity of the data is compromised.

SAS is a statistical software tool designed for data access, transformation, and reporting. It includes ready-to-use programs for data manipulation, information storage and retrieval, descriptive statistics, and report writing. The advantage of using SAS is that it comes with ready-to-use statistical programs that provide extensive statistical capabilities.

Both analytic tools were used and produced similar results. The number of incidents generated by SAS was slightly higher than the number of incidents generated by ADAPT_X. The team expected this result because ADAPT_X eliminates the multiple entries of a single incident. Because ADAPT_X is more reliable and easier to use, it was decided that ADAPT_X would be the primary tool for the analyses of grade crossing incidents.

3.0 Phase I

When the Transportation Research Board (TRB) Oversight Committee posed the question, "Why was there an incident reduction from 1994 to 2003?," no prior research had been conducted in this area. During this period, multiple safety countermeasures, laws, and programs could have affected driver behavior at highway-rail grade crossings. Societal changes and technological evolution could also have been influential. It was a multifaceted real world problem that needed a creative solution.

3.1 Exposure

The first approach was to examine the exposure levels at highway-rail grade crossings during the study period. This was to ensure that exposure levels were not the reason for the reduction in highway-rail grade crossing incidents. An ideal way to measure exposure at grade crossings would be to take the product of the average annual daily traffic (AADT) and trains per day for each crossing. The AADT and trains per day in the Crossing Inventory, however, are not updated every year and are therefore not reliable. Instead, the overall national vehicle miles traveled (VMT), train miles traveled (TMT), and number of crossings was used to calculate an exposure index for each year. Table 4 shows VMT, TMT, number of crossings, exposure index, overall number of incidents, and incident index for the years 1994 through 2003. The exposure index is equal to the normalized product of VMT, TMT, and the number of crossings. The incident index is equal to the overall number of incidents divided by the exposure index.

Table 4: Exposure Index and Incident Index

Exposure Index						
	Vehicles Miles Traveled (Millions)	Train Miles Traveled (Millions)	Number of Crossings	Exposure Index	Overall Number of Incidents	Incident Index
1994	2,359,984	655.1	272724	4.2164	4979	1180.9
1995	2,422,775	669.8	268454	4.3564	4633	1098.8
1996	2,482,202	670.9	265695	4.4246	4257	1009.6
1997	2,552,233	676.7	262268	4.5296	3863	916.2
1998	2,628,148	682.9	259240	4.6527	3508	832.0
1999	2,690,241	712.5	257565	4.9370	3489	827.5
2000	2,746,925	722.9	254288	5.0495	3502	830.6
2001	2,797,339	711.6	252491	5.0261	3237	767.7
2002	2,855,756	728.9	250243	5.2090	3077	729.8
2003	2,890,893	748.6	242734	5.2531	2924	556.6
Percent Change	+22.5%	+14.3%	-11.0%	+24.6%	-41.2%	-52.9%
Sources	FHWA, Office of Highway Policy Information *Highway Statistics* (1994-2003) [5]	Office of the Inspector General (2004). *Audit of the Highway -Rail Grade Crossing Safety Program,* [6]	FRA *Rail-Highway Crossing Inventory Bulletin* (1994-1996) [7], FRA *Railroad Safety Statistics Annual Report* (1997-2003) [8]			

3.2 Success Factor Identification

The research methodology for this project began with trying to identify all possible highway-rail grade crossing incident reduction success factors. The comprehensive list of success factors was derived from brainstorming and literature reviews. The team used their knowledge and experience in grade crossing research to discuss possible factors. Extensive research was conducted via the World Wide Web, published reports, State and Federal regulations, and other documentation. This helped identify any factors that were overlooked and refine the comprehensive list of potential success factors.

The next step in this phase was to select the most probable success factors. The comprehensive list was organized in a matrix (see Appendix B) that contained various pieces of information necessary to make the selection. The team reviewed the data sources available for each factor, the methods of analysis, the projected impact on incident reduction, and the perceived difficulty of analysis. The projected impact was based on a scale of low, medium, or high. The factors with a high projected impact were believed to have affected incident reduction from 1994 to 2003. The perceived difficulty of analysis was based on a scale of easy, medium, and very difficult. The factors that had a high projected impact and were easy or medium to analyze were selected for quantitative analysis in Phase II. The researchers used the Crossing Inventory database and the RAIRS Grade Crossing database for this quantitative analysis. Other factors with a high projected impact and a difficult or very difficult level of analysis were evaluated differently.

The team selected 10 success factors for further analysis in Phase II. The following lists a description of each, in no particular order. The matrix in Appendix B includes descriptions of all possible success factors. Operation Lifesaver and the Federal Highway Administration's (FHWA) Section 130 Program will be analyzed qualitatively because a thorough analysis would require an intensive data collection process that is beyond the scope of this study. The other eight factors will be analyzed quantitatively.

> *Commercial Driver Safety*. During the period 1994-2003, a greater emphasis was put on commercial driver safety. The Motor Carrier Safety Improvement Act established the Federal Motor Carrier Safety Administration (FMCSA) and emphasized commercial vehicle safety. The primary mission of FMCSA is to reduce crashes, injuries, and fatalities involving large trucks and buses. In October 1999, the law on Commercial Driver Disqualification (Title 69 Code of Federal Regulations (CFR) 48104) stated that commercial drivers convicted of violating the highway-rail grade crossing warning devices would have their Commercial Drivers' Licenses (CDL) suspended. This factor relates to the commercial vehicle involvement field within the RAIRS Grade Crossing database.
>
> *Locomotive Conspicuity*. Making locomotives more conspicuous aids drivers in not only seeing an oncoming train, but judging its distance and speed. A final rule, Locomotive Safety Standards (49 CFR 229), published in March 1996,

effective December 1997, stated that all locomotives exceeding 20 mph over the crossing must have auxiliary alerting lights in addition to the headlight. This factor relates to the visibility, railroad equipment, and type of accident fields within the RAIRS Grade Crossing database.

More Reliable Motor Vehicles. During the period of study, automobiles were improved to be safer and more reliable. A more reliable vehicle reduces the likelihood of breaking down or stalling on the tracks and subsequently being struck by an oncoming train. This factor relates to the stalled vehicle field within the RAIRS Grade Crossing database.

Sight Lines Clearance. The clearing of vegetation and removal of obstructions surrounding a grade crossing enables highway-users to observe the tracks and a possible oncoming train at farther distances from the crossing. Adequate sight distance allows highway-users to stop safely and the risk of collision with an unexpected train is reduced. This factor relates to the obstruction of track view field within the RAIRS Grade Crossing database.

Grade Crossing Maintenance Rule. In 1995, the Final Rule on Grade Crossing Signal System Safety (49 CFR 234) was issued. This rule stated that railroads must implement specific maintenance, inspection, and testing requirements for active crossing warning systems. The regular maintenance and inspection would reduce the risk of warning device malfunction. This factor relates to the active warning device malfunction fields within the RAIRS Grade Crossing database.

Crossing Closure and Grade Separation. Crossing closures may have impacted the safety of highway-rail grade crossings over the Action Plan period (1994 to 2003). In 1991, the FRA Administrator recommended closure for 25 percent of all crossings. Closures and grade separations reduce the risk of a collision to nearly zero because the vehicle and train paths no longer intercept at that location. This factor relates to the update reason and type and position fields in the Crossing Inventory database.

*Warning Device Upgrade*s. When crossing warning devices are upgraded to devices with a higher effectiveness value, the risk of a collision at the crossing is reduced. This factor relates to the upgrade reason and warning device code fields from the Crossing Inventory database.

Traffic Signal Preemption. Traffic signal preemption is recommended for highway-rail crossings equipped with active warning devices and with a signalized highway intersection within 200 feet. The normal sequence of traffic control signal indication at a nearby highway intersection is preempted upon the approach of trains. The goal is to avoid entrapment of vehicles on the highway-rail crossing by conflicting highway traffic control signals and the highway-rail grade crossing active warning devices. The factor relates to the traffic light interconnection/preemption field in the Crossing Inventory database.

Operation Lifesaver. Operation Lifesaver is an education and awareness program dedicated to ending tragic collisions, fatalities, and injuries at highway-rail grade crossings and on railroad rights of way.

Section 130 Program. Highway funds are appropriated by Congress under Section 130, Title 23 of the United States Code for improvements to the safety of highway-rail grade crossings. The funds are appropriated by State and each State has its own crossing improvement plan. The Section 130 Program overlaps with other success factors since this money is used to close, separate, and upgrade crossings.

3.3 Metric Selection

Before conducting quantitative analyses on the selected factors, the team chose the appropriate metric to measure the improvement in crossing safety. In this study, incidents were found to be the appropriate metric. Figure 3 shows a graph of the injury per incident rate and fatality per incident rate for each year of study. From 1994 to 2003, the rates remained constant even though incident rates were decreasing. The proportion of injury-incidents and fatality-incidents stayed the same over the course of the study. Incidents, injuries, and fatalities were all declining at the same rate. The reduction in incidents did not vary by incident severity.

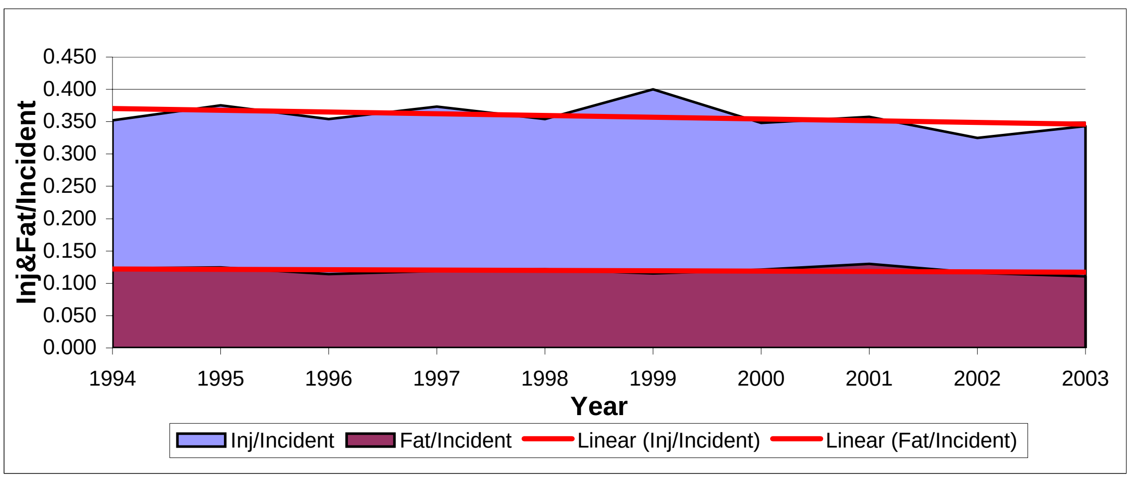


Figure 3: Incident-Injury and Incident-Fatality Rates

4.0 Phase II

Operation Lifesaver and the Section 130 Program were not analyzed quantitatively because a thorough analysis would require an intensive data collection process and these two factors may encompass other factors. Phase II includes a discussion of a qualitative analysis.

4.1 Quantitative Analysis

The research team quantitatively analyzed eight success factors. Detailed analysis is available in Appendix C. The objective was to rank their effectiveness based on two metrics, percent impact and percent reduction. The percent impact is the percentage of incidents, from 1994 to 2003, that can be attributed to behaviors that the factor was attempting to change. The percent reduction is the percentage of incidents reduced, from 1994 to 2003, that can be attributed to the safety countermeasures for a factor. For a few factors, the team concluded additional quantitative analysis on available data. These analyses supported the percent impact and percent reduction results. The following analyzes eight factors. Table 5 summarizes the percent impact and percent reduction results are included at the end of this section.

4.1.1 Commercial Driver Safety

Percent Impact 30.04/26.25, Percent Reduction 52.99/51.75

For the analyses of commercial driver safety, the researchers used incidents from vehicles requiring a CDL (trucks, truck-trailers, buses, and school buses), as identified by the type of vehicles field in the RAIRS Grade Crossing database, to calculate the percent impact and the percent reduction. Two percentages are provided for each percent impact and reduction, because in 1997 two categories, pick-up truck and van, were added to the type of vehicle field. These types of vehicles may have been included in either the truck or auto category pre-1997. The number of incidents was 1784 in the year 1994, 1182 in the year 1997, and 695 in the year 2003.

Commercial Driver Safety has high values for percent impact and percent reduction. It was of interest to further examine the success of this factor. One approach was to compare the proportion of VMT between commercial and non-commercial vehicles over the 10-year period and determine any effect on the number of incidents.

Figure 4 shows the percent of VMT and the number of incidents for commercial and non-commercial vehicles. The figure below shows that over the 10-year period, the proportion of commercial VMT stayed the same, around 8 percent. Commercial vehicle incidents, however, decreased from 1,784 in 1994 to 695 in 2003. Although commercial VMT make up about 8 percent of the overall VMT, they were involved in 35.8 percent of incidents in 1994 and 23.7 percent of incidents in 2003.

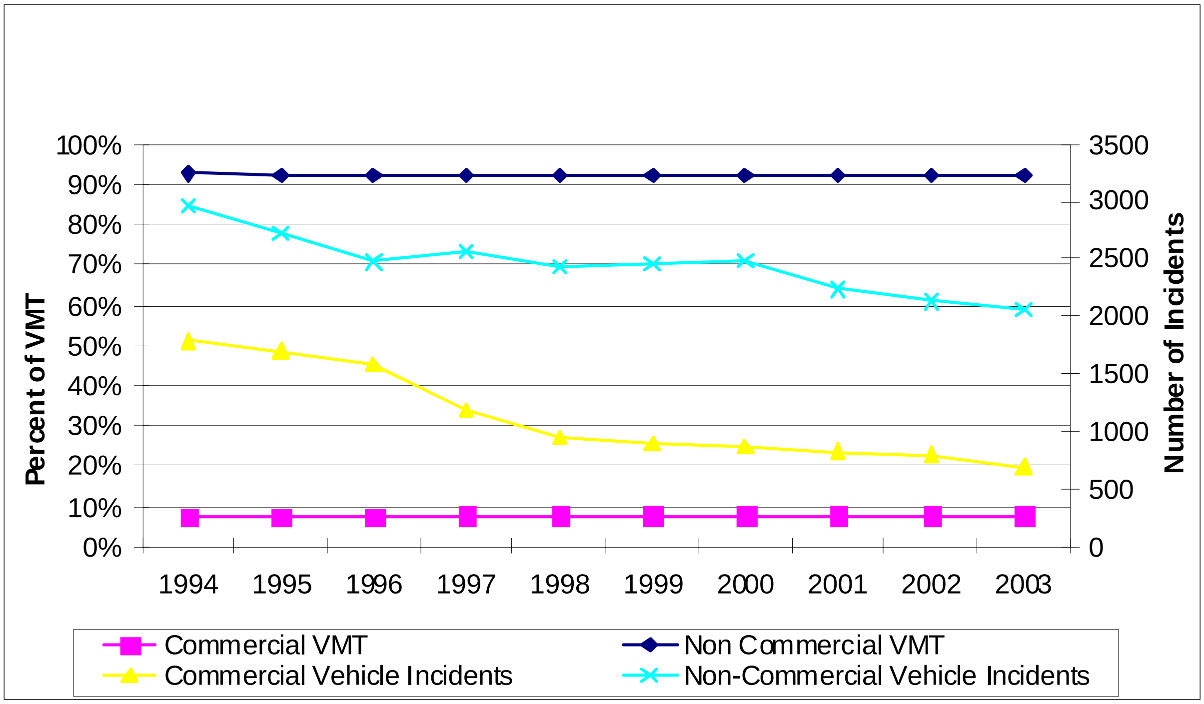


Figure 4. Percent of VMT and Number of Incidents for Commercial versus Non-Commercial Vehicles

The research team also compared the rates of incidents for commercial vehicles, non-commercial vehicles and all vehicles. Commercial vehicle and non-commercial vehicle incident rates start in 1997 because before this year the categories pickup truck and van did not exist. Figure 5 shows the incident rate per one billion VMT for commercial, non-commercial, and all motor vehicles. Commercial vehicles have the highest rate of incidents per VMT but they also have the largest reduction. The incident rate for commercial vehicles decreased by 47.6 percent, from 5.96 in 1997 to 3.12 in 2003. This is compared to a 29.2 percent decrease in the non-commercial vehicle incident rate.

Examining the amount of commercial vehicle traffic on the roads from 1994 through 2003 revealed that commercial vehicles were involved in a larger percentage of incidents than non-commercial vehicles. The incident rate decrease, however, was more dramatic for commercial vehicles than non-commercial vehicles. The results from these analyses suggest that Commercial Driver Safety did have a significant impact on the reduction in highway-rail crossing incidents.

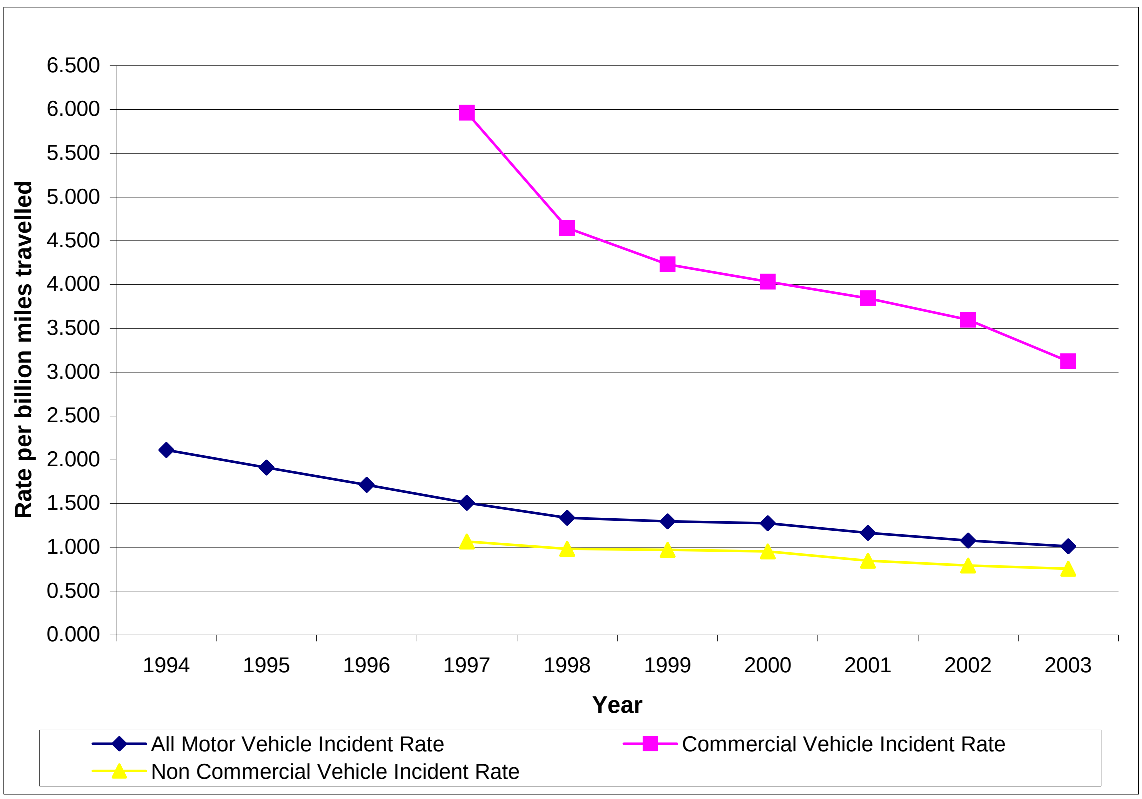


Figure 5. Incident Rate per Billion VMT for Commercial, Non-Commercial, and All Motor Vehicles

The reduction in commercial vehicle incidents at grade crossings is of interest because an incident involving a commercial vehicle may have serious consequences. Although commercial vehicle incidents decreased significantly over the 10-year period, they accounted for 23.7 percent of all incidents in 2003. The commercial vehicle incidents have higher rates of injuries and fatalities to train occupants than non-commercial vehicle incidents. Truck, truck-trailer, and automobile incidents comprise about 83 percent of all incidents in the study period. (See Appendix D.) The team used automobile, truck, and truck-trailer injuries and fatalities obtained from the RAIRS Grade Crossing database to compare the severity of incidents involving commercial and non-commercial vehicles. (Appendix E provides an analysis of severity.) Figure 6 shows the severity to train occupants in terms of injuries, from incidents involving automobiles, trucks, and truck-trailers.

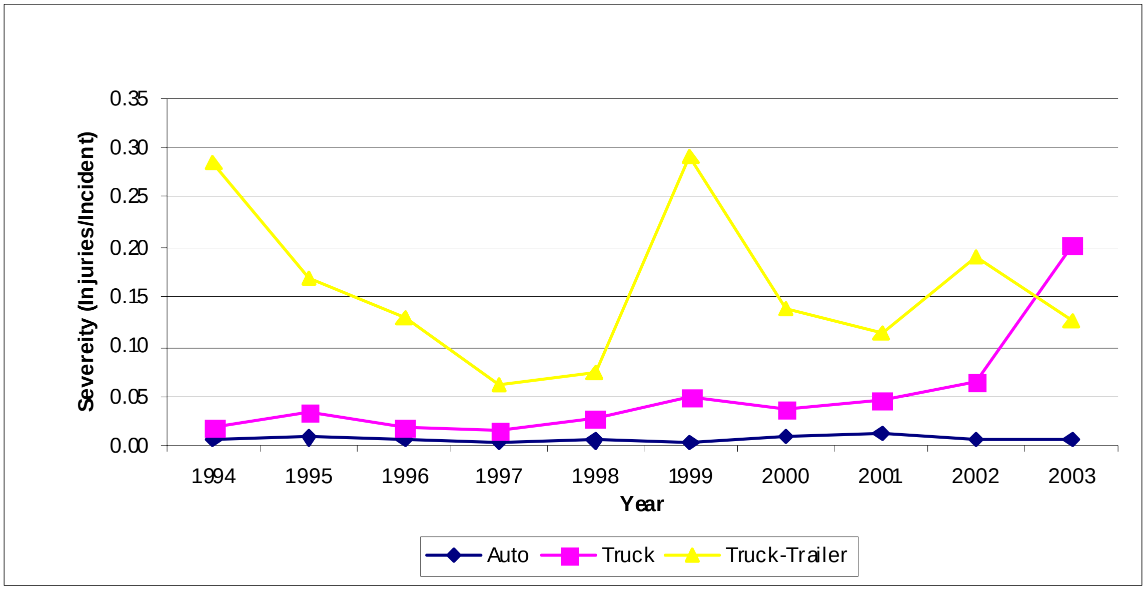


Figure 6. Incident Severity to the Train Occupant from Automobile, Truck, or Truck-Trailer

As expected, Figure 6 shows that the incidents involving commercial vehicles have greater consequences to train occupants than regular automobiles. The reports, *Post-Incident Aggravating Risk Factors in Highway-Rail Grade Crossing Crashes* [9] and *Assessment of Risks for High-Speed Rail Grade Crossings on the Empire Corridor* [10], assert that incidents involving commercial vehicles have a greater chance of derailing a train. A derailment is a greater danger to train occupants. The spike that occurred in 1999 resulted from a severe accident and subsequent derailment in Bourbonnais, IL. An Amtrak train struck a tractor-trailer and derailed, killing 11 passengers on board.

4.1.2 Locomotive Conspicuity

Percent 24.7, Percent Reduction 30.3

The FRA published the report, *Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity* [11], in 1995. It stated that there was a significant difference in the effectiveness of locomotive alerting lights between the daylight and the night. The lights provided more benefit in the night. Therefore, incidents in which the rail equipment struck the highway user at dusk, dawn or dark, from the RAIRS Grade

Crossing database, were used to measure the effects of increased Locomotive Conspicuity. Visibility, railroad equipment, and type of accident fields were chosen as representatives of this factor. The number of incidents decreased from 1320 in 1994 to 696 in 2003.

Figure 7 shows a graph of the proportion of incidents where rail equipment struck the highway user by time of day. The proportion of incidents over the study period increased for incidents at day and decreased for incidents at dark, dawn or dusk. The decrease in proportion of incidents at dark or dusk indicates that safety is improving during the night. This lends credit to using the selected data fields for the analysis of Locomotive Conspicuity.

