Wisconsin Highway-Railway Grade Crossing Safety Action Plan

February 2022

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1. INTRODUCTION

1.1 Mission Statement

The vision of Wisconsin's transportation system is of an integrated multimodal transportation system that maximizes the safe and efficient movement of people and products throughout the state, enhancing economic productivity and the quality of Wisconsin's communities while minimizing impacts to the natural environment.

Railroads have been an integral part of Wisconsin's transportation system since 1847, when the state's first rail service was introduced. Wisconsin has a long history of involvement in rail transportation, from planning and policy development to financial support.

Transportation safety is a top priority of the Wisconsin Department of Transportation (WisDOT). Enhancing safety involves working with partners throughout Wisconsin and around the nation to identify safety issues and best practices. A data-driven process gathers, analyzes, and reports traffic incidents and injuries and uses that data to inform policies and to guide improvement investments and enforcement activities that help ensure safe operations on state transportation systems. The Wisconsin At Grade Rail Crossing Safety Action Plan (SAP) is an important part of Wisconsin's grade crossing program management process and its focus on rail safety. This plan provides a framework to reduce the probability of incident occurrence and the consequence of hazard (severity) at highway-rail and pathway grade crossings in Wisconsin. The purpose of this SAP is to provide implementable strategies and action steps to improve rail safety throughout Wisconsin. Of particular focus are highway-rail and pathway grade crossings, where trains, pedestrians, and vehicles interact; and where unsafe interactions occur that can lead to dangerous consequences for all users.

This plan is available for public viewing at WisDOT's Railroad Crossing Improvements website: https://wisconsindot.gov/Pages/doing-bus/local-gov/astnce-pgms/aid/railcrossing.aspx. A glossary of terms and acronyms can be found in Appendix A.

1.2 Background

The U.S. Congress enacted several acts that required states to adopt a State Grade Action Plan (SAP) as directed by the Federal Railroad Administration (FRA). The timeline of events is summarized below:

2008 The Railroad Safety Improvement Act (RSIA) was enacted by the U.S. Congress in 2008 and required the 10 states with the highest rates of highway-rail grade crossing incidents to adopt a State Grade Crossing Action Plan (SAP). Wisconsin was not one of these states.

2015 In 2015, the Fixing America's Surface Transportation Act (FAST) directed the FRA to extend the SAP requirement to the remaining 40 states and the District of Columbia.

2019 In November 2019, the FRA published a Notice to Proposed Rulemaking (NPRM) that required the remaining states to develop an SAP. In addition, the NRPM required the original 10 states to update their existing plans.

2020 In December 2020, the FRA issued a Final Rule in the Federal Register (49 CFR § 234.11). The final rule establishes required plan elements and provides additional recommendations for consideration.

2022 In February 2022, Wisconsin will submit their SAP to the Federal Railroad Administration (FRA).

1.3 Scope

Several documents were reviewed in the development of this plan, including the FAST Act (Section 11401(b)(2)) outlining State Action Plan requirements and Federal Register Vol. 85, No. 240 which covers the rules and regulations of State Action Plans. The Highway-Rail Grade Crossing Action Plan and Project Prioritization Noteworthy Practices Guide (Report No. FHWA-SA-16-075) was also used as a resource.

FRA requires the State Highway-Rail Grade Crossing Action Plans to address specific elements and to use incident data to help identify crossings that have multiple injuries and/or fatalities. Table 1-1 summarizes the requirements and lists the section and page number of the report that satisfies these requirements.

Table 1-1: Required State Action Plan Elements

#	Required Element	Location
(i)	Hwy-rail grade crossings that experienced at least one accident/incident within the previous 3 years	Section 4.6, pg 34
(ii)	Hwy-rail grade crossings that experienced more than one accident/incident within the previous 5 years	Section 4.5, pg 32
(iii)	Hwy-rail grade crossings that are at high-risk for accidents/incidents as defined in the Action Plan	Section 6, pg 48
	Specific strategies to improve safety over at least 4 years	Section 7.2, pg 50
	Implementation timeline	Section 7.3, pg 58

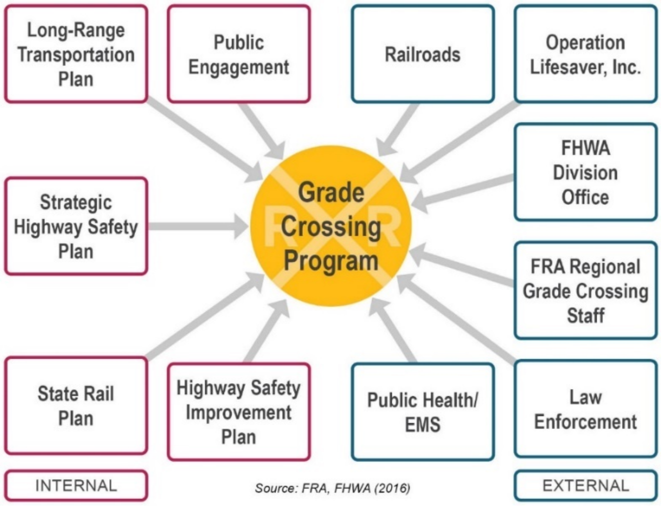
Source: 49 CFR § 234.11

For clarity, this document uses the term "incident" consistently through to indicate impact or collision between railroad on-track equipment and a highway user.

Planning Process

In 2021, WisDOT formed a group dedicated to delivering the SAP. This group included internal WisDOT and Office of the Commissioner of Railroads (OCR) staff, and external consulting firms with the goal to provide a comprehensive and safety-focused plan. This group identified important resources, partners, and stakeholders with which coordination would be very important to maximize the understanding of grade crossing safety efforts and issues. FRA and FHWA provided guidance on internal and external resources for states' SAPs as shown in Figure 1-1.