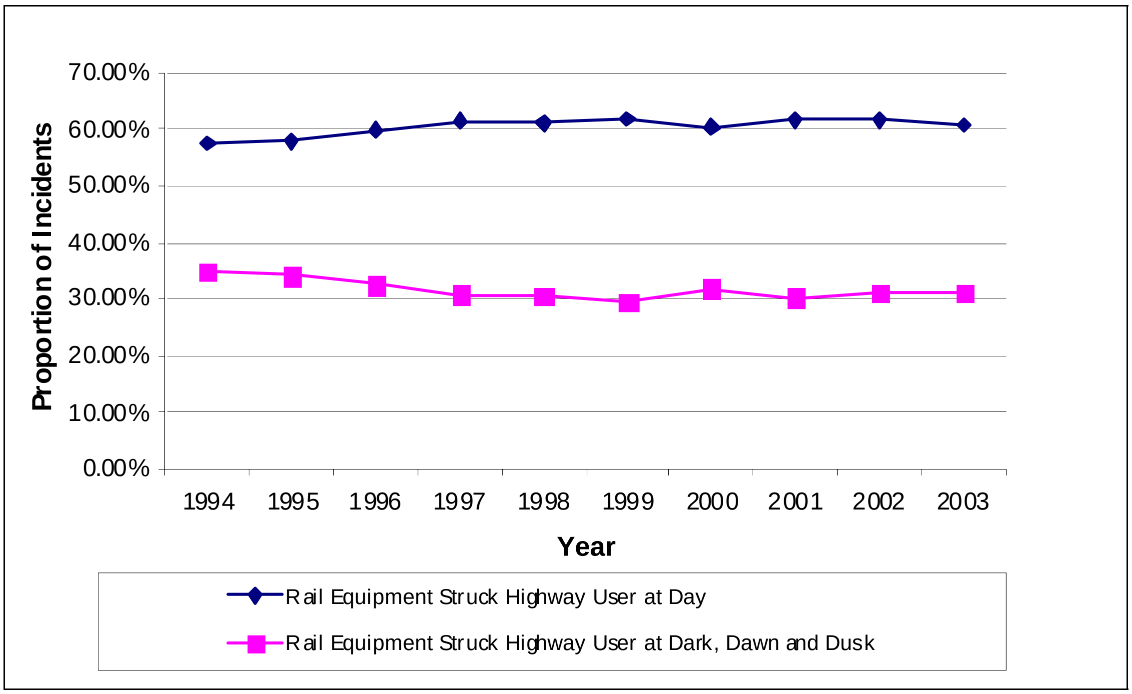


Figure 7: Proportion of Incidents by Time of Day

4.1.3 Grade Crossing Maintenance Rule

Percent Impact 2.23/3.41, Percent Reduction 3.07/13.92

The researchers decided that warning signal malfunctions would be classified into three categories: excessive warning time, abbreviated warning time, or no warning. The signal field in the RAIRS Grade Crossing database identifies incidents that have both alleged and confirmed warning device malfunction. There are two percentages for percent impact and reduction, one from 1994 to 2003 and another from 1997 to 2003. In 1997, five new categories were added to the signal data field. The percent impact was determined from the percentages of the total number of incidents that identified a warning device malfunction. The percent reduction was determined from the number of fewer incidents that identified a warning device malfunction in 2003 versus 1994, or 2003 versus 1997. The number of incidents with a warning device malfunction reduced from 204 in 1997 to 73 in 2003.

To further analyze the effectiveness of the Grade Crossing Maintenance Rule, the researchers used a number of activation failures was used to determine the rate at which active warning devices fail. Figure 8 shows the activation failure rate. Activation failures from 1992 and 1993 were obtained from the report, *Highway-Railroad Grade Crossing Active Signal Systems Analysis* [12]. The researchers obtained activation failure data from the years 1998 and 1999 electronically from FRA and the years 2000 through 2003 were obtained from the FRA Activation Failure records. The FRA was not collecting activation failure data during the years 1994 through 1997, hence, the gap in the data. The activation failure rate is equal to the number of activation failures times 100 divided by the total number of active crossings in the Nation. The activation failure rate sharply declined after the maintenance rule was implemented. This suggests a safer crossing environment after the rule. (See Appendix F for more detailed data.)

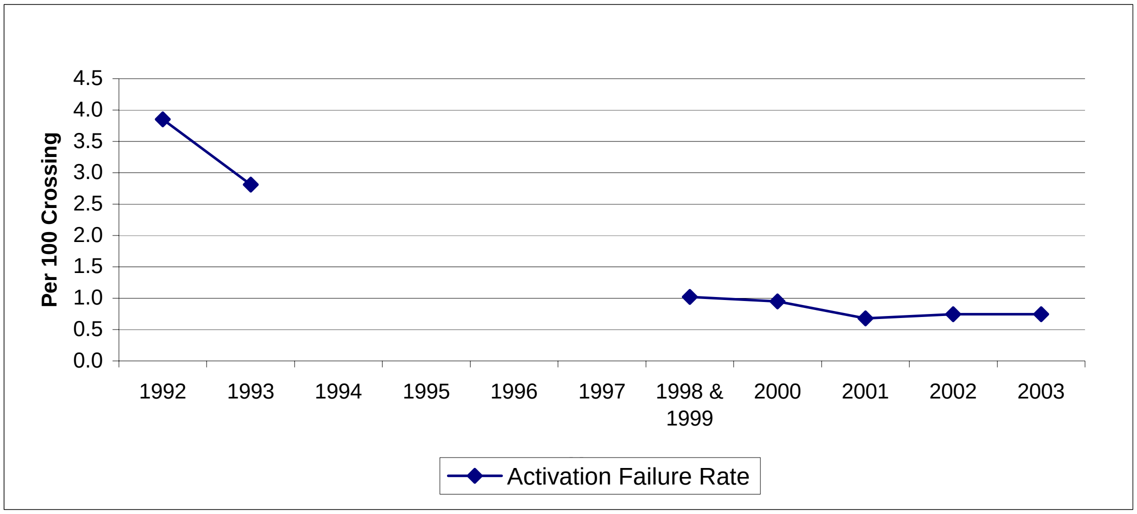


Figure 8: Activation Failure

4.1.4 Crossing Closure and Grade Separation

Percent Impact 4.73, Percent Reduction 16.22

When a crossing is closed or grade separated, the risk of a collision between a highway user and a train is minimal. Because no further incidents at those crossings are likely to occur, it is difficult to derive the effect of crossing closures and grade separations on incident reduction between 1994 and 2003. No fields in the RAIRS Grade Crossing database could be used for the analyses of Crossing Closure and Grade Separation. A new methodology was developed to estimate the impact of closures and grade separations on the decrease in incidents over the 10-year period. 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 researchers used inferential extrapolation to derive a probable number of incidents. 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. The following formulas determined the percent impact and the percent reduction:

(1) Percent Impact = (the sum of probable incidents between 1994 and 2003)/(the sum of the actual and probable incidents between 1994 and 2003) x 100.
(2) Percent Reduction = (the change in the probable number of incidents between 1994 and 2003)/(the change in the sum of the actual and probable incidents between 1994 and 2003) x 100.

4.1.5 Warning Device Upgrades

Percent Impact 3.01, Percent Reduction 8.25

Warning Device Upgrades posed a similar problem as Crossing Closure and Grade Separation. No fields in the RAIRS Grade Crossing database could be used for the analysis of Warning Device Upgrades. The method developed for Crossing Closure and Grade Separation was modified to evaluate the effectiveness of Warning Device Upgrades. All Warning Device Upgrades were categorized into one of three different types: passive to flashing lights, passive to gates or flashing lights to gates. Each type of upgrade has an effectiveness value associated with it. The effectiveness values were obtained from the 1987 *Rail-Highway Crossing Resource Allocation Procedure–A User's Guide, Third Edition* [13].

- Passive to Flashing Lights = 0.70
- Passive to Gates = 0.83
- Flashing Lights to Gates = 0.69

The data for Warning Device Upgrades was based on available data from the State of Illinois and then extrapolated to obtain national data. For each year from 1994 to 2003, an accident rate for each type of warning device was developed. The accident rate was equal to the number of incidents at a crossing with a particular warning device divided by the total number of crossings with that warning device. The probable number of incidents for a particular year was the number of incidents that would have occurred in that year if those crossings upgraded between 1994 and that year had not been upgraded. The percent impact and percent reduction formulas were the same as used for Crossing Closure and Grade Separation.

4.1.6 More Reliable Motor Vehicles

Percent Impact 7.54, Percent Reduction 11.19

The position field in the RAIRS Grade Crossing database identifies incidents where the highway vehicle was stalled on the tracks at the time of impact. The percent impact for More Reliable Motor Vehicles was determined from the percentage of incidents from 1994 to 2003, in which the highway vehicle was stalled on the crossing. A vehicle can stall for a variety of reasons, not all of which are related to the reliability of the motor vehicle. Therefore, the effect of this factor may be over inflated because there RAIRS Grade Crossing database does not provide additional information on the cause of the stall. In the ten years of the study period, 2,824 incidents out of the 37,471 total incidents resulted from vehicles being stalled on the crossing. The percent reduction was determined by finding the number of fewer incidents attributed to stalled vehicles that occurred in 2003 versus 1994. The number of incidents that involved stalled vehicles dropped from 412 to 182.

4.1.7 Sight Lines Clearance

Percent Impact 5.13, Percent Reduction 8.81

The view field in the RAIRS Grade Crossing database describes seven categories of visual obstruction at the highway-rail grade crossing at the time of impact: permanent structure, standing railroad equipment, passing train, topography, vegetation, highway vehicles, and other. The researchers used all seven categories in the analysis except passing train and highway vehicles. These two were not included because it is difficult to eliminate them through safety countermeasures. The number of incidents decreased from 294 in 1994 to 113 in 2003.

4.1.8 Traffic Signal Preemption

Percent Impact 1.82, Percent Reduction 0.0

Limited data was available for this factor. Incidents at crossings with warning devices connected to highway traffic signals were queried from the RAIRS Grade Crossing database. The number of crossings with traffic signal preemption was available from the Crossing Inventory database, but it was not possible to distinguish the number of crossings equipped with traffic signal preemption by year. Therefore, the effectiveness of traffic signal preemption could not be analyzed sufficiently. Another approach was taken involving the position of the highway vehicle during an incident at a crossing equipped with traffic signal preemption. The position of interest was trapped. A vehicle could become trapped on a grade crossing by stopped traffic due to a red traffic signal ahead. Traffic signal preemption could reduce the risk of traffic queuing onto a crossing. However, no data was available to determine the reason the vehicle became trapped. Since the number of preempted crossings makes up less than 2 percent of overall crossings, and the percentage of incidents at preempted crossings did not change over the 10-year period, it was decided not to further pursue this factor.

4.2 Summary of Results

Table 5 summarizes the eight success factors with their percent impact and reduction. Where two percents are shown in the same cell, the first percent is based on the time span 1994 to 2003. The second percent is based on the time span 1997 to 2003. These factors were affected by changes in the database structure in 1997. Appendix F includes detailed data and analysis of each factor.

The team used the analysis of factors by percent impact and percent reduction to select the top factors for further study. Factors with the percent impact and the percent reduction below 8 percent were not pursued. Traffic Signal Preemption was the only factor not pursued. The RAIRS Grade Crossing database analysis may have attributed grade crossing incidents to multiple factors. This overlap of incidents may have resulted in inflated impact and reduction percentages for the factors. The research team conducted factor isolation in Phase III.

Table 5. Phase II Percent Impact and Percent Reduction

Factor	% Impact	% Reduction
Commercial Driver Safety	30.04/26.25	52.99/51.75
Crossing Closure and Grade Separation	4.73	16.22
Grade Crossing Maintenance Rule	2.23/3.41	3.07/13.92
Locomotive Conspicuity	24.7	30.3
More Reliable Motor Vehicles	7.54	11.19
Sight Lines Clearance	5.13	8.81
Traffic Signal Preemption	1.82	0
Warning Device Upgrades	3.01	8.25

5.0 Phase III

5.1 Isolating Success Factors

In Phase II, concern was that the method of data analysis resulted in an overestimation of the effect of the success factors analyzed. This was due to multiple counting of incidents and overlaps of incidents among factors. This situation arose because data fields from the highway-rail crossing accident reports are used to categorize the incidents by success factor and these reports could cite more than one factor per incident. 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 responsible for the incident. Thus, Phase III began by trying to isolate the effect of each success factor. It was necessary to find a methodology that would take one incident and assign it to a particular success factor, a combination of two or more success factors, or a single category of all other factors.

The researchers used inferential extrapolation was used in Phase II to determine how many incidents were impacted and reduced from the two success factors: Crossing Closure and Grade Separation and Warning Device Upgrades. Because this number of incidents was an estimate and could not be obtained directly from the RAIRS Grade Crossing database, these two success factors and their interactions were unable to be isolated. The Section 130 Program and Operation Lifesaver were two success factors that could also not be isolated because they encompassed too many other factors. Additional research conducted in Phase III revealed a potential success factor in Railroad Mergers. Railroad Mergers data was not obtained directly from the RAIRS Grade Crossing database and therefore could not be isolated. The remaining five success factors and their combined interactions could be isolated because the number of incidents assigned to these success factors came from the RAIRS Grade Crossing database. These five success factors were Commercial Driver Safety, Locomotive Conspicuity, Sight Lines Clearance, Grade Crossing Maintenance Rule, and More Reliable Motor Vehicles.

To imagine how they were isolated, the team used a Venn diagram of five factors. The Venn diagram showed the five factors and every intersection (or overlap) possible between them. Incidents could then be isolated to one factor or some intersection of factors. To better understand this concept, an example shown with three factors will be described next.

Imagine three factors exist: A, B, and C. Initially, A includes incidents that intersect with B, incidents that intersect with C, and incidents that intersect with B and C. The goal is to find the number of incidents, A’, that does not include these intersections. It is also desired to find the number of incidents for the intersection of A and B ($A \cap B$), as well as A and C ($A \cap C$), that does not include the intersection of A, B, and C ($A \cap B \cap C$). The same process applies to factors B and C. These new values, which represent the isolated factors and their interactions, will be labeled: A’, B’, C’, $A' \cap B'$, $A' \cap C'$, $B' \cap C'$, and A’∩B’∩C’. (A’∩B’ equals B’∩A’ and the same goes for the other intersections.) Figure 9 shows a Venn diagram of A, B, and C. A, B, and C are the circles in their entirety, including all intersections. Figure 10 shows the Venn diagram with the isolated factors and their isolated interactions. This means that A’ would be the number of incidents that can be attributed only to Factor A and no intersection with the other factors. Table 6 shows the equations to solve for A’, B’, C’, and their isolated interactions.

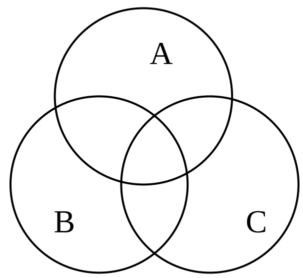


Figure 9. Venn Diagram of Factors A,B,C (pre-isolation)

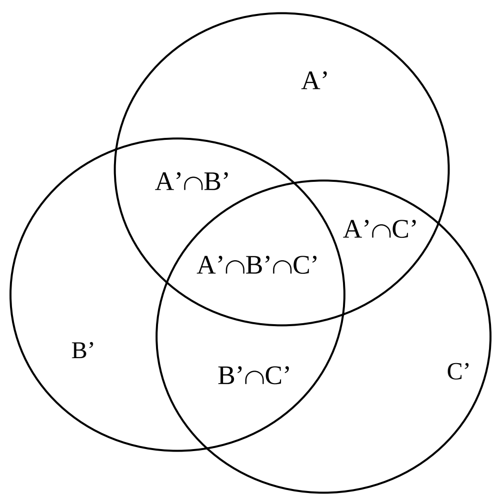


Figure 10. Venn Diagram of Isolated Factors and Isolated Interactions

Table 6. Equations for Isolated Factors and Their Isolated Interactions

Isolated Factor and Interactions
Factor A':
$A' \cap B' \cap C' = A \cap B \cap C$
$A' \cap B' = (A \cap B) - (A' \cap B' \cap C')$
$A' \cap C' = (A \cap C) - (A' \cap B' \cap C')$
$A' = A - [(A' \cap B') + (A' \cap C') + (A' \cap B' \cap C')]$
Factor B':
$A' \cap B' \cap C' = A \cap B \cap C$
$B' \cap A' = (B \cap A) - (A' \cap B' \cap C')$
$B' \cap C' = (B \cap C) - (A' \cap B' \cap C')$
$B' = B - [(B' \cap A') + (B' \cap C') + (A' \cap B \cap C')]$
Factor C':
$A' \cap B' \cap C' = A \cap B \cap C$
$C' \cap A' = (C \cap A) - (A' \cap B' \cap C')$
$C' \cap B' = (C \cap B) - (A' \cap B' \cap C')$
$C' = C - [(C' \cap A') + (C' \cap B') + (A' \cap B' \cap C')]$

The above methodology was performed on the five success factors mentioned above: Commercial Driver Safety, Locomotive Conspicuity, Sight Lines Clearance, Grade Crossing Maintenance Rule, and More Reliable Motor Vehicles. (See Appendix G to see a detailed breakdown of how these success factors were isolated.) The figure below graphs the number of incidents over the 10 years (1994-2003) that can be attributed to a particular isolated success factor. This is shown by the green dashed line and it is associated with the right vertical axis. The pink solid line shows the overall number of incidents nationwide over the 10 years. This line is associated with the left vertical axis.

5.1.9 Commercial Driver Safety

The first graph, Figure 11, shows incidents that can be attributed to Commercial Driver Safety for the years 1994 through 2003. In 1997, pickup trucks and vans received their own category on the accident/incident data forms (represented with a yellow triangle on the graph); in 1999, the Motor Carrier Safety Improvement Act was introduced (represented by an X on the graph). Nationally, incidents were reduced from 4,979 to 2,924, a reduction of approximately 2,000 incidents. The reduction for incidents that were attributed to commercial vehicles was 712 from 1,246 to 534. The reduction in commercial vehicle incidents accounts for about a third of the national reduction. This factor follows the national trend or possibly influences it.

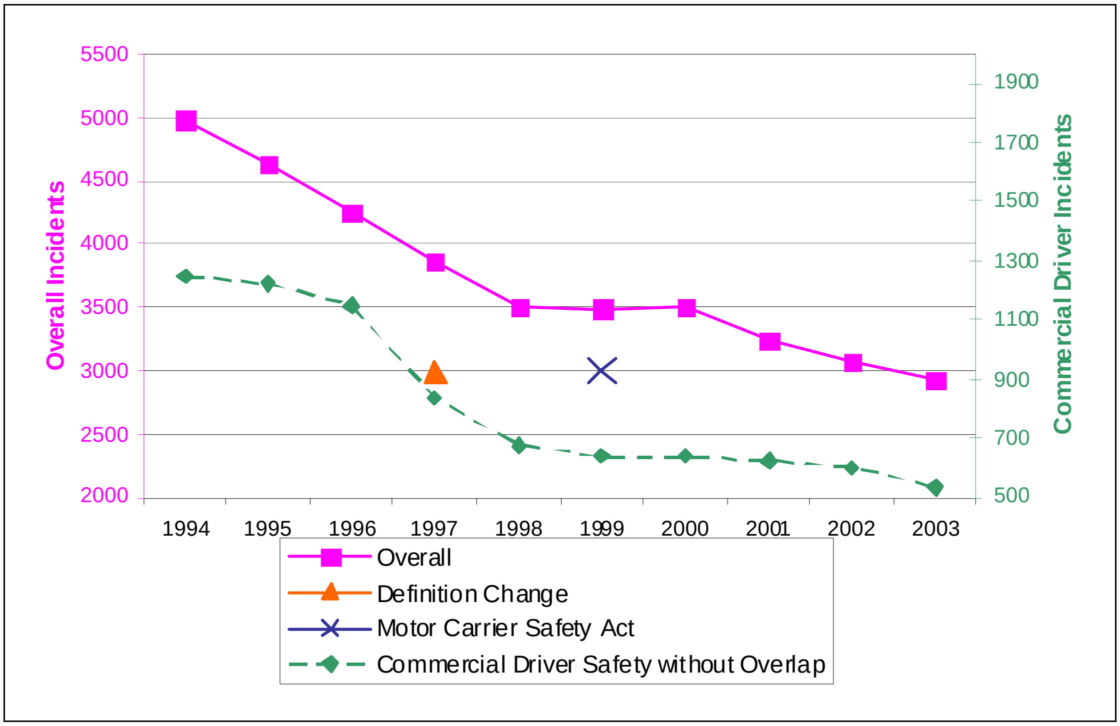


Figure 11. Incidents Attributed to Commercial Drivers for 1994-2003

5.1.10 Locomotive Conspicuity

Figure 12 shows incidents that can be attributed to Locomotive Conspicuity for the years 1994 through 2003. A final rule (49 CFR 229) published in March 1996, effective in December 1997, stated that all locomotives exceeding 20 mph over the crossing must have auxiliary alerting lights in addition to the headlight (this date is represented with a yellow triangle on the graph). Incidents attributed to Locomotive Conspicuity were reduced from 745 to 465 over the study period. Locomotive Conspicuity incidents mimic the national trend. The cause of the spike in incidents in 2000 is unidentified.

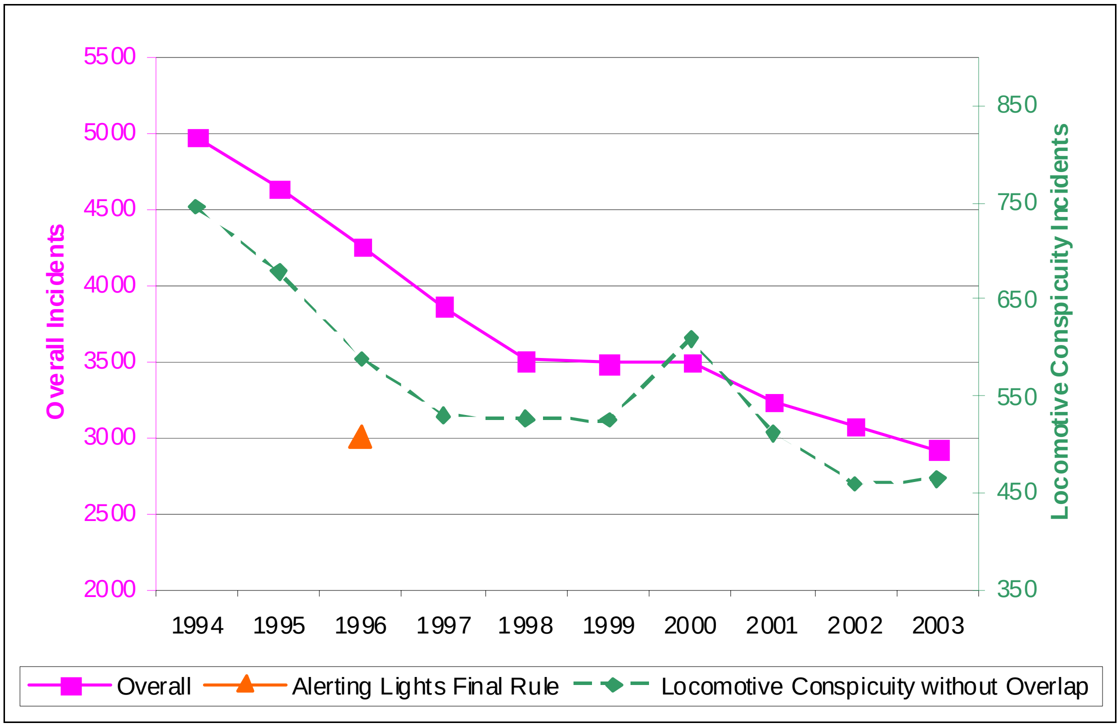


Figure 12. Incidents Attributed to Locomotive Conspicuity for 1994-2003

5.1.11 Sight Lines Clearance

Figure 13 shows incidents that can be attributed to Sight Lines Clearance for the years 1994 through 2003. During the study period, sight line obstructions at crossings and along the right of way drew increased attention. In 1995, FRA included a provision addressing the need to maintain rail rights-of-way adjacent to crossings free of sight obstructing vegetation in its "Notice of Proposed Rulemaking on Track Standards," and in 1998, the final rule on Track Safety Standards (49 CFR 213.37) stated that "vegetation…shall be controlled so that it does not obstruct visibility…at highway-rail crossings." The Technical Working Group report, *Guidance on Traffic Control Devices at Highway-Rail Grade Crossings* [14] contained guidance on appropriate sight distances at crossings and removing obstructions. In 1997, data fields on accident/incident reports were reconfigured. Incidents attributed to obstructed sight lines were reduced from 137 to 63. Although these numbers are small and some variability occurs, they still mimic the national trend.