Figure 1-1: FRA and FHWA Guidance on Internal and External Resources for the SAP



The group also defined the steps to develop the Wisconsin SAP, which are listed below:

Review Previous State Plans

A review of current funding programs and transportation plans was completed. This review ensured that the SAP would be consistent with Wisconsin's existing plans and commitments already in place. A summary of this effort is found in Chapter 2: WISCONSIN HIGHWAY-RAIL CROSSING SAFETY EFFORTS.

Develop Internal and External Stakeholders

A list of stakeholders, agencies, and methods of engagement (such as interviews and an online survey) were defined and completed. This process is summarized in Chapter 3: STAKEHOLDER AND PUBLIC ENGAGEMENT.

Gather Highway-Rail and Pathway Grade Crossing Data

An inventory of available data was compiled to determine the scope of the SAP. State and Federal databases that contained useful and appropriate data were identified for analysis. Chapter 4: DATA ANALYSIS includes a section that lists the sources used for this plan.

Establish Goals and Objectives

WisDOT considered known highway-rail and pathway crossing safety issues to identify improvements to prioritize which were expressed in terms of goals and objectives. The list of ten goals can be found in Section 1.4 of this chapter. A complete summary of the objectives and strategies for each goal is in Section 7.3 of Chapter 7: ACTION PLAN.

Complete Data Analysis and Risk Assessment

The SAP team evaluated the existing highway-rail and pathway crossing safety environment and incident data. Safety risks and higher-level safety considerations were determined throughout the state. Chapter 4: DATA ANALYSIS and Chapter 5: RISK ASSESSEMENT provide documentation and details of this step.

Identify High Priority Highway-Rail Crossing Locations

Based on the results of the data analysis and risk assessment steps, the team determined the highest-priority highway-rail and pathway crossing safety locations. A toolbox of solutions was developed for crossings where focused attention might reduce incidents and their consequences. The list of locations can be found in Chapter 6: PRIORITY HIGHWAY-RAIL GRADE CROSSING LOCATIONS

Refine Goals and Objectives, Define Strategies, Assign Time Constraints

Based on the data analysis, risk assessment, and results from stakeholder interviews and surveys, the team defined specific strategies and timelines for meeting objectives. More information can be found in Chapter 7: ACTION PLAN.

Review, Revise, and Finalize Plan

A draft SAP was circulated to various groups and stakeholders within WisDOT to refine strategies and gain concurrence with the plan.

1.4 SAP Goals

Early coordination within the Wisconsin SAP project team outlined the broad goals, objectives, and strategies for this plan while considering the unique railroad and safety environment in the state. These goals established the direction of the plan and were reviewed and refined as the development process continued.

Goals, objectives, and strategies work together to form an achievable, results-driven plan. These terms are defined in the graphic to the right.

A list of ten statewide goals were defined and numbered for organizational purposes. Numbering does not reflect priority. Detailed descriptions of the objectives and strategies can be found in Section 7.3.

1. Reduce the number and rate of incidents at railroad grade crossings
2. Reduce the number of severe incidents at locations with reoccurring incidents within the last five years
3. Efficiently deliver and manage projects in highway improvement, OCR safety, WisDOT safety and crossing surface repair programs
4. Implement and maintain safety improvements at interconnected crossing systems
5. Maintain a program to repair deficient railroad crossing surfaces on the STH network
6. Evaluate rail corridors for potential crossing consolidations
7. Improve data collection and analysis on railroad crossings
8. Implement design improvements at railroad grade crossings when undertaking highway improvement projects
9. Engage statewide stakeholders in education and enforcement
10. Reduce Trespassing

2. WISCONSIN HIGHWAY-RAIL CROSSING SAFETY EFFORTS

2.1 Introduction

Highway-rail and pathway at-grade crossing safety requires continuous, comprehensive, and cooperative planning and evaluation as an important component of the state's multimodal transportation system. State statutes, plans, and funding programs must work together to provide realistic strategies, measures, and processes to improve safety across Wisconsin. A summary of current statutes, programs, and funding sources available for improving highway and pathway crossing safety in Wisconsin is provided in this section.

2.2 Roles

While the implementation of this plan is primarily WisDOT responsibility, there are other partners that are necessary for the successful implementation of this plan and for the improvement of rail crossing safety. Those integral partners include the Office of Commissioner of Railroads (OCR), FRA, railroad companies, local units of government, first responders, Operation Lifesaver, and law enforcement.

2.3 State Statutes

The Wisconsin statutory references that relate to Wisconsin railways and highway-rail and pathway grade crossings include:

- Chapter 84.05: Railroad crossing improvements
- Chapter 85: Rail program rules, railroad projects and competitive bidding, and acquisition of abandoned rail property.
- Chapter 86: Miscellaneous highway provisions including highway/railroad grade crossings (86.11, 86.12, 86.13, 86.135)
- Chapter 189: Office of the Commissioner of Railroads, powers, and duties
- Chapter 190: Railroads, organization and management including powers of railroads and railroad consolidation; sale or lease of property
- Chapter 191: Railroads, construction, including railroad extensions
- Chapter 192: Railroads, regulations and liabilities including railroad train crews, and trespassing on railroads
- Chapter 195: Railroad regulation, including protecting grade crossings, advance warning signs, rail crossing warning devices (195.28), and new and altered rail crossings (195.29)
- Chapter 349.085: Authority to install stop signs at railroad grade crossings.

2.4 Funding Programs

In state fiscal year 2021, WisDOT completed 51 agreements on projects that improved highway-rail and pathway crossing safety. The graphic below summarizes the number of projects in the various state programs that involve railway crossings.