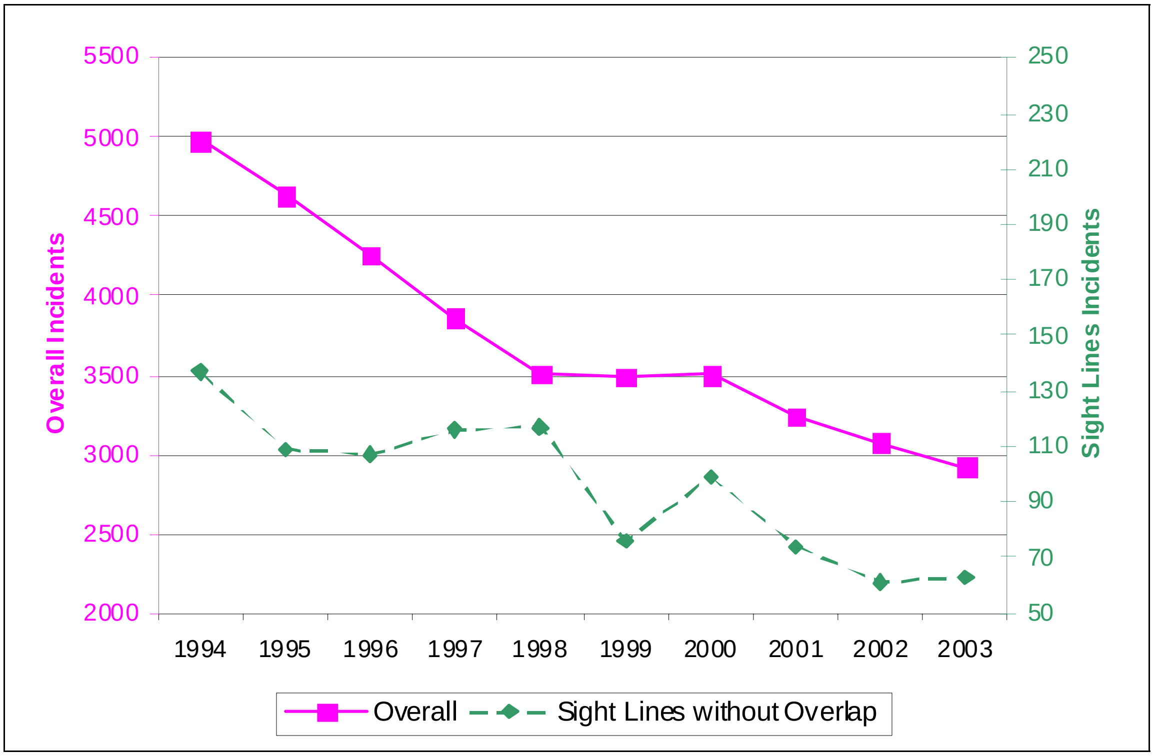


Figure 13. Incidents Attributed to Sight Lines Clearance for 1994-2003

5.1.12 Grade Crossing Maintenance Rule

Figure 14 shows incidents that can be attributed to the Grade Crossing Maintenance Rule for the years 1994 through 2003. In 1995, the Final Rule on Grade Crossing Signal Systems Safety was issued (this is represented by a yellow triangle on the graph). This rule states that railroads must implement specific maintenance, inspection, and warning testing requirements for active crossing systems. The graph shows a peak in 1997 because in that year new categories were added to the signal field in the RAIRS Grade Crossing database. Before 1997, detailed data was not collected for this field. Incidents related to warning device failures were reduced from 116 (in 1997) to 52. The largest decline occurred from 1997 to 2000. After 2000, the reduction leveled off. The benefits of this factor could have been maximized by the year 2000.

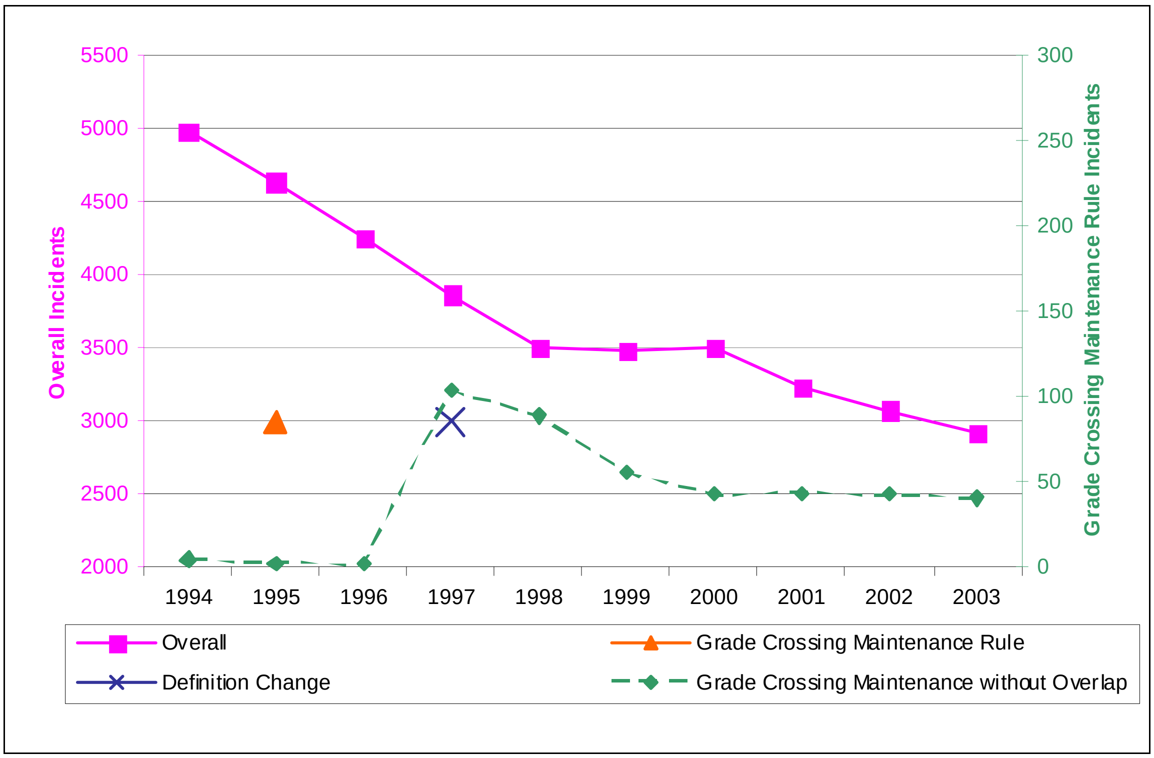


Figure 14. Incidents Attributed to the Grade Crossing Maintenance Rule for 1994-2003

5.1.13 More Reliable Motor Vehicles

Figure 15 shows incidents that can be attributed to More Reliable Motor Vehicles for the years 1994 through 2003. In 1997, a new category, trapped, was added to the position field on the accident/incident form. Incidents attributed to unreliable motor vehicles were reduced from 116 to 52. Similar to Sight Lines Clearance, the numbers are small but still mimic the national trend.

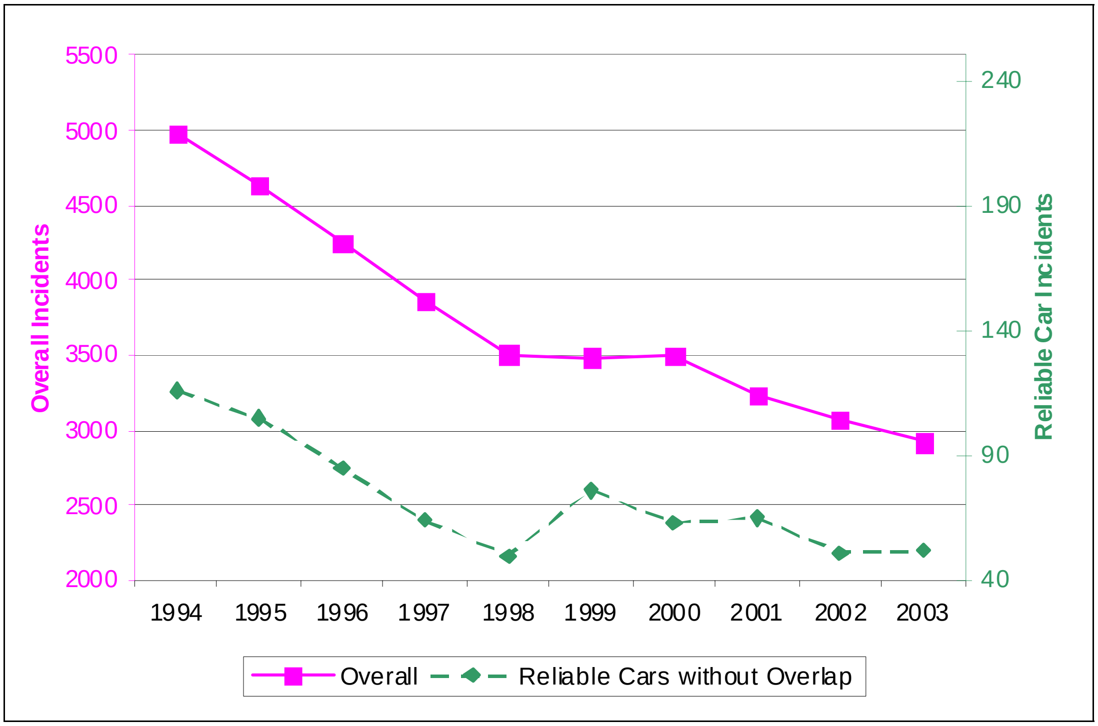


Figure 15. Incidents Attributed to More Reliable Motor Vehicles for 1994-2003

5.2 Final Percent Impact and Percent Reduction

To obtain the new impact and reduction percentages, the incidents were assigned to one of seven categories: the five isolated success factors, a combined interaction of two or more of the five isolated success factors, and a seventh category labeled unidentified factors. The other factors category contained all other incidents that were not assigned to an isolated success factor or some combined interaction of isolated success factors.

Once the success factors were isolated, the team used the same method as in Phase II to find new percent impacts and percent reductions for the five isolated factors and their combined interactions. The numbers were a more realistic representation of the effects of each factor. This method validated that the factors identified were indeed success factors for incident reduction. Table 7 shows these new percent impacts and percent reductions for the five isolated success factors, combined interactions, and unidentified factors. The numbers in this table are based on incidents nationwide from 1994 to 2003.

Table 7. Final Percents Impact and Percents Reduction

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 Interactions	12.8%	21.9%
Other Factors	44.7%	20.0%

Pareto diagrams were found to be an effective tool to display the new results. The Pareto principle states that the majority of wealth is held by a disproportionately small segment of the population. This principle applies to quality improvement. Out of all possible problems, only some occur frequently [15]. For the success factors problem, this translates to mean that a small number of success factors are responsible for the majority of the incident reduction from 1994 to 2003. The five factors and the interactions between them impacted 55 percent of the incidents during these ten years. And, 80 percent of the reduction in incidents, from 1994 to 2003, can be attributed to the five selected factors or the interaction of those factors. (See Table 8, Figure 16, and **Error! Reference source not found.**.) The two isolated factors with the largest effects on incident reduction were Commercial Driver Safety and Locomotive Conspicuity.

Table 8. Factor Key for Pareto Charts

Factor Type	Description
A	Unidentified factors
B	Commercial Driver Safety
C	Locomotive Conspicuity
D	Sight Lines Clearance
E	Grade Crossing Maintenance Rule
F	More Reliable Motor Vehicles
G	Combined interactions

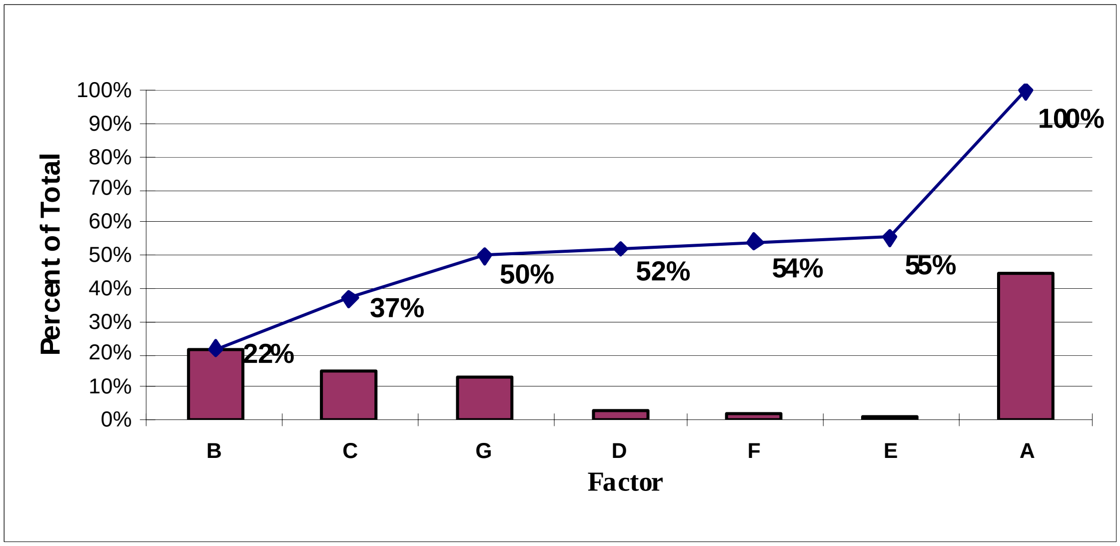


Figure 16. Pareto Chart of Factors Involved in Incidents (Percent Impact)

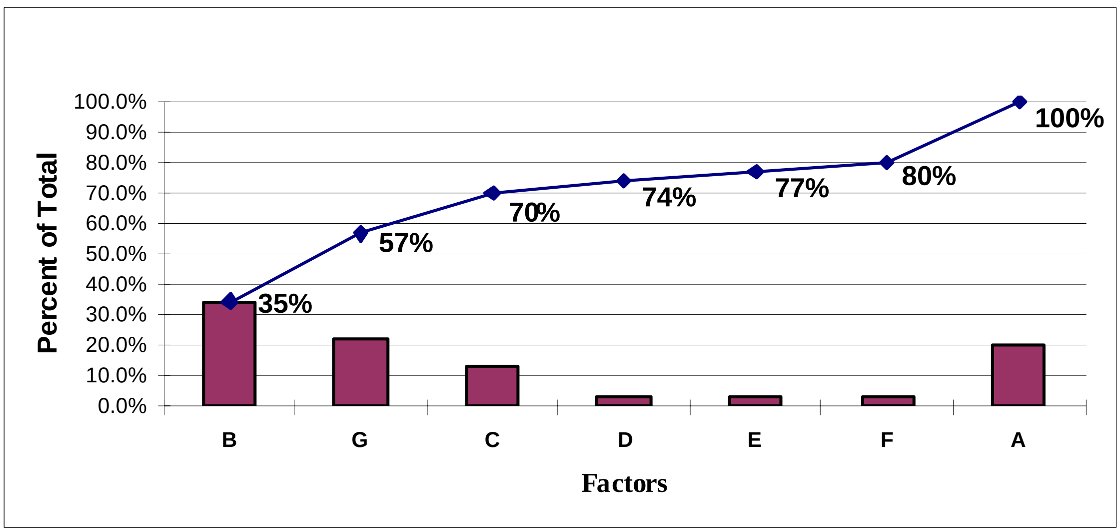


Figure 17. Pareto Chart of Factors that Contributed to a Reduction of Incidents

5.3 Kendall Partial Rank Correlation Coefficient

When analyzing the factors by percent impact and percent reduction, it was not possible to isolate the following two success factors: Crossing Closure and Grade Separation and Warning Device Upgrades. A different methodology was needed to analyze the effects of these two factors. The correlation between each of these two factors and the number of incidents for each year between 1994 and 2003 was examined. The Kendall Partial Rank Correlation Coefficient was used. It is a nonparametric method of partial correlation that ranks the data for each variable on an ordinal scale. This means that no assumptions about the distribution of the population need be made. It determines the correlation between variable X and variable Y, when variable Z is held constant. The correlation coefficient values can range from one to negative one. A correlation coefficient of one indicates that variables X and Y are positively correlated, a coefficient of zero indicates that no correlation exists, and a coefficient of negative one indicates that there is a negative correlation [16].

Table 9 and Table 10 show the Kendall Partial Rank Correlation Coefficient for Crossing Closure and Warning Device Upgrades for each year in the study. The complete Kendall Partial Rank Correlation Coefficient analysis, as well as more detail on the statistical method, is available in Appendix H and Appendix I.

5.3.14 Crossing Closure

Crossing closure and grade separation yield many of the same safety benefits. They eliminate the risk of an incident by preventing highway and rail traffic from intersecting. Because of the limited data available for grade separations and the small number constructed in the Nation, the analysis focused on crossing closures. For the analysis of Crossing Closure, variable X is the number of closed crossings, variable Y is the number of incidents reduced from one particular year to the next, and variable Z is the number of crossings in that year. The data was separated into the eight FRA regions (see Appendix H). For each year of study, the research team ranked the eight regions on the three variables. The rankings were used to obtain Kendall rank correlation coefficients for variables X and Y, Z and Y, and X and Z. With those values, the correlation coefficient of X and Y when Z is held constant was computed.

The Kendall Partial Rank Correlation Coefficients for crossing closures (see Table 9) indicate that the correlation between the number of crossings closed and the number of incidents reduced, is strong for some years and weak in others. The graph in Figure 17 shows that the correlation may be cyclical; however, the span of this study is too short to draw any conclusions. The closure activity may take years to complete and see the benefits. The type of crossings closed also would impact incident reduction. Closing abandoned crossings with little traffic would yield fewer safety benefits than closing a crossing with high exposure.

Table 9. Kendall Partial Rank Correlation Coefficient for Crossing Closure

Year	$\tau_{xy,z}$
1994	0.16
1995	0.47
1996	-0.29
1997	0.09
1998	-0.45
1999	-0.02
2000	0.73
2001	0.32
2002	0.30
2003	0.00

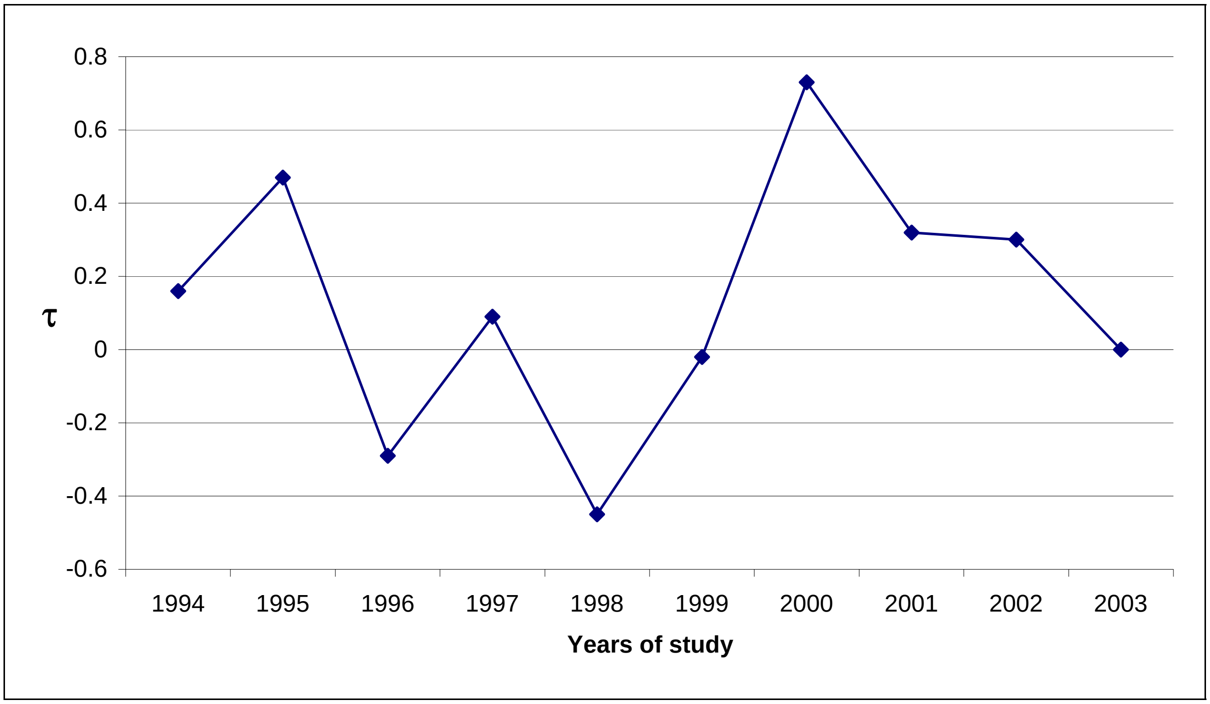


Figure 17. Kendall Partial Rank Correlation Coefficients for Crossing Closure

5.3.15 Warning Device Upgrades

For the analysis of Warning Device Upgrades, variable X is the number of crossing upgrades, variable Y is the number of incidents reduced from one particular year to the next, and variable Z is the number of crossings in that year. The data was separated into the eight FRA regions. For each year of study, the research team ranked the eight regions on the three variables. The rankings were used to obtain Kendall rank correlation coefficients for variables X and Y, Z and Y, and X and Z. With those values, the correlation coefficient of X and Y when Z is held constant was computed.

The Kendall Partial Rank Correlation Coefficients for warning device upgrades also appears to be cyclical. Some years have high correlation values while others are low. The factor isolation conducted in Phase III attributed some incidents to particular factors. These incidents were removed for this correlation analysis. It was assumed that the incident reduction that was not attributed to the five isolated factors could have been attributed to warning device upgrades. Because different types of upgrades (e.g. flashing lights to gates, or crossbucks to gates) exist, a proxy number was used for the total number of upgrades. It was determined by the summation of the number of each type of upgrade multiplied by the effectiveness value of that upgrade, as defined by the *Rail-Highway Crossing Resource Allocation Procedure* [13]. Correlation values were found, as shown in Table 10. Figure 18 graphs the values in Table 10, and a cyclical pattern can be seen. This indicates that the benefits of upgrading the crossing warning devices may take time to be realized, or delays could occur in entering the data into the inventory database.