Section 130 Program

The Section 130 Highway-Rail Crossing Safety Program is an FHWA program that provides funds to states for the elimination of hazards at highway-rail and pathway crossings including crossings at roadways, trails, and pathways. In Wisconsin, this program is a partnership between the Office of the Commissioner of Railroads (OCR), WisDOT, railroad companies, and sometimes local communities. WisDOT and OCR participate in regularly scheduled meetings and ongoing coordination regarding the selection and delivery of projects in the OCR safety program. FRA staff also participate in bi-monthly meetings to review projects and current issues.

OCR Safety Program

25 signal agreements in OCR safety program, FY 2021

The OCR Crossing Safety Program is a 4-year program that has annual program limits of $2.7 million of Section 130 federal funding with a $1.7 million state match. The $1.7 million of state funds can be used only on warning devices. A focus of the program is to improve crossing safety by upgrading both antiquated crossing warning devices and upgrading passive warning devices to active. Candidate crossings are selected using a statewide benefit/cost analysis and ultimately, approximately 20 crossings are improved each year. In fiscal year 2021, the Rail Projects Review Committee was able to fund 25 projects.

WisDOT's Safety Program

7 signal agreements in WisDOT's safety program, FY 2021

The WisDOT Crossing Safety Program is a 4-year program utilizing $592,000 of Section 130 federal funds. Improvements fall under two categories – warning device improvements and elimination of hazards.

1. Replacing obsolete equipment as identified by the railroad. Funding is a 50/50 split between federal and railroad dollars.
2. Elimination of hazards as identified by WisDOT, OCR, and/or local municipalities. Funding is a 90/10 split between federal and railroad or local dollars. Geometric improvements, elimination of hazards, installation of warning devices at passive crossings, and standalone preemption upgrades may be considered.

3. Crossing consolidation incentive payments are also funded with elimination of hazard funds. WisDOT can match railroad incentive funds with up to $30,000 federal Section 130 funds. These are 100% federal funds, and no state match is required.

In fall of 2020 and again in August 2021, WisDOT solicited all the partner railroad companies for lists of projects eligible for the 50/50 program. The programming team has programmed projects through fiscal year 2024 and plans to send another solicitation to rail partners to fill out the program to 2026.

Crossing Surface Repair Program

5 surface agreements in the crossing surface repair program, FY 2021

The Crossing Surface Repair Program is programmed at $467,300 of state funds per year with an 85/15 funding split between the State and railroad. Only crossing surfaces on state highways, not within Connecting Highway limits, are eligible for this program. Due to the fast nature of crossing surface degradation, the program is typically programed two years in advance.

Generally, crossing surfaces are replaced or improved within the highway improvement program projects. This program covers the replacement of railroad crossings on the state highway system that are in poor condition and do not have programmed improvement projects.

The Rails and Harbors Section of WisDOT has developed a ranking system to rate the crossings on a scale from very good to poor, providing a standardized methodology for the prioritization of eligible crossings for the programming process. This effort was designed to be based on an every-other-year field review and subsequent statewide ranking. In 2019, the statewide data was gathered on all crossings eligible for this program. Another statewide field review is planned for 2022.

Highway Improvement Projects

14 surface and signal agreements on highway improvement projects, FY 2021

Every year WisDOT has approximately 12-20 programmed highway improvement projects that include a railroad crossing component. All projects that include a railroad crossing require an agreement with the railroad owner. Each agreement is the culmination of many field visits, multiple meetings with project teams and local stakeholders, scope identification, determination of devices, OCR coordination, estimating, and agreement development. Significant coordination is required with the WisDOT contracting unit, Bureau of State Highway Programs (BSHP) federal funds management section, and Bureau of Fiscal Services to achieve authorization, encumbrance, and contract approval. Nearby signalized intersections generally require additional complex railroad interconnection engineering. WisDOT Rails and Harbors Section staff meet weekly with region railroad coordinators to ensure efforts are focused and efficient and help make sure final agreements are completed before final design deadlines.

Adjustments and changes in railroad facilities required by the highway improvement are generally funded the same as the adjacent highway improvement. Exceptions may be required due to funding policies, funds available, and by negotiated agreement. Exceptions include crossing surface projects not utilizing federal funds.

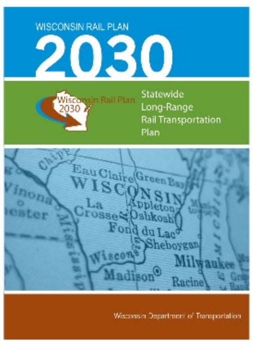
Preemption Projects: Traffic signals interconnected with railroad warning systems

27 current projects involving traffic signals interconnected with railroads

There were 27 projects in Wisconsin involving preemption in fiscal year 2021. These projects came from a combination of the programs summarized above including the WisDOT highway improvement programs, OCR, and WisDOT safety programs. Projects involve the analysis, upgrades, and design of the complex interaction of railroad detection warning systems with traffic signals. This requires in-depth coordination with the railroad companies and engineers with an extensive understanding of preemption.

2.5 State Transportation Plans

Wisconsin Rail Plan



WisDOT is currently in the process of updating its rail plan from the Wisconsin Rail Plan 2030 to Wisconsin Rail Plan 2050. The plan update process is expected to be completed in 2022.

The Wisconsin Rail Plan 2050 will include policies for railroad crossings, freight rail, Wisconsin's state-owned rail system, long distance passenger rail, intercity rail, and commuter rail. The plan will specifically discuss rail data trends, existing and future service levels, rail system conditions, commodity freight movements, and includes a listing of future rail-related improvements. This SAP is consistent with the policies in the Wisconsin Rail Plan. The plan's website is www.wisconsinrailplan.gov.

Wisconsin Freight Plan

Enhancing freight mobility is a WisDOT priority. The State Freight Plan (SFP) provides a vision for multimodal freight transportation and positions the state to remain competitive in the global marketplace. The SFP was approved by the U.S. Department of Transportation on March 19, 2018.