Table 10. Kendall Partial Rank Correlation Coefficient for Warning Device Upgrades

Year	$\tau_{xy,z}$
1994	0.21
1995	0.42
1996	-0.17
1997	0.46
1998	0.17
1999	-0.28
2000	0.57
2001	0.18
2002	0.52
2003	0.09

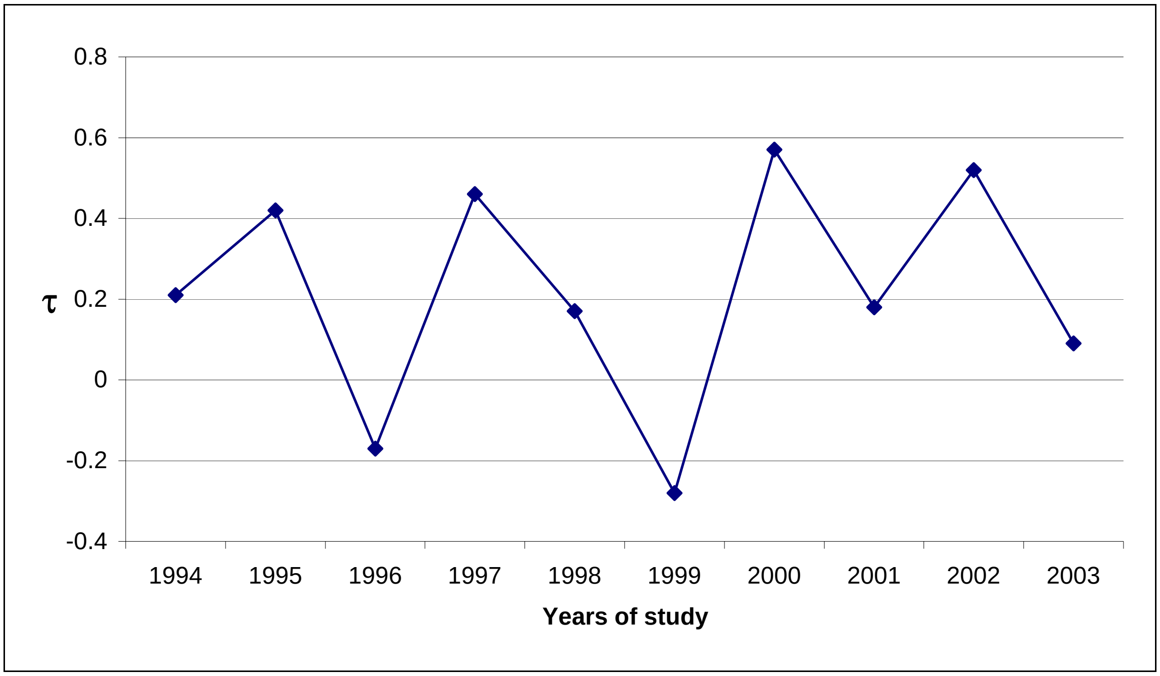


Figure 18. Kendall Partial Rank Correlation Coefficients for Warning Device Upgrades

Although the results varied among years, the tests for correlation between crossing closures or warning device upgrades and the reduction in highway-rail grade crossing incidents suggest that these two factors do have effects on crossing safety. The reduction in incidents from 1994 through 2003 can be related to efforts to close and consolidate crossings and upgrade the crossing warning devices.

5.4 The Section 130 Program

The Section 130 Program is a Federal program under US Code Title 23, Section 130 that provides funds for highway-rail grade crossing safety improvements. Under the Section 130 Program, approximately $220,000,000 is available to states annually. Over the last 15 years, $3.8 billion has been obligated for grade crossing improvements. The crossing safety improvement programs are unique to each state. They can include signage, pavement markings, warning devices, illumination, crossing surface repairs, crossing closures, and grade separations. Because this program encompasses many options to improve crossing safety, it was difficult to isolate its effect on incident reduction. The researchers conducted a qualitative analysis that revealed that the Section 130 Program is beneficial to crossing safety. Table 11 lists literature relevant to the Section 130 Program.

Table 11: Literature Relevant to the Section 130 Program

Article	Author(s)	Date
Accidents That Shouldn't Happen; A Report of the Grade Crossing Safety Task force to Secretary Federico Pena	United States Department of Transportation	March 1996
U.S. Railroad Safety Statistics and Trends	P. French	January 2006

Accidents That Shouldn't Happen; A Report of the Grade Crossing Safety Task Force to Secretary Federico Pena [17] states that FHWA estimates that since the inception of the Section 130 Program, 40,000 injuries have been prevented and 9,000 lives saved. A presentation provided by the Association of American Railroads in January 2006, *U.S. Railroad Safety Statistics and Trends* [18], stated that the installation of gates at a crossing reduced the accident and fatality rates by 93 percent. This statistic indicates that using the funds available from the Section 130 Program to upgrade crossing warning devices has a significant effect on crossing safety. The effects from this factor are conjoined with the effects from Crossing Closure and Grade Separation and Warning Device Upgrades.

5.5 Operation Lifesaver

Operation Lifesaver was also considered a possible success factor. However, proper evaluation of this program's impact would require time and labor intensive data collection. Therefore, the research team chose a qualitative literature review evaluation. Table 12 lists the four most relevant articles.

Table 12: Literature Relevant to Operation Lifesaver

Article	Author(s)	Date
Does Public Education Improve Rail-Highway Crossing Safety?	I. Savage	March 2005
Evaluation of Transport Canada's Contribution to Operation Lifesaver Final Report	Departmental Evaluation Services Transport Canada	November 2003
Public Education and Enforcement Research Study – Draft Report	S. Sposato, P. Bien-Aime, and M. Chaudhary	June 2006
Driver's Behavior at Railroad Grade Crossings: Before and After Safety Campaign. Final Report	K.A. Brewer	March 1992

In the paper, "Does Public Education Improve Rail-Highway Crossing Safety?" [19], negative binomial regression was used to determine a relationship between Operation Lifesaver and grade crossing incidents and fatalities. While no conclusion could be made about the impact of Operation Lifesaver on fatalities, it was determined that the level of Operation Lifesaver educational activity had a significant effect on the number of incidents. One of the reasons the analysis was done at the State level was because Operation Lifesaver activity is measured on a State level.

Transport Canada took a different approach in evaluating Operation Lifesaver in its November 2003 final report titled *Evaluation of Transport Canada's Contribution to Operation Lifesaver* [20]. Transport Canada looked at three data sources: file and document reviews; interviews of Transport Canada railway safety staff, Operation Lifesaver National Office staff, and Operation Lifesaver Stakeholders; and two case studies.

The report indicated that the Operation Lifesaver activity improved the safety behavior and awareness of its target audience. However, the positive results were not conclusive because of a lack of quantitative data. The case studies added additional anecdotal evidence. For example, the mock disaster showed that by improving the awareness about the logic of the events that lead to a grade crossing incident, people's willingness to change their behavior can be influenced.

The *Public Education and Enforcement Research Study (PEERS)* [21] dealt with the impact of education on violations of the grade crossing warning devices. Various types of public education were applied, including crossing safety blitzes and an increase in Operation Lifesaver presentations throughout the community. These activities resulted in the violation rates being reduced by 30.92 percent from the pre-test to the post-test period. In addition, the violation rate when a highway-user enters the grade crossing while warning flashers are active and the gates are fully deployed (horizontal position), showed a 71.4 percent decrease from the pre-test to the post-test period.

Driver's Behavior at Railroad Grade Crossings: Before and After Safety Campaign Final Report [22] covered a new implementation of Operation Lifesaver in Iowa. This study reviewed traffic characteristics at 22 grade crossings before and after the implementation of Operation Lifesaver. Two observations were made before and after the implementation of Operation Lifesaver and then compared. The results showed that Operation Lifesaver was effective in three ways. At low speed crossings, the driver's approach and crossing speeds were slowed. A lower percentage of drivers exceeded the speed limit while approaching the crossings. A higher percentage of drivers made sure the grade crossing was clear of trains before crossing over the tracks.

In summary, while none of the articles contain any strong quantitative data that document the success of Operation Lifesaver on a nationwide or even state level, ample qualitative data does seem to suggest Operation Lifesaver is successful in its mission.

5.6 Railroad Mergers–A Potential Success Factor

In addition to the success factors analyzed in Phases I and II, changes in the railroad industry operations and organization, through mergers and consolidations, could also have influenced the reduction in highway-rail incidents. The mergers and consolidations could have affected the reduction in incidents in any of the following ways: the railroads were operating more efficiently, the success factors were reinforced in the new more efficient culture, or unidentified independent factors arose from the mergers and consolidations.

The number and size of railroads during the 10-year study period, 1994 through 2003, changed. In 1994, there were 15 Class I railroads (as defined by the Surface Transportation Bureau) in the United States; in 2003, there were 9. This merging and consolidation likely resulted from a number of economic forces: modal competition, opportunities for economic efficiencies, changes in the manufacturing sector, and shifting traffic patterns. There could be a safety benefit to merging and an economy of scope or scale. These mergers may have reinforced the effects of the success factors (particularly factors within the railroad industry control, e.g., sight line improvements, crossing maintenance, warning device upgrades, crossing closures, and grade separations), as well as created new independent effects. To fully study this issue is a sizable undertaking; therefore, this study did not determine any independent effects.

In 1994, 23 railroads had 85 percent of the incidents when ranked in descending order of frequency; in 2003, 18 railroads had 85 percent of these incidents. (See Appendix J.) As mentioned, the number of Class I railroads in the United States decreased from 15 in 1994 to 9 by the end of the study period in 2003. (See Table 13.) Currently, Class I status is defined as operating revenues in excess of $289.4 million. In 2004, Class I railroads operated 97,496 of the 140,806 miles (70 percent) of the U.S. railroad network [23].

Table 13. Class I Railroads at the Beginning and End of the Study Period

Class I Railroads at Beginning of Study Period, 1994	Class I Railroads at End of Study Period, 2003
Amtrak (National Railroad Passenger Corp.)	Amtrak (National Railroad Passenger Corp.)
Atchison, Topeka & Santa Fe Railway	Burlington Northern and Santa Fe Railway Co.
Burlington Northern Railroad Co.	Canadian National/Grand Trunk Western Railroad Co.
Chicago and North Western Railway Co.	CSX Transportation, Inc.
Consolidated Rail Corp.	Kansas City Southern Railway Co.
CSX Transportation, Inc.	Norfolk Southern Combined Railroad Subs.
Denver & Rio Grande Western Railroad	Soo Line Railroad Co.
Grand Trunk Western Railroad Inc.	Union Pacific Railroad Co.
Illinois Central Railroad Co.	
Kansas City Southern Railway Co.	
Norfolk Southern Corp.	
Soo Line Railroad Co.	
Southern Pacific Transportation Co.	
St. Louis Southwestern Railway Co.	
Union Pacific Railroad Co.	

While mergers occurred among Class I and other railroads, some Class II and III railroads also merged and/or consolidated. Additionally, Class II and III railroads may respond competitively to Class I operating changes. However, because they operate only a small percentage of U.S. tracks, these mergers are not of much interest.

Highway-rail incidents declined 41.2 percent during the 10-year study period. Over the first 5 years of the study period, the rate of decline was 8.4 percent per year versus 4.4 percent for the final five years. (See Table 14.) In the first period, Union Pacific Railroad Co. (UP) merged with Southern Pacific Transportation Co. (SP) and Chicago Northwestern Railway Co. (CNW) in 1995; Burlington Northern Railroad Co. (BN) and Atchison Topeka Santa Fe Railway (ATSF) merged in 1996. Whether these mergers in any way impacted the incident decline, particularly during the first 5 years, would be of interest.

Table 14. Yearly Rates of Decline in Public and Private Crossing Incidents

Year	Incidents	Percent Decline	5 Year Compound Rate of Decline
1994	4,979		
1995	4,633	-7.0%	
1996	4,257	-8.1%	8.4%
1997	3,865	-9.2%	
1998	3,508	-9.2%	
1999	3,489	-0.5%	
2000	3,502	0.4%	
2001	3,237	-7.6%	4.4%
2002	3,077	-4.9%	
2003	2,920	-5.1%	

Highway-rail incidents for UP and its merger partners, SP and CNW, declined yearly, with the exception of 1999 throughout the study period. The overall reduction, from 1,029 in 1994 to 427 in 2003, was 58.5 percent. (See Table 15.) UP acquired more track miles following the merger in 1995. As UP operations grew as a result of the merger, the incidents decreased. This suggests a safety benefit from railroad mergers that may not have previously been identified.

Table 15. Public Crossing Incidents Reported for UP and Major Merger Partners

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
UP	591	468	583	679	590	656	602	555	479	427
SP	246	201	202							
CNW	192	153	0							
TOTAL	1029	822	785	679	590	656	602	555	479	427

Change	-20.1%	-4.5%	-13.5%	-13.1%	11.2%	-8.2%	-7.8%	-13.7%	-10.9%

Highway-rail incidents for the Burlington Northern and Santa Fe Railway Co. (BNSF) and two of its major merger partners, BN and ATSF, declined yearly with the exception of 1995, throughout the study period. (See Table 16.) The overall reduction from 625 in 1994 to 343 in 2003 was 45.1 percent. A large incident reduction (20.8 percent) occurred in 1996 and again in 1998 (14.0 percent), bracketing the time of the merger. The trend in incidents involving BNSF after the merger suggests a relationship between consolidation and incident declines.

Table 16. Public Crossing Incidents Reported for BNSF and Major Merger Partners

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
BNSF	0	0	243	537	462	446	437	410	408	343
BN	453	474	192	0	0	0	0	0	0	0
ATSF	172	193	93	0	0	0	0	0	0	0
TOTAL	625	667	528	537	462	446	437	410	408	343
Change		6.7%	-20.8%	1.7%	-14.0%	-3.5%	-2.0%	-6.2%	-0.5%	-15.9%

5.7 Summary of Results

The five success factors that were isolated in Phase III accounted for nearly 80 percent of the reduction in incidents from 1994 to 2003. These five factors are Commercial Driver Safety, Locomotive Conspicuity, Grade Crossing Maintenance Rule, Sight Lines Clearance, and More Reliable Motor Vehicles. Figure 19 shows the number of grade crossing incidents by year. The columns are divided into incidents that identified one of the five success factors as a cause and those where the cause was unknown. The incidents attributed to a success factor see a dramatic decline over the decade, whereas the other incidents remain constant. This indicates that the success factors that were instrumental in the reduction of incidents from 1994 to 2003 have been identified.

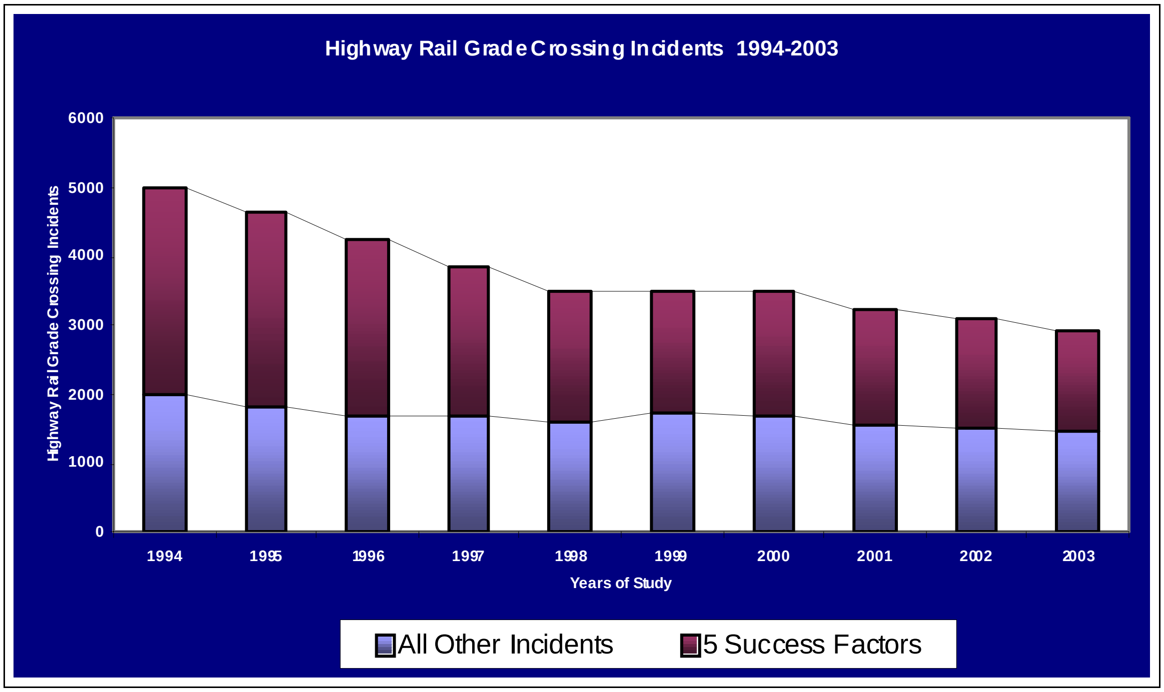


Figure 19. Highway-Rail Grade Crossing Incidents 1994-2003

The two factors, Crossing Closure and Grade Separation and Warning Device Upgrades, were analyzed using the Kendall Partial Rank Correlation Coefficient. This analysis showed positive correlations between the factors and the reduction in incidents. This supports the belief that these two factors contributed to incident decline. The researchers performed qualitative analysis on the two factors, the Section 130 Program and Operation Lifesaver. Previously conducted research suggests these factors are success factors. Additional analysis during the course of this project revealed a potential 10th success factor, Railroad Mergers.

6.0 Findings

6.1 Lessons Learned

Before an analysis can be conducted, it is important to determine which data to use, how to obtain that data, and how to maintain the integrity of that data. In this study, FRA databases were chosen as the data sources. Data mining tools were then needed to extract the data from the databases. ADAPT_X and SAS were chosen as two data mining tools. However, when the incident data generated from ADAPT_X and SAS were compared, the results showed that SAS produced a slightly higher number of incidents. The comparison of the two data sets revealed that in the SAS set, some incidents were counted multiple times. This may occur when more than one railroad is involved in an incident and each railroad files a report with FRA. Instead of only one incident record, two incidents are recorded. Because of the multiple counting generated by SAS, ADAPT_X was chosen as the primary data mining tool. The multiple entries of a single incident in the RAIRS Grade Crossing database could affect results, and measures should be taken to remedy these inconsistencies.

When the data fields from the highway-rail crossing accident/incident reports are used to categorize the incidents by success factor, some incidents are counted multiple times. The overlap of incidents between factors results in an overestimation of the factor's effect. It is important to recognize this, as well as to isolate the factors and any interaction between them. This yields more realistic numbers and a more accurate representation of each factor's effect on incident reduction.

In this study, the researchers examined data from multiple years; therefore, it was important to be aware of database changes over time. Some modifications were the result of the following: changes in definitions and codes used within the database, new fields and categories being added to the database, and new lawmaking rules and regulations. The Crossing Inventory database is divided into a current and a historical section. It is necessary to be aware that changes will be made in the current section of the database without updating the historical section. In addition, it was difficult to discern when a particular change was made to the database. Because the Crossing Inventory is split between the historical and current data, it is important to realize that changes made to one set of data would not necessarily be made to the other.

During the course of the analysis, it became apparent that not enough data fields are collected to determine the effects of all the identified success factors. A limited number of fields are in the accident reports and the grade crossing inventory. Creative and qualitative methods were necessary to examine the effects of some factors. The quantitative methods attributed some portion of the reduction in incidents to the success factors. The qualitative analysis does not rely on mathematical validity, but instead on expert conjecture and prior studies. Some safety programs, such as Operation Lifesaver and the Section 130 Program, encompassed multiple factors. This made it difficult to identify the impact and reduction on incidents due to these safety programs. The differences in analytical methods made it difficult to compare the effects of all factors and presented challenges in determining the top success factors.

The success factors were analyzed using two metrics. These two metrics, percent impact and percent reduction, provided a more accurate picture of the effects of the factors. A factor that reduced a large percentage of incidents could only be considered a top success factor if it impacted a large percentage of the incidents from 1994-2003. For example, a factor that reduced incidents by 50 percent, but only impacted 1 percent of incidents would not be a success factor. But a factor that reduced incidents by 25 percent and impacted 30 percent of incidents would. It was important to consider both metrics when determining the success factors.

A Pareto diagram is a tool that is useful to quickly identify critical areas. In this analysis, the critical areas were those factors that were responsible for the largest reduction in incidents from 1994 to 2003. Pareto diagrams arrange factors in order of importance. In this analysis, the factors were arranged by the number of incidents impacted and the number of incidents reduced. The Pareto diagrams for this project provided evidence that the major success factors in incident reduction, from 1994 to 2003, were responsible for nearly 80 percent of the reduction during this period.

In addition to the sources explicitly referenced in this paper, general knowledge and understanding were obtained from a variety of sources. These papers, reports, and legislative documents offered guidance and insight as the analysis moved forward. Appendix K lists additional sources.

6.2 Recommendations for Next Steps

Proceeding with the following next steps could enhance the results of this analysis. They could provide a better understanding of grade crossing success factors.

6.2.1 Case Studies

Case studies can help validate the results and understand complexities by taking a micro approach. Some regions and States have more pronounced declines. The States and regions selected to study should be larger entities because generally less variation occurs in counts among years. A comparison case study could be conducted between a State with a large reduction in incidents due to a particular success factor and a State without a significant reduction. Another case study approach would be to focus on the incident data and crossing improvement programs for a particular State. The availability of better data could produce a more thorough analysis. Some of the States, like Illinois, collect more detailed grade crossing data than is available from the FRA.

Two potential States for case studies are Florida and Texas. *Rail-Highway Crossing Safety— Fatal Crash and Demographic Descriptors* [25] identified Texas as the State most representative of the Nation as a whole. Florida had a large number of incidents during the study period. Unlike other States with a large number of incidents, the number of crossings was relatively unchanged and the number of gated crossings only increased slightly. This disparity makes it an interesting case study. Examination of the highway-rail grade crossing incident data by FRA region is another possible case study. Variation in incident rates was detected among regions. Regions 4, 5, and 6 showed stronger declines in incidents during the study period (see Appendix J).

The number and size of railroads during the study period changed. A safety benefit to merging may exist. A full study on the effects of railroad mergers would be a large endeavor. A case study of a large railroad State may provide a manageable beginning. Two potential States are Texas or California, where mergers and operational consolidation occurred during the study period. Incidents at public crossings in California declined from 183 in 1994 to 120 in 2003 (see Appendix J). UP and BNSF, two railroads with substantial merger activity during the study period, operate in California. Incidents at public crossings in Texas declined from 502 in 1994 to 258 in 2003 (see Appendix J). The number of railroads reporting incidents also declined (30 to 16). Two major railroad consolidations involving BNSF and UP occurred. These case studies would help reveal the effects of railroad mergers on incidents.

6.2.2 Data Analysis

Collection of additional data may improve understanding of future trends in highway-rail grade crossing incidents. The goal in any additional data collection is to remove the need to make assumptions about incidents. Some areas of data collection that could be improved are: mandatory updates to the data files for current information, more driver behavior data fields, more consistent guidelines for filling out the accident/incident reports and better record keeping for database changes. Information value should be weighed against stakeholder collection costs.

It is important to look at the likelihood that each success factor will continue to provide a reduction in grade crossing incidents. Diminishing returns is a concern because after a certain point, additional spending in a given area will yield fewer benefits than it did in the past. For example, Locomotive Conspicuity had the largest reduction in incidents in the years immediately following the implementation of the alerting lights regulation. Afterwards, the benefit of this safety measure was constant. No expectation exists that another large benefit will be realized from this safety measure because all locomotives are already equipped with alerting lights. However, a safety measure such as Crossing Closure and Grade Separation may continue to yield benefits at the same rate. Every time a crossing is closed or grade separated, an impact on grade crossing incidents occurs. Crossings still need to be closed or grade separated. Diminishing returns are something to consider when investigating the success factors of the next decade.

Analyzing data from grade crossing fatalities could reveal the success factors that would help reduce the most severe incidents. Safety initiatives that save human lives provide invaluable benefits. Two sources of grade crossing fatality data are the RAIRS Grade Crossing database and the FARS database. The FARS database collects more fields than the RAIRS Grade Crossing database, which could be helpful when looking for root causes. Identifying the factors that reduce the most severe incidents can help maximize the benefits of implementing safety countermeasures.

For each of the factors identified in this paper, further analysis should be conducted on the incident data for 2004, 2005, and 2006. The methodology should be similar to the one used in this study. The same data sources and methods of extracting the data from the sources should be used for consistency. The goal of the analysis is to see if the trends identified in this study continue. One benefit of this analysis would be additional validation of the conclusions of this study. It would also help predict where additional safety benefits can be gained in the coming years.

6.2.3 Future Success Factors

Future analysis could explore the impact of enforcement to help reduce grade crossing incidents. Enforcement is an increasingly popular low cost option to enhance safety at highway-rail grade crossings. Research is already being conducted that indicates that enforcement has the potential to decrease grade crossing incidents. Different types of enforcement include photo enforcement or the physical presence of law enforcement at the crossing.

Driver behavior is usually the cause of grade crossing incidents. The Office of the Inspector General report attributed 94 percent of highway-rail grade crossing incidents and 87 percent of fatalities to "risky driver behavior or poor judgment" [6]. For example, an incident can occur when a motorist decides to violate the crossing warning devices and drive around the gates. Enforcement activity can influence drivers to behave safely. *The Use of Photo Enforcement at Highway-Rail Grade Crossings in the U.S. July 2000—July 2001* [24] looked at the use of photo enforcement at six locations. The result was a reduction of violations at all locations. *Public Education and Enforcement Research Study* [21] looked at the effect of law enforcement blitzes (i.e., when a police officer issues a citation to violators of the crossing warning devices). The violation rates were lower on days when law enforcement was present. This indicates that highway-user behavior was changed for the safer during the law enforcement blitzes. Enforcement is a safety tool that was not widely used from 1994 to 2003, but could be a success factor in incident reduction in future decades.

On November 28, 2005, FRA enacted a new rule with the intent to reduce the number of highway-rail grade crossing incidents. The rule, Reflectorization of Rail Freight Rolling Stock (49 CFR 224), states that retro-reflective sheeting shall be applied to every railcar and locomotive. Retro-reflectivity improves train visibility at night or during other low visibility situations. This rule impacts safety at highway-rail grade crossings after the 10-year period studied in this report. It is a potential success factor for future decades.

Another rule that potentially impacts crossing safety after 2003 was the locomotive horn rule. The locomotive horn helps highway users avoid grade crossing incidents. However, communities who are frequently subjected to this train horn may feel that the level of noise the horn creates is affecting their quality of life. On June 24, 2005, FRA's Final Rule on the Use of Locomotive Horns at Highway-Rail Grade Crossings (49 CFR 222-229) went into effect. This new rule requires that train horns be sounded at all highway-rail grade crossings in the United States. It also allows localities to establish areas where locomotive horns are not sounded, provided that alternative safety measures are implemented to eliminate any increase in risk. The changes implemented by this rule will influence highway-rail grade crossing safety. This is a potential success factor in the next decade.

In addition to the mergers and consolidations, other railroad-industry specific factors (e.g., traffic type or commodity mix) might have an effect on incident reduction and its variation among States and FRA regions. Shipments of major commodity groups (e.g., grain, coal, forest products) vary among years. This variation may differentially impact regions. In addition to the overall downward decline in incidents, a railroad activity cycle may be superimposed on the trend. Historically, the decline has occurred as an oscillating process, possibly influenced by fluctuations in railroad business activity.

7.0 Conclusions

At the conclusion of this analysis, 10 factors were identified as successful highway-rail grade crossing safety initiatives and programs. Five factors were isolated and analyzed based on numeric data, and the other five were analyzed inferentially and qualitatively. The five factors that were isolated are:

- Commercial Driver Safety
- Locomotive Conspicuity
- Sight Lines Clearance
- Grade Crossing Maintenance Rule
- 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).

The other five factors that were analyzed alternatively are:

- Crossing Closure and Grade Separation
- Warning Device Upgrades
- Operation Lifesaver
- Section 130 Program
- Railroad Mergers

The team examined Crossing Closure and Grade Separation and Warning Device Upgrades in Phase II of this study. The analysis used a probable number of incidents to determine the percent impact and percent reduction. These factors were unable to be isolated in Phase III. Therefore, a measure of correlation was used to establish a relationship between the factor and the reduction in incidents. Although a percent impact and reduction could not be isolated, the data did show a positive correlation.

Operation Lifesaver and the Section 130 Program were multifaceted programs and addressed safety in a variety of ways. Because of their broad reaching nature, a solid quantitative analysis was difficult. There was not data collected that could be associated with many aspects of these programs. Therefore, a qualitative analysis was undertaken, revealing positive results. Although this analysis did not involve numerical data, it indicated that Operation Lifesaver and the Section 130 Program contributed to safer behavior at highway-rail grade crossings. Funds from the Section 130 Program can be used to close, separate, or upgrade crossings. Therefore, the effects of Crossing Closure and Grade Separation and Warning Device Upgrades also reflect on the effectiveness of the Section 130 Program.

Investigation into alternative methodologies for analysis yielded supporting evidence of the nine success factors and another potential success factor. Railroad Mergers show evidence of dramatic incident reductions, even though the railroads grew in size and their operations expanded. Mergers and consolidation could have reinforced the other success factors identified in this paper, or it could have created independent effects.

The analysis conducted during this study revealed 10 factors that can account for the majority of the reduction in grade crossing incidents from 1994 to 2003.

Appendix A.
FRA Accident/Incident Report

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION (FRA)

HIGHWAY-RAIL GRADE CROSSING ACCIDENT/INCIDENT REPORT

OMB Approval No.: 2130-0500

1. Name of Reporting Railroad	1a. Alphabetic Code	1b. Railroad Accident/Incident No.
2. Name of Other Railroad Involved in Train Accident/Incident	2a. Alphabetic Code	2b. Railroad Accident/Incident No.
3. Name of Railroad Responsible for Track Maintenance *(single entry)*	3a. Alphabetic Code	3b. Railroad Accident/Incident No.
4. U. S. DOT Grade Crossing Identification Number	5. Date of Accident/Incident — month / day / year	6. Time of Accident/Incident — AM ☐ PM ☐

7. Nearest Railroad Station	8. Division	9. County	10. State Abbr. / Code

11. City *(if in a city)*	12. Highway Name or Number — Public ☐ Private ☐
Highway User Involved	Rail Equipment Involved
13. Type: A. Auto, B. Truck, C. Truck-trailer, D. Pick-up truck, E. Van, F. Bus, G. School bus, H. Motorcycle, J. Other motor vehicle, K. Pedestrian, M. Other *(specify)* — Code	17. Equipment: 1. Train *(units pulling)*, 2. Train *(units pushing)*, 3. Train *(standing)*, 4. Car(s) *(moving)*, 5. Car(s) *(standing)*, 6. Light loco(s) *(moving)*, 7. Light loco(s) *(standing)*, 8. Other *(specify)*, A. Train pulling- RCL, B. Train pushing- RCL, C. Train standing- RCL — Code
14. Vehicle Speed *(est. mph at impact)* / 15. Direction *(geographical)*: 1. North 2. South 3. East 4. West — Code	18. Position of Car Unit in Train
16. Position: 1. Stalled on crossing 2. Stopped on crossing 3. Moving over crossing 4. Trapped — Code	19. Circumstance: 1. Rail equipment struck highway user 2. Rail equipment struck by highway user — Code
20a. Was the highway user and/or rail equipment involved in the impact transporting hazardous materials? 1. Highway user 2. Rail equipment 3. Both 4. Neither — Code	20b. Was there a hazardous materials release by 1. Highway user 2. Rail equipment 3. Both 4. Neither — Code

20c. State here the name and quantity of the hazardous material released, if any.

21. Temperature *(specify if minus)* ° F	22. Visibility *(single entry)*: 1. Dawn 2. Day 3. Dusk 4. Dark — Code	23. Weather *(single entry)*: 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow — Code

24. Type of Equipment Consist *(single entry)*: 1. Freight train, 2. Passenger train, 3. Commuter train, 4. Work train, 5. Single car, 6. Cut of cars, 7. Yard/switching, 8. Light loco(s), 9. Maint./inspect. car, A. Spec. MoW Equip. — Code	25. Track Type Used by Rail Equipment Involved: 1. Main 2. Yard 3. Siding 4. Industry — Code	26. Track Number or Name

27. FRA Track Class (1-9, X)	28. Number of Locomotive Units	29. Number of Cars	30. Consist Speed *(Recorded speed, if available)* R - Recorded, E - Estimated — MPH — Code	31. Time Table Direction: 1. North 2. South 3. East 4. West — Code

32. Type of Crossing Warning: 1. Gates, 2. Cantilever FLS, 3. Standard FLS, 4. Wig wags, 5. Hwy. traffic signals, 6. Audible, 7. Crossbucks, 8. Stop signs, 9. Watchman, 10. Flagged by crew, 11. Other *(specify)*, 12. None — Code(s)	33. Signaled Crossing Warning *(See reverse side for instructions and codes)* — Code	34. Whistle Ban: 1. Yes 2. No 3. Unknown — Code
35. Location of Warning: 1. Both sides 2. Side of vehicle approach 3. Opposite side of vehicle approach — Code	36. Crossing Warning Interconnected with Highway Signals: 1. Yes 2. No 3. Unknown — Code	37. Crossing Illuminated by Street Lights or Special Lights: 1. Yes 2. No 3. Unknown — Code

38. Driver's Age	39. Driver's Gender: 1. Male 2. Female — Code	40. Driver Drove Behind or in Front of Train and Struck or was Struck by Second Train: 1. Yes 2. No 3. Unknown — Code	41. Driver: 1. Drove around or thru the gate 2. Stopped and then proceeded 3. Did not stop 4. Stopped on crossing 5. Other *(specify)* — Code

42. Driver Passed Standing Highway Vehicle: 1. Yes 2. No 3. Unknown — Code	43. View of Track Obscured by *(primary obstruction)*: 1. Permanent structure 2. Standing railroad equipment 3. Passing train 4. Topography 5. Vegetation 6. Highway vehicles 7. Other *(specify)* 8. Not obstructed — Code

Casualties to:	Killed	Injured		
			44. Driver was: 1. Killed 2. Injured 3. Uninjured — Code	45. Was Driver in the Vehicle? 1. Yes 2. No — Code
46. Highway-Rail Crossing Users			47. Highway Vehicle Property Damage *(est. dollar damage)*	48. Total Number of Highway-Rail Crossing Users *(include driver)*
49. Railroad Employees			50. Total Number of People on Train *(include passengers and train crew)*	51. Is a Rail Equipment Accident/ Incident Report Being Filed? 1. Yes 2. No — Code
52. Passengers on Train				

53a. Special Study Block	53b. Special Study Block

54. Narrative Description *(Be specific, and continue on separate sheet if necessary)*

55. Typed Name and Title	56. Signature	57. Date

NOTE: This report is part of the reporting railroad's accident report pursuant to the accident reports statute and, as such shall not " be admitted as evidence or used for any purpose in any suit or action for damages growing out of any matter mentioned in said report . . . ." 49 U.S.C. 20903. See 49 C.F.R. 225.7 (b).

FORM FRA F 6180.57 (Revised March 2003)

* NOTE THAT ALL CASUALTIES MUST BE REPORTED ON FORM FRA F 6180.55A

Appendix B.
Comprehensive List of Success Factors

Table Key

- Description–Text description of the item
- Evaluation Method–Description in text of how to evaluate the factor
- Data Needs–Description of the ideal data needed to evaluate the factor
- Interviews–‘Y’ = interviews would be a good data source, ‘N’ = it would not be helpful.
- Data Analysis–‘Y’ = data analysis would be a good data source, ‘N’ = it would not be helpful.
- Literature Review–‘Y’ = literature review would be a good data source, ‘N’ = it would not be helpful.
- Projected Impact–‘L’ = Low Impact; ‘M’ = Medium Impact; ‘H’ = High Impact
- Difficulty to Evaluate–‘E’ = Easy to evaluate; ‘M’ = Medium Difficulty to evaluate; ‘V’ = Very Difficult to Evaluate

Crossing Safety Improvement Items	Description	Evaluation Method	Data Needs	Interview s	Data Analysis	Literature Review	Projected Impact	Difficulty to Evaluate
Highway Traffic Signal Interconnection and Preemption	Traffic signal preemption is recommended for crossings with a highway-highway intersection within 200 feet. The normal sequence of traffic control signal indication is preempted upon the approach of trains to avoid entrapment of vehicles on the highway-rail crossing by conflicting aspects of the traffic control signals and the highway-rail grade crossing active warning devices.	Look at "before and after" incident rates at crossings that have traffic signal preemption at nearby intersections. And conduct a trend analysis versus overall incident reduction. Look at incidents where the motor vehicle was trapped in the grade crossing by highway traffic	Identify crossing with preemption and the date it was installed Identify crossings that are within 200 yards of a traffic signaled intersection	N	Y	N	L	M
Motor Carrier Safety Improvement and Commercial Driver Disqualification	During the period 1994-2003, a greater emphasis was put on commercial driver safety. The Motor Carrier Safety Improvement Act established the Federal Motor Carrier Safety Administration and emphasized truck safety. In October of 1999, a law stated that commercial drivers convicted of violating the grade crossing warning devices would lose their CDL.	Review the Act for details on crossing safety. Evaluate by commercial driver incidents/time for the 10 years 1994-2003. Find number of commercial drivers who lost their CDL as a result of the law.	Annual truck traffic Grade crossing incidents involving commercial vehicles	N	Y	N	H	E
Crossing Improvement Programs/Section 130 Funding	Highway funds are appropriated by Congress under Section 130, Title 23 of the United States Code for improvements to the safety of highway-rail grade crossings. The funds are appropriated by state and each state has its own crossing improvement plan.	Investigate the programs and funding of States that have had the greatest improvements in crossing safety. Rank States by amount spent on crossing safety and then rank states by number of incidents.	Grade crossing incident data by State Crossing improvement plans Levels of funding for CIP	Y	Y	N	M	M

		and number of crossings. Try to see if any pattern between amount spent and number of incidents.						
Locomotive Conspicuity	Making locomotives more conspicuous aids drivers in not only seeing an oncoming train, but judging its distance and speed. A final rule published in March 1996, effective in December 1997, stated that all locomotives exceeding 20 mph over the crossing must have auxiliary alerting lights in addition to the headlight.	Review literature on evaluations done in the mid-1990s. Look for decrease in incidents at night or passive crossings where locomotive is less visible.	Incident data Dates when lights were installed on locomotives	N	Y	Y	M	M
Urbanization	The migration of the public from rural areas of the Nation to more urban areas. Urban centers have fewer grade crossings, especially passive protective crossings.	Compare the number and types of urban and rural crossings. Look at the exposure rates at crossings. Use GIS.	Census data Incident data	N	Y	N	M	M
More Reliable Motor Vehicles	During the period of study, automobiles were improved to be safer and more reliable. A more reliable vehicle reduces the likelihood of breaking down or stalling on the tracks and subsequently being hit by an oncoming train.	Look for decrease in stalled cars on the tracks that led to incidents.	Incident data Automobile reliability ratings	N	Y	N	M	M
Grade Separation	The creation of an over/underpass at highway-rail grade crossings. Grade separations reduce the risk of a collision to zero because the vehicle and train paths no longer at that location.	Look at incident rates specifically in areas with a lot of separated crossings. Analyze the relationship between separated crossings and incidents.	Incident data Identify the separated crossings	N	Y	Y	H	M
Crossing Closure	Crossing closures may have impacted the safety of highway-rail grade crossings over the Action Plan period (1994 to 2003), In 1991, the	Look at incident rates specifically in areas with a lot of crossing closures.	Incident data Identify the closed crossings	N	Y	Y	H	M

	FRA Administrator recommended closing 25% of all crossings. Closures reduce the risk of a collision to almost zero because the vehicle and train paths no longer intercept at that location.	Analyze the relationship between closed crossings and incidents. Consider what types of crossings are being closed e.g. Are they closing the highest risk crossing? Or redundant unused crossings?						
Upgrade of Warning Devices	Physical warning devices at the crossings are upgraded for safety. When crossing warning devices are upgraded to devices with a higher effectiveness value, the risk of a collision at the crossing is reduced.	Look at upgraded crossings incident rates. Analyze incident data by type of warning device. Review literature on the effectiveness of warning devices.	Incident data Records of crossing upgrades	N	Y	Y	M	M
Grade Crossing Maintenance Rule And Constant Warning Time	In 1995, the Final Rule on Grade Crossing Signal System Safety was issued. This rule stated that railroads must implement specific maintenance, inspection, and testing requirements for active crossing warning systems. The regular maintenance and inspection would reduce the risk of warning device malfunction.	Look at incident data before and after the rule to see if a reduction in incidents occurred due to warning device malfunction Look for a significant decrease in incidents with long or short warning times Review Literature on driver impatience, faulty gate activations	Incident data Database cause codes	N	Y	N	H/L	M/V
Sight Lines	The clearing of vegetation and removal of obstructions surrounding a grade crossing enables highway-users to observe an oncoming train from greater distances from the crossing. Highway-users have a better chance to stop safely and the risk of being surprised by a	Review literature on sight line visibility and driver behavior at crossings. Look at incidents that occurred because the driver was not aware of the crossing and/or train.	Incident data	N	Y	Y	L	V

	train is reduced.							

Driver Behavior	The majority of incidents at highway-rail grade crossings are caused by driver error. The change in behaviors over time could result in fewer grade crossing incidents.	Review the compendium reference list on driver behavior at grade crossings. Conduct a data analysis of the incident data to identify causal factors and changes in driver behavior characteristics (time series over 10 years).	Incident data Driver behavior literature	N	Y	Y	M	M/V
Changes in Crossings Characteristics	Physical changes in the characteristics of a crossing could result in a safer environment.	Do a time series analysis of crossing characteristics to identify changes in the incident rates over 10 years.	Incident data Records of crossing upgrades Literature on effectiveness of warning devices	N	Y	Y	M	M
Accident Reporting	A rule on accident reporting mandated in 1996 required the railroads to report incidents Changes in the accident reporting requirements result in different data being collected. It also holds the railroads accountable for incidents and encourages a safety culture.	Identify the changes in reporting.	Reporting errors Rule changes	?	?	?	L	?
On Board Train Technology	Improved communications between locomotive and wayside computers alert the engineer to potential dangers at upcoming crossings.	Identify technology available and when it was implemented.	List of technologies available and implementation records	Y	Y	Y	L	V
Training & Manuals for Locomotive Engineers	New manuals and training for locomotive engineers have increased safety as a priority.	Create survey questions for locomotive engineers. Investigate what is included in the manuals/training.	Railroad Safety Data	Y	N	N	L	V
AADT	Changes in AADT affect exposure rates at grade crossings.	Compare changes in AADT (or exposure) with changes in grade crossing incidents	AADT Incident data	N	Y	N	L	V

Trains Per Day (TPD)	Changes in trains per day affect exposure rates at grade crossings.	Compare changes in train traffic (or exposure) with changes in grade crossing incidents.	TPD Incident data	N	Y	N	L	V
Operation Lifesaver	Education and awareness program dedicated to ending tragic collisions, fatalities, and injuries at highway-rail grade crossings and on railroad rights of way.	Interview Operation Lifesaver staff and presenters. Use the most active state Operation Lifesaver programs to see if there is any correlation between rail safety and Operation Lifesaver.	State Operation Lifesaver Programs Incident data	Y	Y	Y	M	V
Drunk Driver Programs	Increased awareness of the dangers of drunk driving result in a safer environment for all highway users. In 1998, all states had zero tolerance laws. The TEA-21 provides grants to States for DUI programs.	Look for a decrease in incidents that identified the highway user as impaired by alcohol over the 10 years.	Incident data	N	Y	N	L	M
Enforcement	Law and photo enforcement of traffic laws related to the crossing discourage risky behavior at highway-rail grade crossings.	Look at tickets and fines for crossing violations over 10 years. Review existing studies involving enforcement (PEERS, Naperville, IL).	Violation data Tickets and fines Incident data	N	Y	Y	L	V
Corridor Approach	Decisions about crossing improvements are made by considering a stretch of crossings together rather than each crossing individually.	Compare crossings on a corridor with other similar crossings. Review literature on existing corridors.	Corridor information Incident data	N	Y	Y	L	M

Appendix C.
Percent Impact and Percent Reduction

The research team quantitatively analyzed eight success factors. The objective was to rank their effectiveness based on two metrics, percent impact and percent reduction. The percent impact is the percentage of incidents, from 1994 to 2003, that can be attributed to behaviors that the factor was attempting to change. The percent reduction is the percentage of incidents reduced, from 1994 to 2003, that can be attributed to the safety countermeasures for a factor. Table C-1 shows the analysis of the eight factors.

Table C-1. Percent Impact and Reduction Table

FACTOR	% IMPACT	% REDUCTION
Traffic Signal Preemption	1.82	0
Commercial Driver Safety	30.04/26.25	52.99/51.75
Locomotive Conspicuity	24.7	30.3
More Reliable Motor Vehicles	7.54	11.19
Sight Lines Clearance	5.13	8.81
Grade Separation	0.34	1.02
Crossing Closure	4.39	15.20
Warning Device Upgrades	3.01	8.25
Grade Crossing Maintenance Rule	2.23/3.41	3.07/13.92

A. Percent of incidents impacted (caused) that can be attributed to behaviors that the factor was attempting to change.
B. Percent of incidents reduced that can be attributed to safety countermeasures for the factor

Traffic Signal Preemption
The Factor: Traffic signal preemption is available for crossings with a highway-highway intersection within 200 feet. The normal sequence of traffic control signal indication is preempted upon the approach of trains to avoid entrapment of vehicles on the highway-rail crossing by conflicting aspects of the traffic control signals and the highway-rail grade crossing active warning devices.

Data Source: FRA Inventory (Highway-Rail Crossing Inventory by State); RAIRS

Method: Limited data was available for this field. The team was able to determine the number of incidents that occurred at crossings interconnected to highway traffic signals for each year. However, an interconnection is not necessarily indicative of preemption. The team was also able to identify the total number of crossings for all 10 years that had preemption. This data could not be reduced further to determine the number that existed each year. Other approaches were taken, including looking at interconnected and not interconnected crossings that had incidents where the vehicle was trapped on the crossing. This also proved fruitless because no way existed to determine the reason that the vehicle became trapped or if preemption was a possibility in preventing it. The total number of preempted crossings was less than 2 percent of all crossings; the percentage of incidents occurring at preempted crossings did not change over the ten year period.

	Crossings with Preemption	Total Crossings	
Total	4514	248564	1.82%

Success Factor: No

Next Steps: This factor will not be pursued any further.

Commercial Driver Safety

The Factor: Highway-rail grade crossing incidents involving trucks have the potential to be more severe than passenger automobiles. During the period 1994-2003, a greater emphasis was put on commercial driver safety. The Motor Carrier Safety Improvement Act of 1999 established the Federal Motor Carrier Safety Administration and emphasized truck safety. In October 1999, commercial drivers convicted of violating the grade crossing warning devices would lose their CDL.

Data Source: RAIRS

Method: The team used incidents from vehicles that would require a CDL. The percent impact was determined by using the percentage of the total number of incidents from 1994 to 2003 that involved commercial drivers. The percent reduction was determined by finding the number of fewer incidents attributed to commercial drivers that occurred in 2003 versus 1994. The data structure changed in 1997. Pickup trucks and vans were added as separate categories. These counts could have been included in the category of trucks pre-1997. Therefore, the team also looked at the number of fewer incidents attributed to commercial drivers that occurred in 2003 versus 1997.

	Truck	Truck-trailer	Bus	School Bus	Total Commercial Driver	Total
1994	1235	543	3	3	**1784**	**4979**
1995	1189	504	3	3	**1699**	**4633**
1996	1097	471	8	4	**1580**	**4257**
1997	681	490	10	1	**1182**	**3863**
1998	460	477	3	4	**944**	**3508**
1999	408	475	6	1	**890**	**3489**
2000	407	446	4	4	**861**	**3502**
2001	350	465	7	3	**825**	**3237**
2002	338	452	4	3	**797**	**3077**
2003	313	375	7	0	**695**	**2924**
TOTAL	**6478**	**4698**	**55**	**26**	**11257**	**37471**

A. 30.04% = 11257/37471
B. 52.99% = (695-1784)/(2924-4979)

However, in 1997 pick-up trucks were separated out

A. 26.25% = 6194/23600
B. 51.75% = (695-1182)/(2924-3863)

Success Factor: Yes

Next Steps: This category could be confounded with other factors and therefore appear to have a much larger effect than actual. Some areas to pursue are: to incorporate the number of CDLs by year, or truck miles by year, investigate how many drivers lost their CDL as a result of the disqualification rule, and combine a subset of commercial drivers and the other factors to determine the overlap.

Locomotive Conspicuity

The Factor: A final rule published in March 1996, effective in December 1997 stated that all locomotives exceeding 20 mph over the crossing must have auxiliary alerting lights in addition to the headlight.

Data Source: RAIRS

Method: The FRA published report *Safety of Highway-Railroad Crossings: Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity* [11], which stated that a significant difference existed in the effectiveness of the alerting lights during the day and night. The lights provided more benefit in the night. The team used incidents in which the rail equipment struck the highway user at dark, dawn and dusk as the measure of locomotive conspicuity. The percent impact was determined by using the percentage of the total number of incidents from 1994 to 2003 in which the rail equipment struck the highway user at dark or dusk. The percent reduction was determined by finding the number of fewer incidents that occurred in 2003 versus 1994.