The State Freight Plan:

- Links transportation investments to economic development activities
- Places Wisconsin within a national and global context
- Engages and reflects the interests of a wide array of freight stakeholders
- Guides implementation – from planning to programming to project development
- Provides performance measures and management

Guidance and policies resulting from comments on the draft plan include continuing efforts to promote safe rail crossings throughout the state. The plan outlines the responsibilities assigned to entities like the railroad companies, WisDOT, and OCR. Chapter 6.4 summarizes system safety and includes a section on Rail-Highway crossings which is consistent with this document.

State Highway Safety Plan (SHSP)

Wisconsin's Strategic Highway Safety Plan is a statewide comprehensive plan that provides a synchronized framework for reducing traffic fatalities, injuries, and incidents over a three-year period. The plan examines various issue areas that affect highway safety in Wisconsin. The current version includes the years 2017-2020 and can be found on WisDOT's website http://wisconsindot.gov. "Reduce Vehicle-Train incidents" is defined as a continuing highway safety issue area in the plan.

Statewide Transportation Improvement Program (STIP)

The Statewide Transportation Improvement Program (STIP) required by 23 CFR 450.216 is a four-year prioritized listing of highway and transit projects for the state of Wisconsin. The STIP includes both capital and non-capital projects that are federally funded or considered regionally significant in both urban and rural areas. The STIP incorporates the Transportation Improvement Programs (TIPs) prepared by the state's 14 Metropolitan Planning Organizations (MPOs) by reference. Approval of the STIP is done jointly by the Federal Highway Administration and the Federal Transit Administration and constitutes formal approval of the incorporated MPO TIPs.

As discussed in the funding programs section of this SAP, many highway projects include a rail crossing component. WisDOT routinely includes improvements to crossing surfaces and warning devices when highway projects involve grade crossings. WisDOT Railroads and Harbors Section is involved in all highway projects with federal funding to coordinate crossing surface and warning device upgrades. OCR makes the final determination on cost apportionment for these improvements and warning device adequacy. Standalone warning device and crossing surface projects are included in the STIP.

Connect 2050, Long-Range Transportation Plan

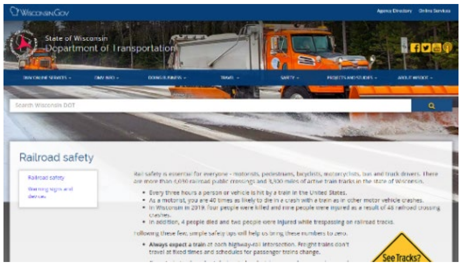
Wisconsin's statewide, multimodal, long-range plan, required by 23 CFR 450.216(a) is currently being updated from Connections 2030 to Connect 2050. The plan facilitates decision-making or improvements to and investments in all types of transportation throughout Wisconsin from now to 2050. The format of Connect 2050 relies on technical plans like this Grade Crossing State Action Plan to ensure that Connect 2050 will stay relevant over time by pointing to the most up-to-date data, policies, and actions affecting each transportation mode. This SAP is consistent with and supports Connect 2050's vision, goals, and objectives. The Connect 2050 plan update process is expected to be complete in early 2022. A website for the plan can be found at https://connect2050.wisconsindot.gov/plan.

2.6 System Plan Environmental Evaluation Determination

Trans 400.07(2)(b)2 of the Wisconsin Administrative Code indicates a System Plan Environmental Evaluation (SEE) may be prepared for a system plan if it is concluded the plan includes major and significant new proposals. WisDOT has determined that a SEE is not necessary for this plan. The SAP does not constitute a statewide system plan and does not include major and significant new proposals.

2.7 Education and Awareness Efforts

WisDOT Railroad Safety Website



WisDOT acknowledges that rail safety is essential for everyone - motorists, pedestrians, bicyclists, motorcyclists, emergency responders, bus drivers, and truck drivers. To help educate everyone, WisDOT hosts a Railroad Safety webpage on the WisDOT website that includes incident statistics, safety tips, crossing precautions, stopping requirements, and information on emergency notification system signs. https://wisconsindot.gov/Pages/safety/education/rail/default.aspx

Wisconsin Operation Lifesaver

Wisconsin Operation Lifesaver (OLI) is a non-profit safety education and awareness program dedicated to reducing incidents, fatalities, and injuries at highway-rail grade crossings and on railroad rights of way in the State of Wisconsin. Wisconsin Operation Lifesaver offers free presentations to all age groups and targeted audiences that include bus drivers, professional truck drivers, law enforcement, first responders, and school children. Operation Lifesaver educates the public on making safe decisions on or near railroad property. Wisconsin Operation Lifesaver is supported by railroads operating in Wisconsin, private citizens, corporations, and an energetic team of volunteers and members. https://oli.org/

Rail Safety Week

Wisconsin hosted state-wide rail safety weeks prior to 2017 when the event went national through Operation Lifesaver. Wisconsin has joined and collaborated with the National Rail Safety Week since 2017. This annual week-long event is a collaborative effort among Operation Lifesaver, Inc., state Operation Lifesaver programs, and rail safety partners across the U.S., Canada, and Mexico. https://oli.org/about-us/public-awareness-campaigns/rail-safety-week

3. STAKEHOLDER AND PUBLIC ENGAGEMENT

3.1 Introduction and Key Stakeholders

This plan was developed by WisDOT with input and engagement from a wide variety of stakeholders including federal, state, and local agencies, railroads, safety organizations, trade organizations, law enforcement, and the public. The project team worked to interview stakeholders, gather survey responses, and conducted a webinar for local jurisdictions on rail safety issues, trends, and problems.

3.2 Key Issues, Trends, and Problems

Through the engagement process, input was gathered about rail safety concerns, changing trends, and upcoming issues. The feedback was summarized into three categories:

- **Key issues** are specific rail safety concerns that were identified through interviews and surveys and warrant further investigation.
- **Trends** include rail safety concerns under development or experiencing change noted through the stakeholder engagement.
- **Problems** are concerns identified through engagement that the team believes need attention.

Key Issues

The recurring key issue is ensuring good coordination across jurisdictions and expertise silos. Consistent and ongoing conversations across railroads, safety organizations, law enforcement, the state, and local municipalities was cited as an important issue to address.

Trends

Survey respondents and interviewees identified similar trends to be tracking. Railroads are interested in the local jurisdictions' land use plans to mitigate the following trends:

- **Resiliency** and emergency planning: Resiliency in promptly restoring service after disaster or incident and emergency planning was cited as the most important emergency response strategy by survey participants.
- **Smart crossings**: Outfit some crossings with technology to provide better intel on safety issues, near misses, etc. in real time
- **Safety and Patrols**: Focused patrols near heavily travelled crossings was favored by survey participants as the most effective enforcement technique.
- **Engineering Solutions**: The most favored approach to improving safety at rail crossings was engineering strategies, closely followed by emergency response improvements.

Problems

Through surveys and stakeholder interviews, various problems were identified. Below are summarized the key problems based upon comments and other feedback.

Trespassing

All stakeholders acknowledge that trespassing is a problem. Trespassing is walking, loitering, or being present upon the track of any railroad by unauthorized persons not at designated crossing locations. Potential solutions identified in the engagement process include fencing, education, enforcement, and combating potential laws that would exacerbate the problem. A potential change to existing law allowing trespassing on all railroad rights of way statewide has recently been brought forward by advocacy groups and state legislators.

Educating public, drivers and other highway users, and law enforcement on rail safety.

Law enforcement and Operation Lifesaver cited the need for rail safety education. Railroads cited the need for driver and law enforcement training, including changing the law to require more robust rail safety education for new drivers.

Hot spots

The following geographies were cited across the answers given by stakeholders who used the interactive online map to note problem crossing areas in the state:

- Buntrock Avenue Crossing in Thiensville, WI
  - Noted to have potential issues with the state of the equipment.
- Milwaukee area
  - More areas of concern were cited in and around Milwaukee than anywhere else, with 11 crossing sites identified by survey participants in the Milwaukee area.
- Madison area
  - The Madison area had 8 locations identified by survey participates as areas of concern.

4. DATA ANALYSIS

4.1 Introduction and Approach

This chapter includes a description of the highway-rail and pathway (including sidewalks) crossing inventory data and outlines the data collection and identification of trends for the Wisconsin State Action Plan. The team took a strategic approach to data gathering and review. First, the appropriate data sources were identified. Data from the various sources were reviewed and compared to determine the accuracy and age/currency of the data. From there, the data was reviewed by location to determine focus locations and areas and then compared to national averages to determine outliers.

Data Sources

The primary data sources for data collection were:

FRA Highway-Rail Crossing Inventory (Form 6180.71)

This database is maintained by the Federal Railroad Administration where data is submitted using Form 6180.71. Information includes location and classification information, railroad information, highway and traffic control information, and physical characteristics.

FRA Highway-Rail Grade Crossing Accident/Incident Report (Form 6180.57),

Contains information on each reported accident at highway-rail crossings. Information on crossing conditions, vehicle user profile, and incident particulars are reported in this form.

FRA Rail Equipment Accident/Incident Report (Form 6180.54)

Contains data on accidents or incidents involving the operation of railroad on-track equipment causing reportable damages.

FRA Railroad Injury and Illness Summary (Form 6180.55), Trespasser Casualties

Contains data on reported causalities including trespassing incidents.

Rail Inventory Management System (RIMS)

Web-based service that manages rail inventory data. This system used in the analysis of FRA Grade Crossing Inventory System (GCIS) including Wisconsin data for information on the Wisconsin Highway-Rail Grade Crossings.

Fatal Analysis Reporting System (FARS) Database

Maintained by National Highway Traffic Safety Administration (NHTSA) and is a nationwide yearly census regarding fatal injuries suffered in motor vehicle traffic incidents.

Wisconsin Rail Data Systems

Used by WisDOT to compile and maintain accurate information on the Wisconsin rail network.

4.2 Wisconsin Highway-Rail Crossing Inventory Data Summary

Wisconsin has over 3,300 miles of rail lines – a combination of publicly and privately owned railroad corridors. There are ten principal operators including four class 1 rail operators: Burlington Northern-Santa Fe (BNSF), Canadian National, Canadian Pacific, and Union Pacific; and six short line and regional rail operators: Escanaba & Lake Superior, East Troy Railroad Co., Wisconsin Northern, Tomahawk Railway, Wisconsin Great Northern, and Wisconsin & Southern Railroad (WSOR). The following section summarizes the inventory data for Wisconsin crossings. Data is current as of July 21, 2021. Table 4-1 shows the current highway-rail and pathway crossing information for Wisconsin. There was limited data collected regarding pedestrians and bicyclists.

The data presented in this report includes private crossings. However, WisDOT does not have a role in controlling, constructing, or maintaining private crossings. Federal and state funds cannot be used on private crossings.