	Rail Equip. struck highway user at dark, dawn and dusk		
Year	**Pulling**	**Pushing**	**Total Incidents**
1994	1220	100	**4,979**
1995	1107	107	**4,633**
1996	981	88	**4,257**
1997	834	67	**3,865**
1998	763	79	**3,508**
1999	728	70	**3,489**
2000	804	81	**3,502**
2001	694	78	**3,237**
2002	644	95	**3,077**
2003	616	80	**2,920**
TOTAL	**8391**	**845**	**37,467**

A. 24.7% = (8391+845)/37,467
B. 30.3% = ((616+80)-(1220+100))/(2920-4979)

Success Factor: Yes

Next Steps: Use data to rank crossings by darkness. The FRA published report *Use of Auxiliary External Alerting Devices to Improve Locomotive Conspicuity* [11] states a statistically significant difference in the effectiveness of alerting lights in daylight and darkness. Consider the railroad equipment accident database as a source, which lists a cause of "Highway user misjudgment under normal weather and traffic conditions". The narratives could provide more detailed information.

More Reliable Motor Vehicles

The Factor: During the period 1994 to 2003 automobiles have been improved to be safer and more reliable. A more reliable vehicle reduces the likelihood of breaking down (stalling) on the tracks and subsequently being hit by an oncoming train.

Data Source: RAIRS

Method: The database identifies incidents in which the highway vehicle was stalled on the tracks at the time of impact. The percent impact was determined by using the percentage of the total number of incidents from 1994 to 2003 in which the highway vehicle was stalled on the crossing. The percent reduction was determined by finding the number of fewer incidents attributed to stalled vehicles that occurred in 2003 versus 1994.

Year	Stalled on Crossing	Total
1994	412	**4,979**
1995	438	**4,633**
1996	370	**4,257**
1997	252	**3,864**
1998	227	**3,508**
1999	243	**3,489**
2000	231	**3,502**
2001	228	**3,236**
2002	241	**3,077**
2003	182	**2,924**
TOTAL	**2,824**	**37,471**

A. 7.54% = 2824/37471
B. 11.19% = (182-412) / (2924-4979)

Success Factor: Yes

Next Steps: Use JD Power Associates or Consumer Reports as a source on automobile reliability by years. The National Highway Traffic Safety Administration database FARS contains driver information and vehicle types.

Sight Lines Clearance

The Factor: The clearing of vegetation and removal of obstructions surrounding a grade crossing enables highway-users to observe an oncoming train from greater distances from the crossing. Highway-users have a better chance to stop safely, and the risk of being surprised by a train is reduced.

Data Source: RAIRS

Method: The percent impact was determined by using the percentage of the total number of incidents from 1994 to 2003 that described some visual obstruction present at the grade crossing at the time of impact. The percent reduction was determined by finding the number of fewer incidents in which an obstruction was present that occurred in 2003 versus 1994.

Year	Permanent Structure	Standing Railroad Equipment	Passing Train	Topography	Vegetation	Highway Vehicles	Other (Specify in Narrative)
1994	94	39	18	37	84	22	40
1995	88	27	19	39	58	14	38
1996	76	20	14	48	63	7	35
1997	73	25	8	38	61	13	46
1998	59	27	16	24	74	11	32
1999	55	20	14	14	40	12	17
2000	41	22	10	21	50	7	36
2001	34	19	6	13	39	11	28
2002	31	9	14	23	40	18	13
2003	36	11	12	22	21	9	23
TOTAL	**587**	**219**	**131**	**279**	**530**	**124**	**308**

A. 5.13% = 1923/37471
B. 8.81% = (113-294)/(2924-4979)

Success Factor: Uncertain

Next Steps: Examine the proportion of obstructed sightlines that are attributed to ones that could be influenced by countermeasures (e.g., vegetation) and those that are not (e.g., topography). Consider the railroad equipment accident database as a source, which lists a cause of "Highway user unaware due to environmental factors." The narratives could provide more detailed information.

Crossing Closure

The Factor: When a crossing is little used or redundant, eliminating the crossing becomes an option. A crossing closure physically removes all access to the grade crossing, eventually eliminating it completely. When a crossing is closed, the risk associated with a collision between a vehicle and a train is reduced to nearly zero.

Data Source: FRA Inventory (Hwy-Rail Crossing Inventory by State); RAIRS

Method:
Probable incident rate is x_i incident per year, which is (total incidents over 9+i years)/(9+i years), where i is 1 to 10.
1984 was used as the base year to compute the probable incident rate and incidents at closed crossing since 1984 were examined.
The total probable incident rate (298.98) is the number of incidents that may have occurred in 2003 if all the closed crossings stayed open.

Probable incidents for year i = the sum from 1994 to year i of (probable incident rate * i). Probable incidents for year i is the number of incidents that may have occurred for year i if the crossings closed between 1994 and year i stayed open.

Probable incidents between year i and 2003 = (x_i incidents per year)*(11-i). Probable incidents between year i and 2003 is the number of incidents that may have occurred between year i and 2003 if the crossings closed in year i stayed open.

	Year (i)	Number of incidents (RAIRS)	# of incidents from closed crossings since 1984 (RAIRS)	# of Crossings Closed (FRA INVENTORY)	Probable incident Rate	Probable incidents for year i	Probable incidents from year i to 2003	Actual plus Probable
1994	1	4979	278	4010	27.80	27.80	278.00	5006.80
1995	2	4633	327	4249	29.73	57.53	267.55	
1996	3	4257	609	6020	50.75	108.28	406.00	
1997	4	3865	411	4734	31.62	139.89	221.31	
1998	5	3508	348	3582	24.86	164.75	149.14	
1999	6	3489	335	3404	22.33	187.08	111.67	
2000	7	3502	413	4442	25.81	212.90	103.25	
2001	8	3237	646	4543	38.00	250.90	114.00	
2002	9	3077	389	3070	21.61	272.51	43.22	
2003	10	2924	503	3948	26.47	298.98	26.47	3222.98
Total		**37471**	**4259**	**42002**	298.98		**1720.61**	

Percent Impact = 4.39%
Percent Impact = (the sum of probable incidents between 1994 and 2003)/(the sum of actual and probable incidents between 1994 and 2003)*100
Percent Impact = 1720.61/(1720.61+37471)*100
Percent Reduction = 15.20%

Percent Reduction = the absolute value of the (change in probable incidents from 1994 to 2003)/(change in actual incidents plus probable incidents from 1994 to 2003)*100
Percent Reduction = ABS(27.80-298.98)/(5006.80-3222.98)*100

Success Factor: Yes

Next Steps: Re-examine the predicted number of incidents. Find a better approximation than linear extrapolation. Cite case studies as supporting evidence, such as North Carolina Sealed Corridor. Consider the impact of rerouted traffic on adjacent crossings.

Grade Separation
The Factor: Grade Separation is offsetting the rail tracks from the roadway by either an underpass or an overpass. The risk of a collision is reduced because the vehicle and train paths no longer intercept.

Data Source: FRA Inventory (History & Current File); RAIRS

Method: For detailed explanation see crossing closures above.

	Year (i)	Number of Incident (RAIRS)	Number of Incidents from Separated Xing Since 1984 (RAIRS)	Number of Crossing Separated (FRA INVENTORY)	Probable Incident Rate	Probable Incident for Year i	Probable Incidents from Year i to 03	Actual Plus Probable
1994	1	4979	11	25	1.10	1.1	11.00	4980.1
1995	2	4633	3	29	0.27	1.37	2.45	
1996	3	4257	83	28	6.92	8.29	55.33	
1997	4	3865	25	18	1.92	10.21	13.46	
1998	5	3508	31	23	2.21	12.43	13.29	
1999	6	3489	24	19	1.60	14.03	8.00	
2000	7	3502	43	24	2.69	16.71	10.75	
2001	8	3237	55	27	3.24	19.95	9.71	
2002	9	3077	16	30	0.89	20.84	1.78	
2003	10	2924	18	27	0.95	21.79	0.95	2945.79
		37471	**309**	**250**	21.79		**126.72**	

Percent Impact	0.34%
Percent Reduction	1.02%

Success Factor: No

Next Steps: Grade Separation is a useful tool for increasing safety at highway-rail grade crossings. By removing the intersection for cars and trains to meet, the risk of a vehicle-train incident at that crossing is eliminated. However, during the period of study 1994-2003, only 274 crossings were separated. This is not a large enough number to produce a significant effect on a national scale.

Warning Device Upgrades
The Factor: Each type of warning device has an effectiveness value associated with it. A passive warning device is less effective than flashing lights and gates. When crossing warning devices are upgraded to ones with a higher effectiveness value the risk of collision at the crossing is reduced.

Data Source: FRA Inventory (History & Current File); RAIRS

Method: Due to the time consuming nature of evaluating the warning device upgrades for each state, the team looked only at the State of Illinois. Illinois has a large number of crossings and highway-rail grade crossing incidents. To determine the number of incidents that were saved by upgrading warning devices, the team used an effectiveness rate for each type of upgrade:

- Passive to Flashing Lights 0.7
- Passive to Gates 0.83
- Passive to Stop Signs 0.35
- Flashing Lights to Gates 0.69

For each year 1994 to 2003, the team also developed an accident rate for each type of warning device. This formula was accident rate = number of incidents at crossing with warning device/number of total crossings with warning device.

The probable incident rate for year i was determined by
(accident rate) x (number of upgraded crossings) x (upgrade effectiveness).

The probable incident year i column is the number of additional incidents that would have occurred that year if no crossings were upgraded (either in that year or any previous years).

The probable incidents from year i to 2003 is the number of additional incidents that would have occurred over the ten years from the crossings upgraded in year i.

Upgrade of Warning Devices for Illinois

	Year (i)	# Incidents	Guesstimate Rate	Guesstimate Year i	Guesstimate Incidents from Year i to 03	Actual plus Guesstimate
1994	1	337	1.960560782	1.961	19.6056078	338.961
1995	2	295	1.085918267	3.04691827	9.77326441	
1996	3	232	1.115561317	4.16247958	8.92449054	
1997	4	213	0.753095961	4.91557555	5.27167173	
1998	5	199	0.942962012	5.85853756	5.65777207	
1999	6	202	1.370298279	7.22883584	6.8514914	
2000	7	217	0.377446653	7.60628249	1.50978661	
2001	8	212	0.823870976	8.43015347	2.47161293	
2002	9	172	1.028719964	9.45887343	2.05743993	
2003	10	157	0.235026135	9.69389957	0.23502613	166.6939
		2236	9.693460348		62.3581636	

Percent Impact 2.71%

Percent Reduction 4.49%

Upgrade of Warning Devices

	Year (i)	Number of Incidents	Probable Incident Rate	Probable Incident Year i	Probable Incidents from Year i to 03	Actual Plus Probable
1994	1	4979	27.627	1.961	276.268	4980.961
1995	2	4633	24.318	26.279	218.858	
1996	3	4257	20.442	46.721	163.540	
1997	4	3865	23.640	70.361	165.479	
1998	5	3508	14.905	85.266	89.428	
1999	6	3489	19.164	104.429	95.818	
2000	7	3502	17.642	122.071	70.566	
2001	8	3237	17.459	139.529	52.376	
2002	9	3077	10.810	150.339	21.619	
2003	10	2924	8.302	158.641	8.302	3082.641
		37471	**184.307**		**1162.255**	

Percent Impact 3.01%

Percent Reduction 8.25%

Success Factor: Uncertain

Next Steps: A deeper look into inventory data provided by the State of Illinois should reveal whether the majority of upgrades were done prior to the study period. The FRA inventory yielded inconclusive results.

Grade Crossing Maintenance Rule

The Factor: In 1995, the Final Rule on Grade Crossing Signal System Safety was issued. This rule stated that railroads must implement specific maintenance, inspection, and warning testing requirements for active crossing systems. The regular maintenance and inspection would reduce the risk of warning device malfunction.

Data Source: RAIRS

Method: For this factor, the team assumed that the ways in which a warning device could malfunction would be too long a warning, too short a warning, or no warning at all. The database identifies incidents that have both alleged and confirmed warning device malfunction. The percent impact was determined by using the percentage of the total number of incidents from 1994 to 2003 that had either a confirmed or alleged warning device malfunction. The percent reduction was determined by finding the number of fewer incidents with warning device malfunction that occurred in 2003 versus 1994. However, it appeared in 1997 that better data was collected for this field. Therefore, the team also looked at the number of fewer incidents with a warning device malfunction that occurred in 2003 versus 1997.

	Alleged Warning Time Greater Than 60 Seconds	Alleged Warning Time Less Than 20 Seconds	Alleged No Warning	Confirmed Warning Time Greater Than 60 Seconds	Confirmed Warning Time Less Than 20 Seconds	Confirmed No Warning	Empty	Total Malfunction
1994	0	0	10	0	0	0	0	**10**
1995	0	0	7	0	0	0	0	**7**
1996	0	0	10	0	0	0	0	**10**
1997	159	8	4	12	4	17	0	**204**
1998	145	6	4	13	4	19	0	**191**
1999	46	11	7	8	1	21	0	**94**
2000	50	7	4	2	0	22	0	**85**
2001	38	16	12	2	2	13	0	**83**
2002	32	7	9	8	3	18	0	**77**
2003	35	8	9	3	1	17	0	**73**
TOTAL	**505**	**63**	**76**	**48**	**15**	**127**	**0**	**823**

A. 2.23% = 823/37471
B. 3.07% = (73-10)/(2924-4979)

However, better data was collected in 1997
A. 3.41% = 807/23600
B. 13.92% = (73-204)/(2924-3865)

Success Factor: Yes

Next Steps: The FRA collects data on activation failures that are available on its Web site. The data exists for the years 2000 through 2003. A time series or trend analysis of this data might be useful. General inspection reports are available from 1995 to the present. A concern exists because of the inclusion of alleged malfunctions, should these be removed the percentages would be much lower. Consider the railroad equipment accident database as a source, which lists a cause of "Malfunction, improper operation of train activated warning devices."

Other Factors Considered

From the inception of this project the team considered other possible factors in addition to those listed above. Some were found to be too difficult to analyze with the available data, and others were simply not determined to have a large impact.

Difficult to Analyze

- *Section 130 funding* – FHWA ceased collecting the state crossing improvements plans prior to the period in study. Section 130 funds cover upgrades, closures, and separations. There is overlap between this factor and many of the other factors in study.
- *Urbanization* – The distribution of grade crossings that are urban versus rural ceased to be collected after 1997. Population censuses are taken only every ten years. The team was unable to conclude anything about population migration toward urban climates, and/or the location of the highway-rail grade crossings.
- *Driver behavior* – This factor is extremely difficult to analyze, there are few human behavior studies conducted on highway-rail intersections. Driver behavior is involved in many of the other factors so there is overlap. It may be useful for supporting data.
- *Operation Lifesaver* – Little to no evaluations have been done on OL. There is no evaluation on a national scale. Without conducting a controlled experiment, it is extremely difficult to analyze.

Low Impact

- Changes in crossing characteristics
- Changes in accident reporting
- Onboard train technology
- New training and manuals available for train crews
- AADT
- Trains per day
- Drunk driver programs
- Enforcement
- Corridor approach

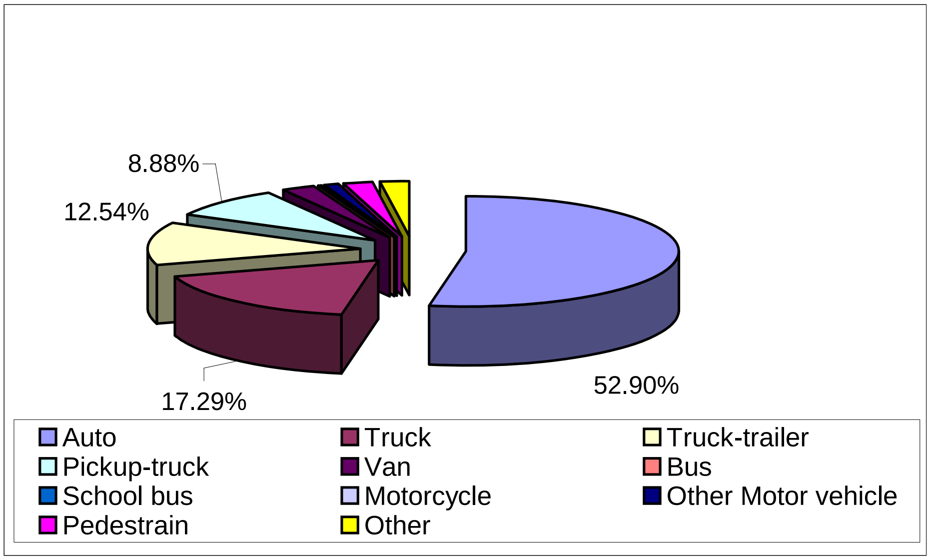
Appendix D.
Distribution of Incidents by Type of Vehicles

Table D-1. Total Incidents by Type of Vehicles

	Auto	Truck	Truck Trailer	Pickup-Truck	Van	Bus	School bus	Motorcycle	Other Motor Vehicle	Pedestrian	Other	Total
1994	2940	1235	543	0	0	3	3	22	0	77	156	**4979**
1995	2703	1189	504	0	0	3	3	14	0	74	143	**4633**
1996	2463	1097	471	0	0	8	4	11	0	95	108	**4257**
1997	2078	681	490	335	96	10	1	7	49	73	43	**3863**
1998	1810	460	477	444	114	3	4	7	56	87	46	**3508**
1999	1763	408	475	513	129	6	1	7	47	81	59	**3489**
2000	1697	407	446	554	161	4	4	12	67	88	62	**3502**
2001	1516	350	465	523	129	7	3	6	65	92	81	**3237**
2002	1449	338	452	490	141	4	3	8	45	71	76	**3077**
2003	1401	313	375	470	137	7	0	12	47	79	83	**2924**
TOTAL	**19820**	**6478**	**4698**	**3329**	**907**	**55**	**26**	**106**	**376**	**817**	**857**	**37469**

Table D-2. Percent of Incident by Type of Vehicles

	Auto	Truck	Truck Trailer	Pickup-Truck	Van	Bus	School bus	Motorcycle	Other Motor Vehicle	Pedestrian	Other	Total
1994	59.05%	24.80%	10.91%	0.00%	0.00%	0.06%	0.06%	0.44%	0.00%	1.55%	3.13%	100.00%
1995	58.34%	25.66%	10.88%	0.00%	0.00%	0.06%	0.06%	0.30%	0.00%	1.60%	3.09%	100.00%
1996	57.86%	25.77%	11.06%	0.00%	0.00%	0.19%	0.09%	0.26%	0.00%	2.23%	2.54%	100.00%
1997	53.79%	17.63%	12.68%	8.67%	2.49%	0.26%	0.03%	0.18%	1.27%	1.89%	1.11%	100.00%
1998	51.60%	13.11%	13.60%	12.66%	3.25%	0.09%	0.11%	0.20%	1.60%	2.48%	1.31%	100.00%
1999	50.53%	11.69%	13.61%	14.70%	3.70%	0.17%	0.03%	0.20%	1.35%	2.32%	1.69%	100.00%
2000	48.46%	11.62%	12.74%	15.82%	4.60%	0.11%	0.11%	0.34%	1.91%	2.51%	1.77%	100.00%
2001	46.83%	10.81%	14.37%	16.16%	3.99%	0.22%	0.09%	0.19%	2.01%	2.84%	2.50%	100.00%
2002	47.09%	10.98%	14.69%	15.92%	4.58%	0.13%	0.10%	0.26%	1.46%	2.31%	2.47%	100.00%
2003	47.91%	10.70%	12.82%	16.07%	4.69%	0.24%	0.00%	0.41%	1.61%	2.70%	2.84%	100.00%
Total	52.90%	17.29%	12.54%	8.88%	2.42%	0.15%	0.07%	0.28%	1.00%	2.18%	2.29%	100.00%



Distribution of Incidents by Type of Vehicle

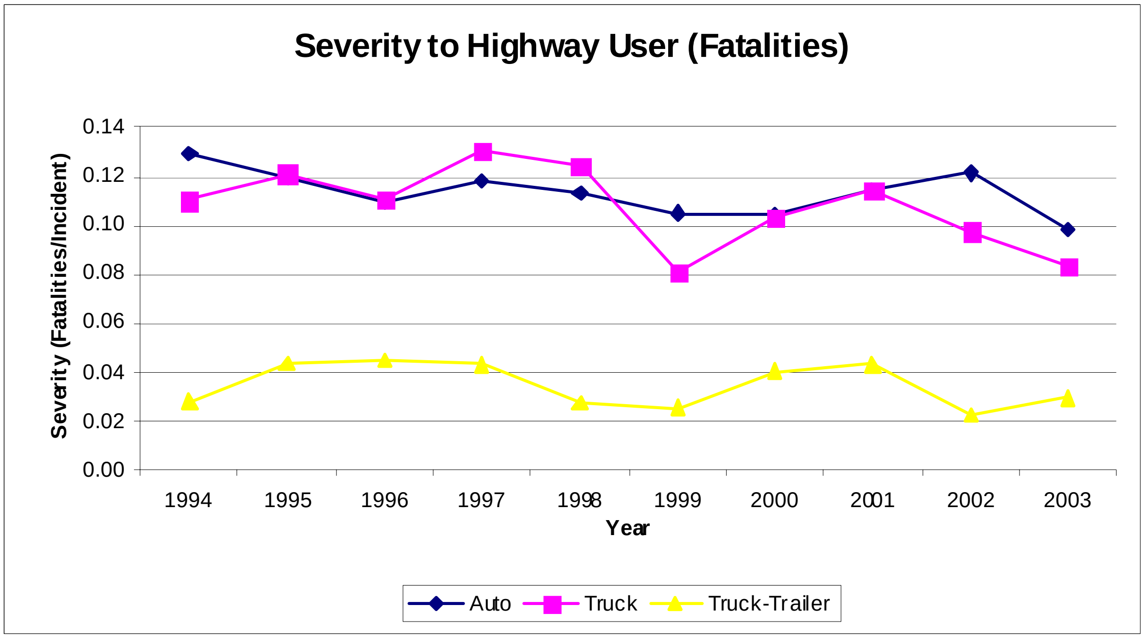
Appendix E.
An Analysis of Severity

Table E-1. Fatalities Involving Auto, Truck, and Truck-Trailer

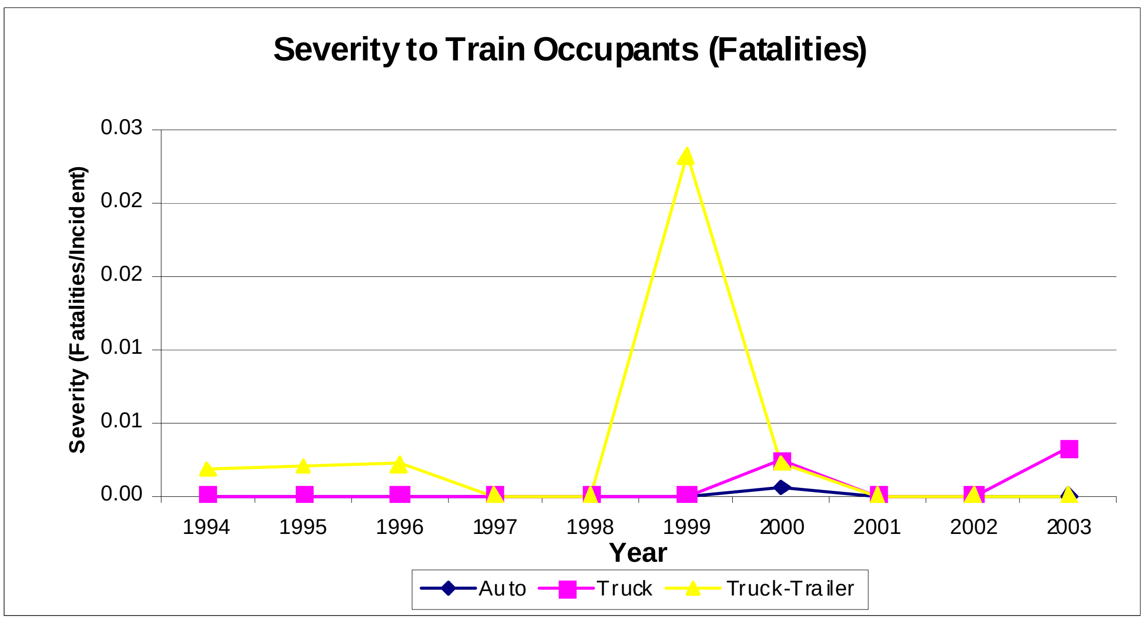
	Auto			Truck			Truck-Trailer		
	Incident	Vehicle Fat	Train Fat	Incident	Vehicle Fat	Train Fat	Incident	Vehicle Fat	Train Fat
1994	2940	381	0	1235	136	0	543	15	1
1995	2703	324	0	1189	144	0	504	22	1
1996	2463	269	0	1097	121	0	471	21	1
1997	2078	246	0	681	89	0	490	21	0
1998	1810	205	0	460	57	0	477	13	0
1999	1763	185	0	408	33	0	475	12	11
2000	1697	177	1	407	42	1	446	18	1
2001	1516	174	0	350	40	0	465	20	0
2002	1449	176	0	338	33	0	452	10	0
2003	1401	138	0	313	26	1	375	11	0
Total	**19820**	**2275**	1	**6478**	**721**	2	**4698**	**163**	15