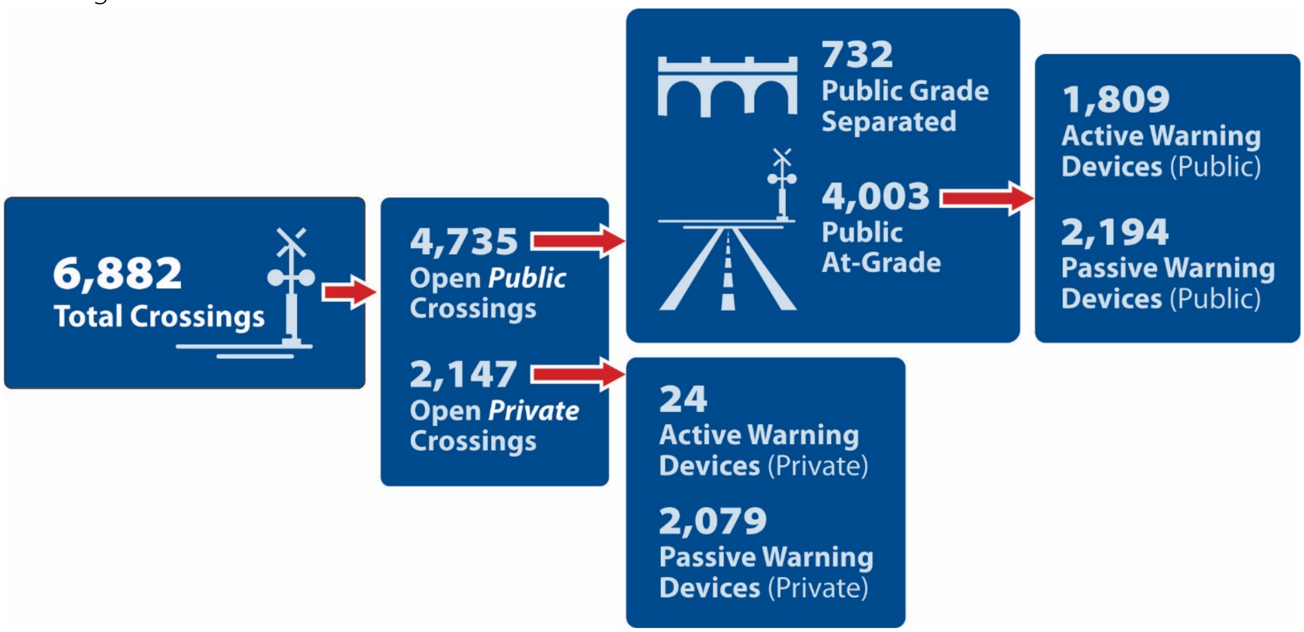


Table 4-1: Rail Crossing Inventory Data Summary

Total Open Crossings	6882	Percent of Total
Open Public	4735	69%
Open Private	2147	31%

Total Open Public Crossings (includes pathways)	4735	Percent of Total
Public Grade Separated	732	15%
Public At-Grade	4003	85%

Total Public At-Grade Crossings	4003	Percent of Total
Public Active Warning Devices At-Grade	1809	45%
Public Passive Warning Devices At-Grade	2194	55%

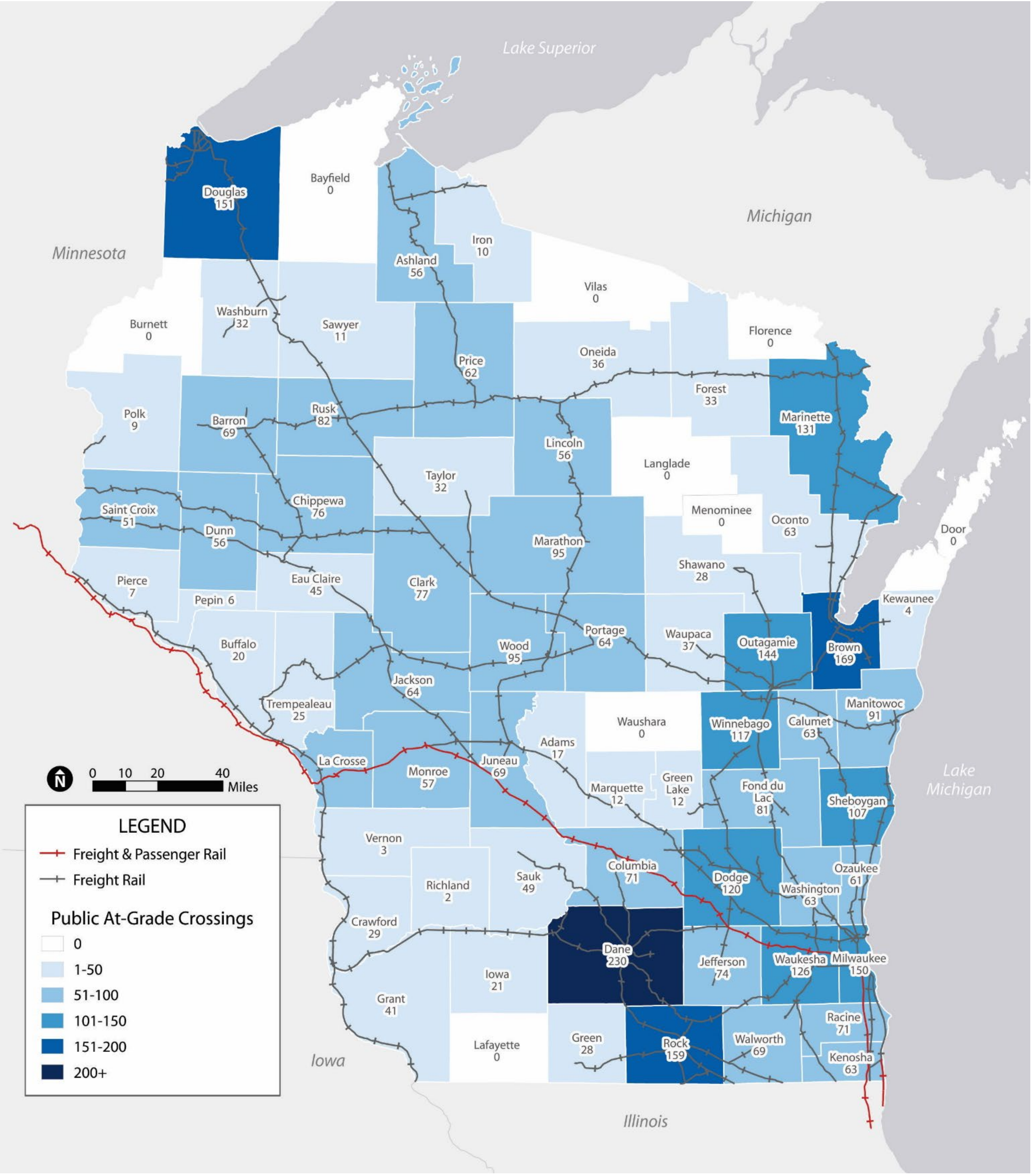
Total Open Private Crossings	2147	Percent of Total
Private Active Warning Devices At Grade	24	1%
Private Passive Warning Devices At Grade	2079	99%

Figure 4-1 is a view of the entire state with both freight and passenger rail lines shown. Included are all 6,882 open crossing locations. Locations are categorized by at-grade crossing or grade separated crossing.

Figure 4-1: Public Highway-Rail and Pathway Crossings in Wisconsin Map

Figure 4-2 shows a map of counties with the highest number of at-grade highway-rail and pathway crossings in the state. The concentration of crossings spans the state and there are multiple high-density areas. Of the 72 counties in Wisconsin, Dane County has the highest with 230 crossings followed by Brown (169), Rock (159) and Douglas (151). Nine counties do not have any active railroad tracks so there are no public at-grade crossings.

Figure 4-2: Public At-Grade Crossings by County Map



4.3 Data Quality Evaluation

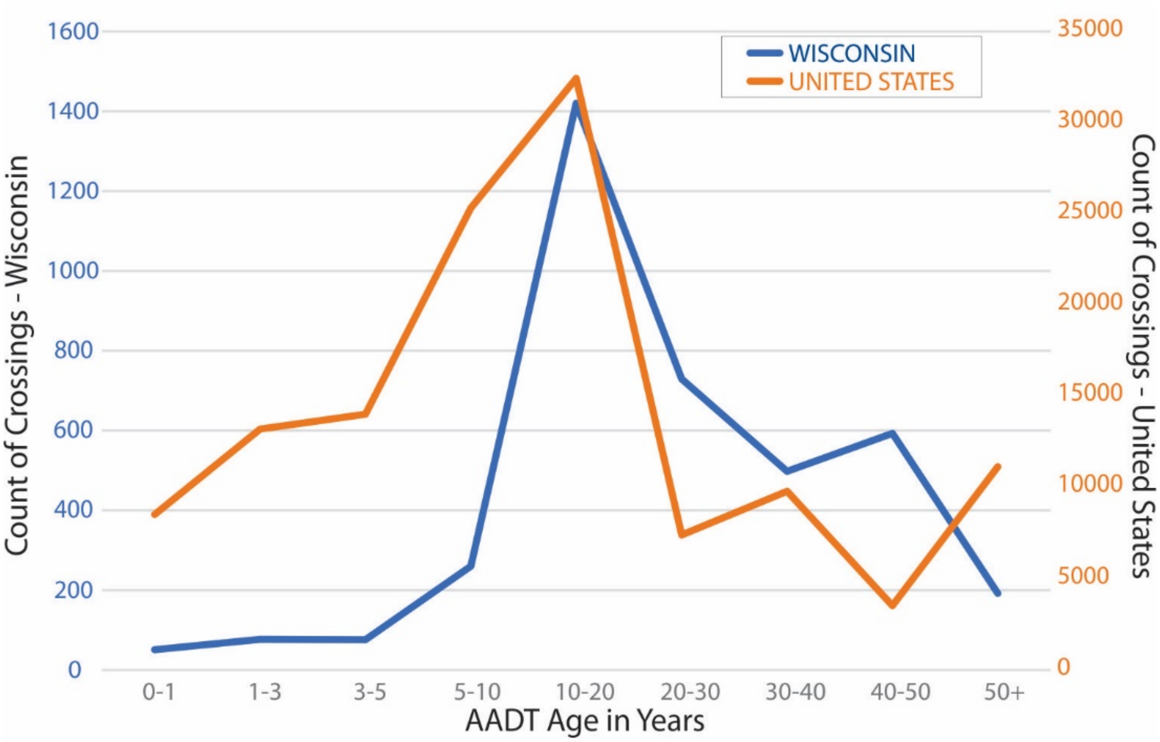
The Wisconsin highway-rail and pathway crossing data was evaluated and compared to national averages for traffic count and train count ages. When comparing two sets of data from different sources, it is important to determine if comparing it is reasonably based on the accuracy and age/currency of the data.

AADT Age

Figure 4-3 illustrates that the majority of WI crossings have AADT values with a collection age of 10-20 years or older. On average, the Wisconsin AADT age is 8 percent older than the national AADT age. This coincides with the significant reduction in the number of locations in the three-year counting cycle. For many minor road locations, the last count was 10-20 years ago.

AADTs on some minor roads are estimates that were computed many years ago based on development and other assumptions and do not have recorded count data. WisDOT does not have a count program for minor roads. Traffic counting programs have not been geared toward providing counts specifically at crossing locations, so often extrapolation is used to ascertain a count at a crossing location. Therefore, many minor crossings do not have a specific count at the rail-highway crossing location.