Table E-2. Fatality Rate (Fatality/Incident) for Auto, Truck and Truck-Trailer

	Auto		Truck		Truck-Trailer	
	Vehicle	Train	Vehicle	Train	Vehicle	Train
1994	0.13	0.00	0.11	0.00	0.03	0.00
1995	0.12	0.00	0.12	0.00	0.04	0.00
1996	0.11	0.00	0.11	0.00	0.04	0.00
1997	0.12	0.00	0.13	0.00	0.04	0.00
1998	0.11	0.00	0.12	0.00	0.03	0.00
1999	0.10	0.00	0.08	0.00	0.03	0.02
2000	0.10	0.00	0.10	0.00	0.04	0.00
2001	0.11	0.00	0.11	0.00	0.04	0.00
2002	0.12	0.00	0.10	0.00	0.02	0.00
2003	0.10	0.00	0.08	0.00	0.03	0.00

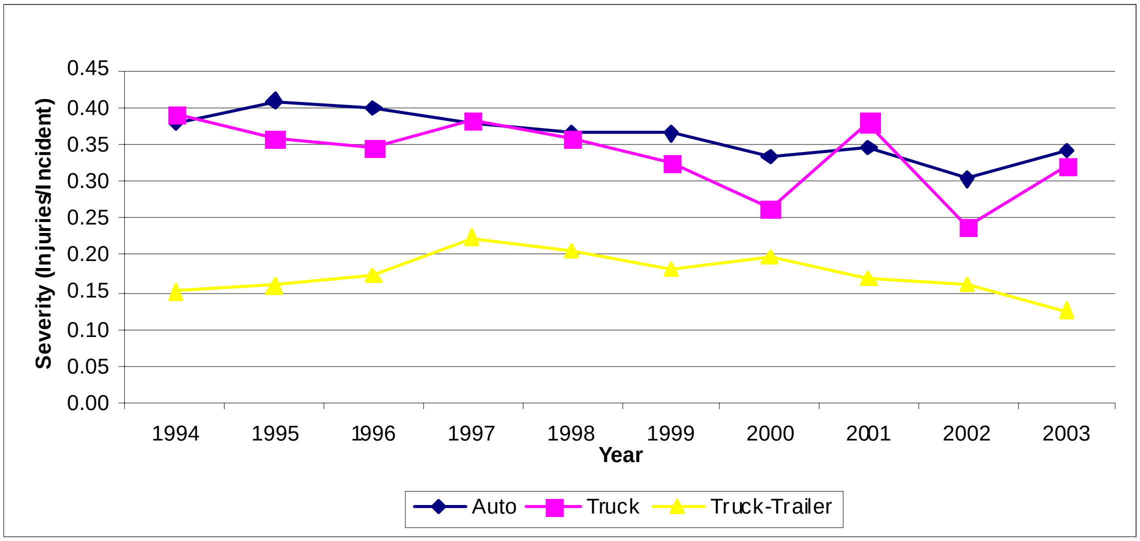


Fatality Rate for Highway Users for Auto, Truck, Truck-Trailer



Fatality Rate for Train Occupants for Auto, Truck, and Truck-Trailer

From the figure below, the severity to highway users of incidents that involved automobiles and trucks is higher than incidents that involved truck trailers. This could be because on average, automobiles and trucks have more passengers than truck trailers. Thus, automobiles and trucks have the possibility of more injuries during an incident.



Incident Severity to Highway User from Automobile, Truck, or Truck-Trailer

Appendix F.
Activation Failure

Table F-1. Failure Rates for Active Grade Crossing Warning Devices

Year	Activation Failure	Active Crossing				Failure Rate[b]
		Gates	Lights	Other[a]	Total	
1992	2279	27507	29949	1726	59182	3.851
1993	1672	28139	29645	1672	59456	2.812
1994		29050	29325	1661	60036	
1995		29912	28910	1583	60405	
1996		30813	28614	1557	60984	
1997		31696	28354	1515	61565	
1998 & 1999	1269	65641	55972	2984	124597	1.018
2000	595	34296	27100	1417	62813	0.947
2001	429	35422	26558	1342	63322	0.677
2002	472	36403	25841	1188	63432	0.744
2003	472	36440	25656	1269	63365	0.745
Source	FRA	FRA Publication				

[a]Other includes WigWag, Highway Signal, and Bells.
[b]Rate equals activation failure times 100 divided by total active crossing

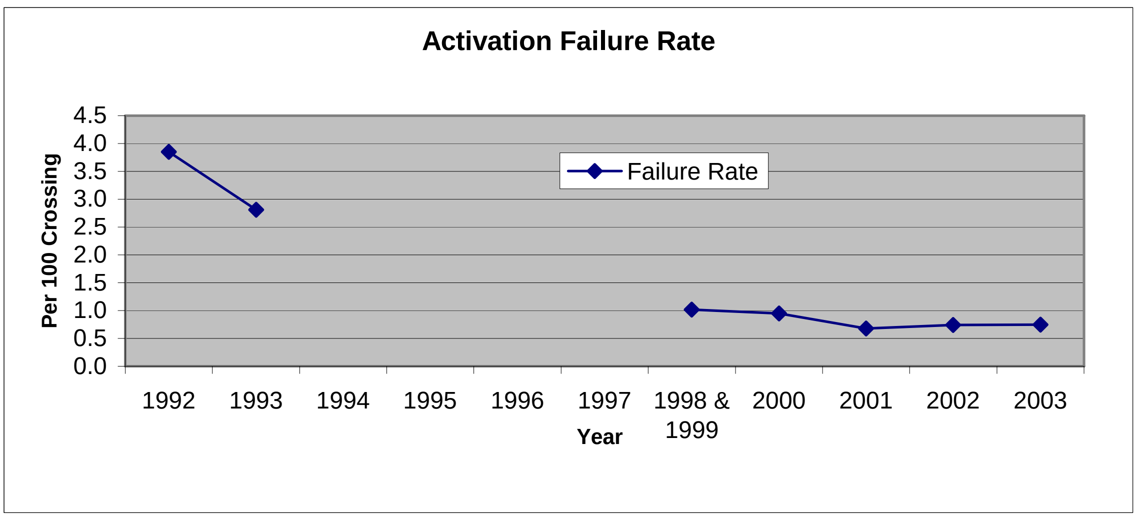


Table F-1. Failure Rate for Active Grade Crossing Warning Devices

Appendix G.
Breakdown of Isolated Success Factors

Success Factors Keys

- C = Commercial Driver Safety
- L = Locomotive Conspicuity
- M = Grade Crossing Maintenance Rule
- R = More Reliable Motor Vehicles
- S = Sight Lines Clearance

Table G-1. Breakdown of Commercial Driver Safety Overlap by Year

Year	C'	CL'	CR'	CM'	CS'	CLR'	CLM'	CLS'	CRM'	CRS'	CMS'	CLRM	CLRS	CLMS	CRMS	CLRMS
1994	1246	295	62	2	98	62	0	15	0	3	0	0	1	0	0	0
1995	1223	240	66	2	85	66	0	10	0	5	0	0	2	0	0	0
1996	1150	224	63	2	80	40	0	15	0	1	1	1	3	0	0	0
1997	834	157	30	42	70	28	8	4	1	2	5	0	1	0	0	0
1998	676	106	24	36	54	29	5	3	0	2	5	2	1	1	0	0
1999	638	123	36	16	48	20	3	3	1	0	1	1	0	0	0	0
2000	638	110	30	14	35	22	4	5	1	1	1	0	0	0	0	0
2001	623	98	27	10	37	21	2	1	0	0	3	3	0	0	0	0
2002	602	99	38	8	24	21	1	3	0	0	0	1	0	0	0	0
2003	534	93	18	12	23	6	0	4	0	2	2	0	0	1	0	0

C	CL	CR	CM	CS	CLR	CLM	CLS	CRM	CRS	CMS	CLRM	CLRS	CLMS	CRMS	CLRMS
11257	1964	744	198	661	331	33	73	11	24	20	8	8	2	0	0
					315	23	63	3	16	18					
	1545	394	144	554											
8164															

C'= 8164
C'=C-(CL'+CR'+CM'+CS'+CLR'+CLM'+CLS'+CRM'+CRS'+CMS'+CLRM+CLRS+CLMS+CRMS+CLRMS)

CLR'= 315
CLR'=CLR-(CLRM+CLRS+CLRMS)

CLM'= 23
CLM'=CLM-(CLRM+CLMS+CLRMS)

CLS'= 63
CLS'=CLS-(CLRS+CLMS+CLRMS)

CRM'= 3
CRM'=CRM-(CLRM+CRMS+CLRMS)

CRS'= 16
CRS'=CRS-(CLRS+CRMS+CLRMS)

CMS'= 18
CMS'=CMS-(CLMS+CRMS+CLRMS)

CL'= 1545
CL'=CL-(CLR'+CLM'+CLS'+CLRM+CLRS+CLMS+CLRMS)

CR'= 394
CR'=CR-(CLR'+CRM'+CRS'+CLRM+CLRS+CRMS+CLRMS)

CM'= 144
CM'=CM-(CLM'+CRM'+CMS'+CLRM+CLMS+CRMS+CLRMS)

CS'= 544

CS'=CS-(CLS'+CRS'+CMS'+CLRS+CLMS+CRMS+CLRMS)

Table G-2. Breakdown of Locomotive Conspicuity Overlap by Year

Year	L'	LC'	LS'	LR'	LM'	LCS'	LCR'	LCM'	LSR'	LSM'	LRM'	LCSR	LSRM	LRMC	LMCS	LCSRM
1994	745	295	34	162	3	15	62	0	3	0	0	1	0	0	0	0
1995	678	240	26	182	1	10	66	0	8	1	0	2	0	0	0	0
1996	589	224	23	166	2	15	40	0	6	0	0	3	0	1	0	0
1997	530	157	31	105	24	4	28	8	4	0	9	1	0	0	0	0
1998	527	106	21	104	32	3	29	5	3	0	8	1	0	2	1	0
1999	525	123	10	101	8	3	20	3	2	0	2	0	0	1	0	0
2000	609	110	16	103	10	5	22	4	2	0	4	0	0	0	0	0
2001	512	98	13	104	13	1	21	2	1	0	4	0	0	3	0	0
2002	459	99	20	117	12	3	21	1	2	0	4	0	0	1	0	0
2003	465	93	12	99	12	4	6	0	3	0	1	0	0	0	1	0

L	LC	LS	LR	LM	LCS	LCR	LCM	LSR	LSM	LRM	LCSR	LSRM	LRMC	LMCS	LCSRM
9236	1964	314	1640	183	73	331	33	42	3	40	8	0	8	2	0
					63	315	23	34	1	32					
	1545	206	1243	117											
5639															

L'= 5639

L'=L-(LC'+LS'+LR'+LM'+LCS'+LCR'+LCM'+LSR'+LSM'+LRM'+LCSR+LSRM+LRMC+LMCS+LCSRM)

LCS'= 63

LCS'=LCS-(LCSR+LMCS+LCSRM)

LCR'= 315

LCR'=LCR-(LCSR+LRMC+LCSRM)

LCM'= 23

LCM'=LCM-(LRMC+LMCS+LCSRM)

LSR'= 34

LSR'=LSR-(LCSR+LSRM+LCSRM)

LSM'= 1

LSM'=LSM-(LSRM+LMCS+LCSRM)

LRM'= 32

LRM'=LRM-(LSRM+LRMC+LCSRM)

LC'= 1545

LC'=LC-(LCS'+LCR'+LCM'+LCSR+LRMC+LMCS+LCSRM)

LS'= 206

LS'=LS-(LCS'+LSR'+LSM'+LCSR+LSRM+LMCS+LCSRM)

LR'= 1243

LR'=LR-(LCR'+LSR'+LRM'+LCSR+LSRM+LRMC+LCSRM)

LM'= 117

LM'=LM-(LCM'+LSM'+LRM'+LSRM+LRMC+LMCS+LCSRM)

Table G-3. Breakdown of Grade Crossing Maintenance Rule Overlap by Year

Year	M'	MS'	MR'	MC'	ML'	MSR'	MSC'	MSL'	MRC'	MRL'	MCL'	MSRC	MSCL	MRCL	MSRL	MSRCL
1994	5	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0
1995	3	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0
1996	2	1	1	2	3	0	1	0	0	-1	0	0	0	1	0	0
1997	104	6	5	42	25	0	5	0	1	8	8	0	0	0	0	0
1998	89	8	5	36	34	0	5	0	0	6	5	0	1	2	0	0
1999	56	4	2	16	8	0	1	0	1	2	3	0	0	1	0	0
2000	43	7	1	14	10	0	1	0	1	4	4	0	0	0	0	0
2001	44	2	2	10	14	0	3	0	0	3	2	0	0	3	0	0
2002	43	3	5	8	13	0	0	0	0	3	1	0	0	1	0	0
2003	41	3	1	12	12	0	2	0	0	1	0	0	1	0	0	0

M	MS	MR	MC	ML	MSR	MSC	MSL	MRC	MRL	MCL	MSRC	MSCL	MRCL	MSRL	MSRCL
834	55	59	198	183	0	20	3	11	34	33	0	2	8	0	0
					0	18	1	3	26	23					
	34	22	144	123											
430															

M'= 430
M'=M-(MS'+MR'+MC'+ML'+MSR'+MSC'+MSL'+MRC'+MRL'+MCL'+MSRC+MSCL+MRCL+MSRL+MSRCL)

MSR'= 0
MSR'=MSR-(MSRC+MSRL+MSRCL)

MSC'= 18
MSC'=MSC-(MSRC+MSCL+MSRCL)

MSL'= 1
MSL'=MSL-(MSCL+MSRL+MSRCL)

MRC'= 3
MRC'=MRC-(MSRC+MRCL+MSRCL)

MRL'= 26
MRL'=MRL-(MRCL+MSRL+MSRCL)

MCL'= 23
MCL'=MCL-(MSCL+MRCL+MSRCL)

MS'= 34
MS'=MS-(MSR'+MSC'+MSL'+MSRC+MSCL+MSRL+MSRCL)

MR'= 22
MR'=MR-(MSR'+MRC'+MRL'+MSRC+MRCL+MSRL+MSRCL)

MC'= 144
MC'=MC-(MSC'+MRC'+MCL'+MSRC+MSCL+MRCL+MSRCL)

ML'= 123

ML'=ML-(MSL'+MRL'+MCL'+MSCL+MRCL+MSRL+MSRCL)

Table G-4. Breakdown of More Reliable Motor Vehicles Overlap by Year

Year	R'	RM'	RC'	RL'	RS'	RCL'	RCM'	RCS'	RLM'	RLS'	RSM'	RCLS	RCLM	RCMS	RMSL	RCLMS
1994	116	0	62	162	3	62	0	3	0	3	0	1	0	0	0	0
1995	105	0	66	182	4	66	0	5	0	8	0	2	0	0	0	0
1996	85	0	63	166	5	40	0	1	0	6	0	3	1	0	0	0
1997	64	4	30	105	4	28	1	2	9	4	0	1	0	0	0	0
1998	50	3	24	104	1	29	0	2	8	3	0	1	2	0	0	0
1999	76	2	36	101	2	20	1	0	2	2	0	0	1	0	0	0
2000	63	1	30	103	4	22	1	1	4	2	0	0	0	0	0	0
2001	65	1	27	104	2	21	0	0	4	1	0	0	3	0	0	0
2002	51	4	38	117	3	21	0	0	4	2	0	0	1	0	0	0
2003	52	1	18	99	0	6	0	2	1	3	0	0	0	0	0	0

R	RM	RC	RL	RS	RCL	RCM	RCS	RLM	RLS	RSM	RCLS	RCLM	RCMS	RMSL	RCLMS
2824	59	744	1640	86	331	11	24	40	42	0	8	8	0	0	0
					315	3	16	32	34	0					
	16	394	1243	28											
727															

R'= 727
R'=R-(RM'+RC'+RL'+RS'+RCL'+RCM'+RCS'+RLM'+RLS'+RSM'+RCLS+RCLM+RCMS+RMSL+RCLMS)

RCL'= 315
RCL'=RCL-(RCLS+RCLM+RCLMS)

RCM'= 3
RCM'=RCM-(RCLM+RCMS+RCLMS)

RCS'= 16
RCS'=RCS-(RCLS+RCMS+RCLMS)

RLM'= 32
RLM'=RLM-(RCLM+RMSL+RCLMS)

RLS'= 34
RLS'=RLS-(RCLS+RMSL+RCLMS)

RSM'= 0
RSM'=RSM-(RCMS+RMSL+RCLMS)

RM'= 16
RM'=RM-(RCM'+RLM'+RSM'+RCLM+RCMS+RMSL+RCLMS)

RC'= 394
RC'=RC-(RCL'+RCM'+RCS'+RCLS+RCLM+RCMS+RCLMS)

RL'= 1243
RL'=RL-(RCL'+RLM'+RLS'+RCLS+RCLM+RMSL+RCLMS)

RS'= 28

RS'=RS-(RCS'+RLS'+RSM'+RCLS+RCMS+RMSL+RCLMS)

Table G-5. Breakdown of Sight Lines Clearance Overlap by Year

Year	S'	SM'	SR'	SC'	SL'	SRM'	SMC'	SML'	SRC'	SRL'	SCL'	SMRC	SMCL	SRCL	SLMR	SMRCL
1994	137	0	3	98	34	0	0	0	3	3	15	0	0	1	0	0
1995	109	0	4	85	26	0	0	1	5	8	10	0	0	2	0	0
1996	107	1	5	80	23	0	1	0	1	6	15	0	0	3	0	0
1997	116	6	4	70	31	0	5	0	2	4	4	0	0	1	0	0
1998	117	8	1	54	21	0	5	0	2	3	3	0	1	1	0	0
1999	76	4	2	48	10	0	1	0	0	2	3	0	0	0	0	0
2000	99	7	4	35	16	0	1	0	1	2	5	0	0	0	0	0
2001	74	2	2	37	13	0	3	0	0	1	1	0	0	0	0	0
2002	61	3	3	24	20	0	0	0	0	2	3	0	0	0	0	0
2003	63	3	0	23	12	0	2	0	2	3	4	0	1	0	0	0

S	SM	SR	SC	SL	SRM	SMC	SML	SRC	SRL	SCL	SMRC	SMCL	SRCL	SLMR	SMRCL
1923	55	86	661	314	0	20	3	24	42	73	0	2	8	0	0
					0	18	1	16	34	63					
959	34	28	554	206											

S'= 959
S'=S-(SM'+SR'+SC'+SL'+SRM'+SMC'+SML'+SRC'+SRL'+SCL'+SMRC+SMCL+SRCL+SLMR+SMRCL)

SRM'= 0
SRM'=SRM-(SMRC+SLMR+SMRCL)

SMC'= 18
SMC'=SMC-(SMRC+SMCL+SMRCL)

SML'= 1
SML'=SML-(SMCL+SLMR+SMRCL)

SRC'= 16
SRC'=SRC-(SMRC+SRCL+SMRCL)

SRL'= 34
SRL'=SRL-(SRCL+SLMR+SMRCL)

SCL'= 63
SCL'=SCL-(SMCL+SRCL+SMRCL)

SM'= 34
SM'=SM-(SRM'+SMC'+SML'+SMRC+SMCL+SLMR+SMRCL)

SR'= 28
SR'=SR-(SRM'+SRC'+SRL'+SMRC+SRCL+SLMR+SMRCL)

SC'= 554
SC'=SC-(SMC'+SRC'+SCL'+SMRC+SMCL+SRCL+SMRCL)

SL'= 206

SL'=SL-(SML'+SRL'+SCL'+SMCL+SRCL+SLMR+SMRCL)

Appendix H.
Kendall Partial Rank Correlation for Crossing Closure

Kendall Partial Rank Correlation Coefficient Methodology

Subject	**a**	**b**	**c**	**d**
Rank on Z	1	2	3	4
Rank on X	3	1	2	4
Rank on Y	2	1	3	4

A + is assigned to the pairs in which the lower rank precedes the higher. A - is assigned to the pairs in which the higher rank precedes the lower.

Pair	(a,b)	(a,c)	(a,d)	(b,c)	(b,d)	(c,d)
Z	+	+	+	+	+	+
X	-	-	+	+	+	+
Y	-	+	+	+	+	+

If Z is + and X is +, then X's sign agrees with Z's sign. If Z is + and Y is -, then Y's sign disagrees with Z's sign.

	Y pairs whose sign agrees with Z's sign	Y pairs whose sign disagrees with Z's sign	Total
X pairs whose sign agrees with Z's sign	A	B	A+B
X pairs whose sign disagrees with Z's sign	C	D	C+D
Total	A+C	B+D	$\left(\frac{N}{2}\right)$

$$\tau_{xy,z} = \frac{AD - BC}{\sqrt{(A+B)(C+D)(A+C)(B+D)}}$$

Table H-1. The Eight FRA Regions

Region #	Region Name	States in the Region
1	Northeast	ME, NH, VT, MA, NY, RI, CT, NJ
2	Middle Atlantic	PA, OH, WV, VA, MD, DE
3	Southeast	KY, TN, NC, SC, GA, AL, MS, FL
4	North Central	MN, WI, IL, IN, MI
5	South	NM, TX, OK, AR, LA
6	Central	CO, NE, KS, IA, MO
7	Southwest	CA, NV, UT, AZ
8	Northwest	AK, WA, OR, ID, MT, WY, ND, SD

Table H-2. Kendall Partial Ranking for Year 1994

Region	1994 Crossings Closed	1994-95 Incident Reduction	1994 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	1249	63	52928	1	3	1
R4	538	122	50352	4	1	2
R6	628	28	40334	3	5	3
R5	450	84	38998	5	2	4
R2	679	35	31239	2	4	5
R8	322	-6	30127	6	8	6
R7	89	4	16856	8	7	7
R1	153	16	15283	7	6	8

$\tau_{xy,z}$	0.1615146

Table H-3. Kendall Partial Ranking for Year 1995

Region	1995 Crossings Closed	1995-96 Incident Reduction	1995 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	1123	86	52078	1	1	1
R4	544	86	49656	4	1	2
R6	258	38	40128	6	5	3
R5	529	73	38213	5	4	4
R2	1015	84	30263	2	3	5
R8	627	3	29589	3	7	6
R7	156	6	16805	7	6	7
R1	15	0	15279	8	8	8

$\tau_{xy,z}$	0.4714045

Table H-4. Kendall Partial Ranking for Year 1996

Region	1996 Crossings Closed	1996-97 Incident Reduction	1996 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	1287	105	51573	3	1	1
R4	1470	80	49341	2	2	2
R6	605	36	39662	4	6	3
R5	439	37	37777	5	5	4
R2	1858	20	29477	1	7	5
R8	301	49	29377	6	4	6
R7	88	59	16749	7	3	7
R1	73	6	15279	8	8	8

$\tau_{xy,z}$	-0.2948839

Table H-5. Kendall Partial Ranking for Year 1997

Region	1997 Crossings Closed	1997-98 Incident Reduction	1997 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	2099	-6	50851	1	7	1
R4	833	107	48788	2	2	2
R6	392	70	38710	4	3	3
R5	331	144	37537	5	1	4
R8	285	10	29374	6	6	5
R2	596	36	28966	3	4	6
R7	105	-39	16682	8	8	7
R1	169	35	14883	7	5	8

$\tau_{xy,z}$	0.0895622

H-6. Kendall Partial Ranking for Year 1998

Region	1998 Crossings Closed	1998-99 Incident Reduction	1998 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	775	53	49330	2	1	1
R4	593	-10	48208	3	5	2
R6	823	-19	38558	1	8	3
R5	484	-18	37196	4	7	4
R8	155	45	29189	7	2	5
R2	408	-7	28661	6	3	6
R7	6	-9	16661	8	4	7
R1	421	-16	14897	5	6	8

$\tau_{xy,z}$	-0.452267

H-7. Kendall Partial Ranking for Year 1999

Region	1999 Crossings Closed	1999-2000 Incident Reduction	1999 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	557	30	49475	3	2	1
R4	649	-30	48081	2	7	2
R6	759	17	37704	1	3	3
R5	100	-37	37092	8	8	4
R2	329	-3	28800	6	4	5
R8	405	-11	28644	5	5	6
R7	110	39	16556	7	1	7
R1	526	-18	14767	4	6	8

$\tau_{xy,z}$	-0.0157103

H-8. Kendall Partial Ranking for Year 2000

Region	2000 Crossings Closed	2000-01 Incident Reduction	2000 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	252	13	49091	6	5	1
R4	2002	99	45777	1	1	2
R6	429	34	37738	3	3	3
R5	853	87	36843	2	2	4
R2	301	26	28659	5	4	5
R8	368	4	28236	4	7	6
R7	53	-9	16557	8	8	7
R1	197	11	14507	7	6	8

$\tau_{xy,z}$	0.7302967

H-9. Kendall Partial Ranking for Year 2001

Region	2001 Crossings Closed	2001-02 Incident Reduction	2001 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	252	-6	49091	6	8	1
R4	2002	56	45777	1	2	2
R6	429	12	37738	3	4	3
R5	853	59	36843	2	1	4
R2	301	-4	28659	5	6	5
R8	368	-5	28236	4	7	6
R7	53	50	16557	8	3	7
R1	197	-2	14507	7	5	8

$\tau_{xy,z}$	0.3162278

H-10. Kendall Partial Ranking for Year 2002

Region	2002 Crossings Closed	2002-03 Incident Reduction	2002 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	287	61	48946	4	1	1
R4	1176	52	44409	1	4	2
R6	544	54	37241	2	3	3
R5	407	57	36258	3	2	4
R2	111	-35	28156	8	8	5
R8	281	5	28081	5	5	6
R7	134	-15	16493	7	6	7
R1	278	-26	13814	6	7	8

$\tau_{xy,z}$	0.3015113

H-11. Kendall Partial Ranking for Year 2003

Region	2003 Crossings Closed	2003-04 Incident Reduction	2003 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	335	-56	48733	5	8	1
R4	206	-43	43177	7	6	2
R6	954	-51	35231	2	7	3
R5	401	-23	34610	4	5	4
R2	1017	3	27908	1	3	5
R8	275	12	27164	6	1	6
R7	61	0	16029	8	4	7
R1	727	11	13430	3	2	8

$\tau_{xy,z}$	0

Appendix I.
Kendall Partial Rank Correlation for Warning Device Upgrades

I-1. Kendall Partial Ranking for Year 1994

Region	1994 Crossings Upgraded	1994-95 Incident Reduction	1994 Number Crossings	Rank Closed	Rank Reduction	Rank Crossings
R3	358.28	48	52928	1	2	1
R4	173.56	71	50352	2	1	2
R6	150.63	12	40334	5	5	3
R5	160.95	27	38998	4	3	4
R2	169.64	4	31239	3	6	5
R8	16.62	-5	30127	8	7	6
R7	22.96	20	16856	7	4	7
R1	23.86	-5	15283	6	7	8

$\tau_{xy,z}$	0.2110267

I-2. Kendall Partial Ranking for Year 1995

Region	1995 Crossings Upgraded	1995-96 Incident Reduction	1995 Number Crossings		Rank Closed	Rank Reduction	Rank Crossings
R3	287.87	24	52078		1	3	1
R4	137.37	6	49656		3	6	2
R6	99.47	28	40128		5	2	3
R5	127.42	20	38213		4	4	4
R2	220.8	46	30263		2	1	5
R8	64.52	12	29589		6	5	6
R7	52.85	-6	16805		7	7	7
R1	22.74	-9	15279		8	8	8

$\tau_{xy,z}$	0.4195732

I-3. Kendall Partial Ranking for Year 1996

Region	1996 Crossings Upgraded	1996-97 Incident Reduction	1996 Number Crossings		Rank Closed	Rank Reduction	Rank Crossings
R3	156.32	37	51573		2	1	1
R4	136.23	19	49341		4	2	2
R6	113.09	-26	39662		5	7	3
R5	151.5	-4	37777		3	5	4
R2	294	-34	29477		1	8	5
R8	36.17	15	29377		6	3	6
R7	12.87	14	16749		7	4	7
R1	9.26	-4	15279		8	5	8

$\tau_{xy,z}$	-0.1730567

I-4. Kendall Partial Ranking for Year 1997

Region	1997 Crossings Upgraded	1997-98 Incident Reduction	1997 Number Crossings		Rank Upgraded	Rank Reduction	Rank Crossings
R3	472.94	7	50851		1	5	1
R4	141.62	40	48788		3	1	2
R6	78.8	13	38710		6	4	3
R5	118.16	-5	37537		4	6	4
R8	16.78	-5	29374		7	6	5
R2	192.05	30	28966		2	2	6
R7	13.95	-18	16682		8	8	7
R1	94.4	14	14883		5	3	8

$\tau_{xy,z}$	0.4624973

I-5. Kendall Partial Ranking for Year 1998

Region	1998 Crossings Upgraded	1998-99 Incident Reduction	1998 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	199.12	-12	49330	1	4	1
R4	188.97	-23	48208	2	6	2
R6	40.38	-26	38558	7	7	3
R5	98.42	-45	37196	4	8	4
R8	63.92	-1	29189	5	1	5
R2	143.25	-3	28661	3	2	6
R7	3.06	-15	16661	8	5	7
R1	62.12	-3	14897	6	2	8

$\tau_{xy,z}$	0.1666667

I-6. Kendall Partial Ranking for Year 1999

Region	1999 Crossings Upgraded	1999-2000 Incident Reduction	1999 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	239.55	49	49475	1	1	1
R4	231.85	-20	48081	2	8	2
R6	111.93	32	37704	5	2	3
R5	153.18	-9	37092	3	6	4
R2	146.8	-6	28800	4	4	5
R8	94.06	-8	28644	6	5	6
R7	14.53	9	16556	8	3	7
R1	39.15	-9	14767	7	6	8

$\tau_{xy,z}$	-0.2786522

I-7. Kendall Partial Ranking for Year 2000

Region	2000 Crossings Upgraded	2000-01 Incident Reduction	2000 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	122.54	-28	49091	3	8	1
R4	170.07	48	45777	2	2	2
R6	98.55	25	37738	5	3	3
R5	271.13	58	36843	1	1	4
R2	120.78	13	28659	4	4	5
R8	37.24	-3	28236	8	7	6
R7	39.77	1	16557	7	6	7
R1	64.64	4	14507	6	5	8

$\tau_{xy,z}$	0.5705443

I-8. Kendall Partial Ranking for Year 2001

Region	2001 Crossings Upgraded	2001-02 Incident Reduction	2001 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	182.87	-28	49091	3	8	1
R4	218.18	48	45777	2	2	2
R6	63.63	25	37738	6	3	3
R5	282.15	58	36843	1	1	4
R2	57.9	13	28659	7	4	5
R8	113.79	-3	28236	4	7	6
R7	18.38	1	16557	8	6	7
R1	97.54	4	14507	5	5	8

$\tau_{xy,z}$	0.1766043

I-9. Kendall Partial Ranking for Year 2002

Region	2002 Crossings Upgraded	2002-03 Incident Reduction	2002 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	31.1	11	48946	6	4	1
R4	199.35	23	44409	2	2	2
R6	67.2	21	37241	3	3	3
R5	202.48	33	36258	1	1	4
R2	58.32	-39	28156	4	8	5
R8	33.66	-6	28081	5	6	6
R7	4.45	-17	16493	8	7	7
R1	28.11	-4	13814	7	5	8

$\tau_{xy,z}$	0.518545

I-10. Kendall Partial Ranking for Year 2003

Region	2003 Crossings Upgraded	2003-04 Incident Reduction	2003 Number Crossings	Rank Upgraded	Rank Reduction	Rank Crossings
R3	30.29	-42	48733	5	8	1
R4	83.14	-11	43177	4	6	2
R6	86.08	-12	35231	3	7	3
R5	204.1	-4	34610	1	4	4
R2	88.6	1	27908	2	2	5
R8	27.11	11	27164	6	1	6
R7	5.53	-2	16029	8	3	7
R1	14.84	-7	13430	7	5	8

$\tau_{xy,z}$	0.0860663

Appendix J.
Railroad Mergers

J-1. Incidents at Public Crossings by Railroad, 1994 and 2003

			1994			2003
	Railroad	**Incidents**	**Cumulative Percent**	**Railroad**	**Incidents**	**Cumulative Percent**
1	**UP**	896	19.8	**CSX**	496	19.0
2	**NS**	649	34.2	**UP**	462	36.7
3	**CSX**	568	46.7	**NS**	418	52.7
4	**BNSF**	354	54.5	**BNSF**	348	66.1
5	**KCS**	171	58.3	**KCS**	98	69.8
6	**BN**	166	62.0	**ATK**	83	73.0
7	**CR**	133	64.9	**IC**	83	76.2
8	**IC**	110	67.4	**WC**	45	77.9
9	**NW**	102	69.6	**GTW**	31	79.1
10	**SP**	97	71.8	**SOO**	27	80.2
11	**WC**	90	73.8	**CRSH**	22	81.0
12	**CNW**	83	75.6	**FEC**	21	81.8
13	**ATSF**	74	77.2	**ICE**	17	82.5
14	**ATK**	67	78.7	**NIRC**	17	83.1
15	**SOO**	56	80.0	**SCAX**	17	83.8
16	**GTW**	46	81.0	**WE**	17	84.4
17	**CC**	35	81.7	**CC**	12	84.9
18	**SSW**	32	82.5	**AM**	9	85.2
19	**FEC**	28	83.0			
20	**WE**	28	83.7			
21	**WSOR**	24	84.2			
22	**NIRC**	22	84.7			
23	**IHB**	18	85.1			
	Sub total	3,849	85.1%		2,223	85.2%
	Other RRs	674	14.9%		386	14.8%
	Total	4,523	100.0%		2,609	100.0%

J-2. Public Crossings Incidents in California by Railroad

Railroad	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
UP	86	74	86	71	90	94	60	63	49	47
BNSF	27	27	31	34	38	35	47	44	38	24
SP	21	13	17							
ATSF	14	11	5							
ATK	9	15	4	11	14	22	20	27	10	20
SJVR	8	4	8	3	1	4	1	3	1	5
SCAX	7	15	14	8	12	10	12	13	14	16
TVRR	3	3	1	1				1		
CCT	2	1								1
CFNR	2	2	2	2		2		2	3	
ARZC	1		1							1
OTR	1			1						
SCBG	1		1							
SDNX	1	1		2	1	2		2		2
AL						1				1
CORP		1		1						2
CWR				1						
LAJ						1				
MET		1	1			1				
NVWT						2		1		
PCMZ						1	1	1		1
PHL					1			1		
RSIX								2	1	
SDTI									1	
SERA						1				
SMV					2					
STE			1					1		
VCY		2								
YSLR					1			2		
Total	183	170	172	135	160	176	141	163	117	120
Railroads reporting incidents	14	14	13	11	9	13	6	14	8	11

J-3. Incidents for Texas by Railroad, 1994 through 2003

Railroad	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
UP	293	226	217	214	144	191	186	182	155	148
BNSF	55	52	44	70	67	64	76	70	58	55
SP	34	39	32							
ATSF	22	13	13							
KCS	22	26	24	38	34	30	19	28	11	16
BN	11	10	5							
RVSC	6	5	3	6	3	2	1	2	6	7
SSW	6	11	9							
TM	6	2	4	11	11	9	9	5	16	5
TNER	6	1				1	2			1
DGNO	5	5	4	3	3	9	7	4	5	6
AUAR	4	1	1	1	3			2	2	
PTRA	4	5	4	4	3		3	6	4	6
TRE	4	1	1	1		1			1	2
ANR	3				1		1	2	1	
FWWR	3	8	8	4	1	9	6	3	6	3
TIBR	3	7	1	2	6	2	6	4	4	2
SWGR	2	1								
WTLR	2	1	4	4	2					
ATK	1	2	4	3	3	3	5	3	3	
CHRC	1									
CRLX	1	1								
CYCY	1									
DART	1	1	1	1		1		1		
PVS	1									
SRN	1	1	1		2		1			
SSC	1	1	1							
TCT	1	1	1		1				2	
TELX	1									
TXPF	1	3	1		1					1
ANR					1					
ATCX					1					
BRG							1	1		2
GCSR				1	1				1	
GVSR		2	1				1			
HBT			2	1						
KRR				1			1			
LHRR			1							
PCN										1
PNR		1	1	1					1	
SAW							1			
SO		1	1	1						
SW										2
TN			1		1					
TNMR			1	1						
TREX						1	2			
TXNW						1				
TXTX							1			
WATX										1
WI									1	
Total	502	428	391	368	289	324	329	313	277	258

J-4. Public Crossing Incidents by State, Ranked by Percent Change from 1994 to 2003

State	% Change	1994 Incidents	2003 Incidents	State	% Change	1994 Incidents	2003 Incidents
CT	-100.0%	4	0	LA	-34.7%	202	132
NV	-85.7%	7	1	CA	-34.4%	183	120
AK	-66.7%	3	1	VT	-33.3%	3	2
WI	-60.8%	176	69	CO	-32.6%	43	29
IA	-60.5%	157	62	UT	-30.8%	26	18
WY	-57.1%	7	3	SC	-29.9%	87	61
NC	-55.9%	145	64	VA	-28.6%	56	40
NM	-55.6%	18	8	GA	-28.2%	149	107
NE	-54.7%	86	39	WV	-26.8%	41	30
ID	-53.8%	39	18	TN	-25.7%	101	75
MO	-53.4%	116	54	FL	-19.8%	116	93
AL	-53.1%	177	83	MT	-11.1%	18	16
MN	-52.2%	138	66	KY	-10.0%	80	72
SD	-51.7%	29	14	MA	-6.3%	16	15
IN	-50.9%	275	135	NY	-2.7%	37	36
IL	-50.8%	309	152	PA	-2.7%	73	71
NH	-50.0%	2	1	DC	0.0%	0	0
OH	-49.8%	229	115	HI	0.0%	0	0
MS	-49.7%	167	84	ND	10.0%	20	22
AR	-48.9%	139	71	NJ	11.4%	35	39
TX	-48.6%	502	258	DE	20.0%	5	6
WA	-48.3%	60	31	AZ	29.2%	24	31
KS	-46.8%	94	50	MD	50.0%	12	18
OK	-44.8%	116	64	ME	60.0%	5	8
OR	-42.1%	38	22	RI	+100.0%	0	2
MI	-36.1%	158	101				
				Total	**-42.3%**	**4,523**	**2,609**

J-5. Public Crossings by State, Ranked by Percent Change from 1994 to 2003

State	% Change	1994 Crossings	2003 Crossings	State	% Change	1994 Crossings	2003 Crossings
DC	-362.5%	37	8	**NE**	-8.4%	4,058	3,744
MA	-45.7%	1,192	818	**MI**	-7.8%	5,791	5,374
WY	-33.5%	530	397	**VA**	-7.3%	2,201	2,051
KS	-27.0%	7,912	6,231	**GA**	-6.9%	6,197	5,796
WV	-25.1%	1,972	1,576	**SC**	-6.6%	3,111	2,918
IL	-25.0%	10,265	8,213	**KY**	-6.4%	2,639	2,480
NH	-24.8%	503	403	**TN**	-5.9%	3,371	3,183
NJ	-22.2%	1,862	1,524	**OH**	-5.3%	6,713	6,374
AL	-19.2%	4,008	3,362	**AR**	-5.2%	3,325	3,162
ID	-19.1%	1,556	1,307	**MO**	-4.9%	4,872	4,643
WI	-17.6%	4,899	4,167	**ME**	-4.9%	882	841
PA	-16.9%	5,599	4,788	**FL**	-4.4%	4,077	3,905
IA	-14.2%	5,290	4,632	**MT**	-4.2%	1,533	1,471
WA	-13.3%	3,018	2,664	**AZ**	-4.2%	941	903
NY	-12.0%	3,279	2,928	**MN**	-3.9%	5,218	5,024
MS	-11.4%	3,028	2,717	**OR**	-3.3%	2,343	2,269
OK	-11.4%	4,627	4,155	**CA**	-2.9%	7,988	7,761
TX	-11.2%	12,706	11,431	**MD**	-0.3%	693	691
ND	-11.1%	4,631	4,167	**SD**	-0.3%	2,137	2,131
NC	-10.7%	4,875	4,405	**AK**	0.0%	227	227
NM	-10.3%	815	739	**CT**	0.0%	370	370
CO	-10.1%	2,076	1,885	**VT**	0.0%	496	496
IN	-10.0%	6,678	6,071	**NV**	3.7%	288	299
UT	-9.0%	1,009	926	**DE**	12.1%	269	306
LA	-8.5%	3,770	3,475	**HI**	25.0%	6	8
RI	-8.5%	128	118				
				Totals	**-9.9%**	**166,011**	**149,534**

J-6. Changes in Public Incidents and Public Crossings by State

State	% Change Incidents	% Change Crossings	State	% Change Incidents	% Change Crossings
CT	-100.0%	0.0%	LA	-34.7%	-8.5%
NV	-85.7%	3.7%	CA	-34.4%	-2.9%
AK	-66.7%	0.0%	VT	-33.3%	0.0%
WI	-60.8%	-17.6%	CO	-32.6%	-10.1%
IA	-60.5%	-14.2%	UT	-30.8%	-9.0%
WY	-57.1%	-33.5%	SC	-29.9%	-6.6%
NC	-55.9%	-10.7%	VA	-28.6%	-7.3%
NM	-55.6%	-10.3%	GA	-28.2%	-6.9%
NE	-54.7%	-8.4%	WV	-26.8%	-25.1%
ID	-53.8%	-19.1%	TN	-25.7%	-5.9%
MO	-53.4%	-4.9%	FL	-19.8%	-4.4%
AL	-53.1%	-19.2%	MT	-11.1%	-4.2%
MN	-52.2%	-3.9%	KY	-10.0%	-6.4%
SD	-51.7%	-0.3%	MA	-6.3%	-45.7%
IN	-50.9%	-10.0%	NY	-2.7%	-12.0%
IL	-50.8%	-25.0%	PA	-2.7%	-16.9%
NH	-50.0%	-24.8%	DC	0.0%	-362.5%
OH	-49.8%	-5.3%	HI	0.0%	25.0%
MS	-49.7%	-11.4%	ND	10.0%	-11.1%
AR	-48.9%	-5.2%	NJ	11.4%	-22.2%
TX	-48.6%	-11.2%	DE	20.0%	12.1%
WA	-48.3%	-13.3%	AZ	29.2%	-4.2%
KS	-46.8%	-27.0%	MD	50.0%	-0.3%
OK	-44.8%	-11.4%	ME	60.0%	-4.9%
OR	-42.1%	-3.3%	RI	+100.0%	-8.5%
MI	-36.1%	-7.8%			

Table J-7. The Eight FRA Regions

Region #	Region Name	States in the Region
1	Northeast	ME, NH, VT, MA, NY, RI, CT, NJ
2	Middle Atlantic	PA, OH, WV, VA, MD, DE
3	Southeast	KY, TN, NC, SC, GA, AL, MS, FL
4	North Central	MN, WI, IL, IN, MI
5	South	NM, TX, OK, AR, LA
6	Central	CO, NE, KS, IA, MO
7	Southwest	CA, NV, UT, AZ
8	Northwest	AK, WA, OR, ID, MT, WY, ND, SD

J-8. Percent Decline in Public and Private Incidents by FRA Region

FRA Region	1994 Incidents	2003 Incidents	Percent Change
1	134	117	-12.7%
7	283	197	-30.4%
2	487	330	-32.2%
3	1,119	759	-32.2%
8	260	154	-40.8%
6	526	306	-41.8%
5	1,074	610	-43.2%
4	1,116	590	-47.1%
total	4,999	3,063	-38.7%

J-9. Public and Private Incidents for First Quarter (January, February, March) of Year, 1994 through 2006

Year	Incidents	Percent Decline
1994	1,437	
1995	1,245	-13.4%
1996	1,200	-3.6%
1997	1,060	-11.7%
1998	918	-13.4%
1999	895	-2.5%
2000	899	0.4%
2001	865	-3.8%
2002	777	-10.2%
2003	756	-2.7%
2004	766	1.3%
2005	724	-5.5%
2006	696	-3.9%

J-10. Incidents as Public and Private Crossings, 1980 through 2005

Year	Incidents	Year	Incidents	Year	Incidents	Year	Incidents
1980	10,796	1987	6,426	1994	**4,979**	2001	**3,237**
1981	9,461	1988	6,617	1995	**4,633**	2002	**3,077**
1982	7,932	1989	6,526	1996	**4,257**	2003	**2,977**
1983	7,305	1990	5,715	1997	**3,865**	2004	3,072
1984	7,456	1991	5,388	1998	**3,508**	2005	3,035
1985	7,073	1992	4,910	1999	**3,489**	2006	696*
1986	6,513	1993	4,892	2000	**3,502**		

* 2006 incident counts are for months January, February, and March

Appendix K.
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Acronyms

AADT	average annual daily traffic
ADAPT_X	Accident Data Analytical Prospective Tool for Highway-Grade Crossing Incidents
ATSF	Atchison Topeka Santa Fe Railway
BN	Burlington Northern Railroad Co.
BNSF	Burlington Northern Santa Fe Railway Co.
CDL	Commercial Driver's License
CNW	Chicago Northwestern Railway Co.
Crossing Inventory	National Highway-Rail Crossing Inventory
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
RAIRS Grade Crossing	Rail Accident Incident Reporting System–Highway-Rail Grade Crossing
RAIRS Rail Equipment	Railroad Accident Incident Reporting System–Rail Equipment
SP	Southern Pacific Transportation Co.
TMT	train miles traveled
TRB	Transportation Research Board
UP	Union Pacific Railroad Co.
USDOT	U.S. Department of Transportation
VMT	vehicle miles traveled
Volpe Center	John A. Volpe National Transportation Systems Center

Glossary

Exposure–A measure of grade crossing traffic that includes vehicle miles traveled, Class I train miles traveled, and the number of at-grade crossings

Fatality Rate–The number of grade crossing fatalities per vehicle miles traveled

Incident-Fatality Rate–The number of fatalities per grade crossing incident

Incident-Injury Rate–The number of injuries per grade crossing incident

Incident Rate–The number of grade crossing incidents per vehicle miles traveled

Kendall Partial Rank Correlation Coefficient–A nonparametric method of partial correlation using ranks, in which the correlation between two variables is found with the third variable held constant

Overlap–The number of incidents that can be attributed to behaviors associated with more than one of the success factors

Pareto Diagram–Graphical tool used to summarize and display the relative importance of the differences between groups of data

Percent Impact–Percentage of incidents, from 1994 to 2003, that can be attributed to behaviors that the factor was attempting to change

Percent Reduction–Percentage of incidents reduced, from 1994 to 2003, which can be attributed to the safety countermeasures for a factor

Success Factors–The safety initiatives that were the most successful in reducing incidents at highway-rail grade crossings during the years 1994 through 2003