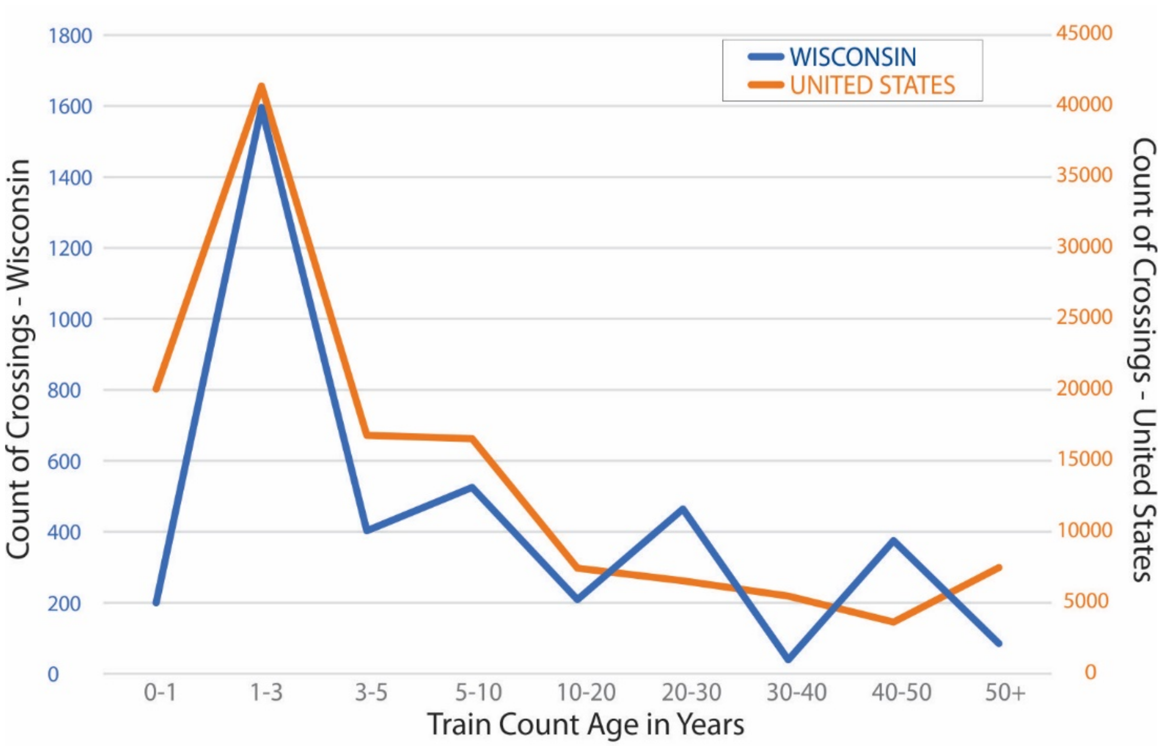
Figure 4-3: Distribution of AADT Age for WI and US, Public At-Grade Crossings



Train Count Age

Figure 4-4 illustrates that the Majority of WI crossings have Total Train Count values with a collection age of 1-3 years. WI has higher concentrations of crossings with older ages when compared to the Total Train Count age for the US, potentially due to higher concentrations of short-line railroads.

Figure 4-4: Distribution of Total Train Count Age for WI, Public At-Grade Crossings



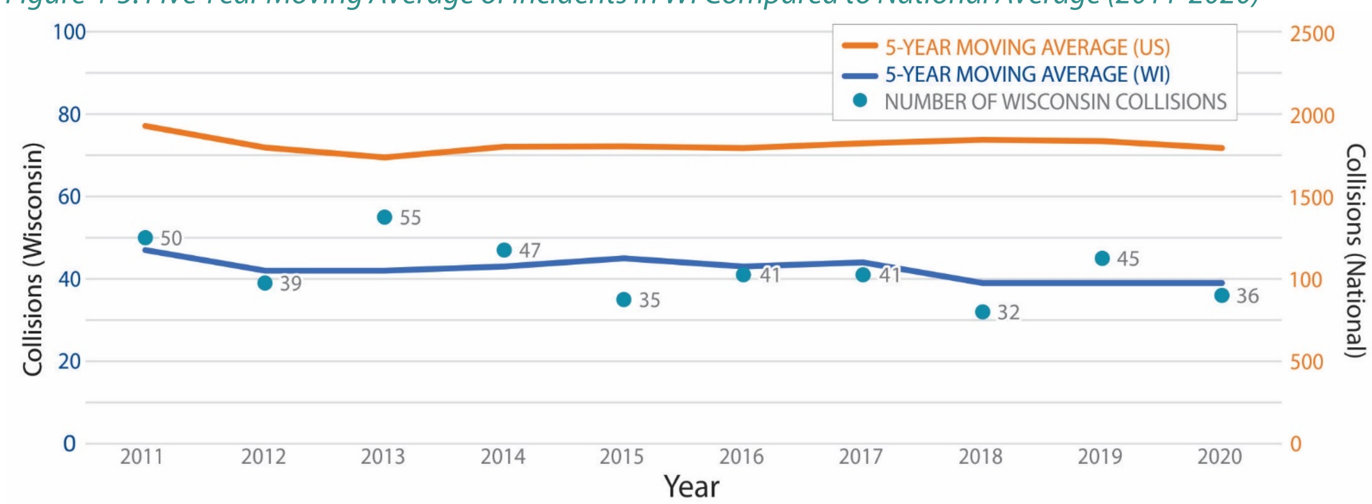
4.4 Wisconsin Highway-Rail Crossing Safety Trend Analysis

This section summarizes the incident data, analysis, and recent trends for incidents that occurred at public crossings in Wisconsin. Items with a blue background signify key findings.

Ten Year Incident Trends

From FRA Highway-Railroad Incident Data, the total incidents occurring at public crossings in Wisconsin over ten years (2011-2020) was compared to all the incidents that occurred in the US. These figures were graphed in relation to a five-year moving average to illustrate the high-level trend. As seen in Figure 4-5, aside from slight upticks in 2015 and 2017, there was a consistent decline between 2011 and 2020. This contrasts with the national moving average which has remained steady over the past ten years.

Figure 4-5: Five Year Moving Average of Incidents in WI Compared to National Average (2011-2020)



Five Year Incident Trends

FRA Highway-Railroad Incident Data (FRA Form 6180.57) was obtained from the FRA for the complete years of 2016 through 2020 for public crossings in Wisconsin. This data was compared to the same five-year period for the nation. This baseline was established for use by the WisDOT rail safety section for future trend analysis.

The information is shown in seven categories which are summarized below.

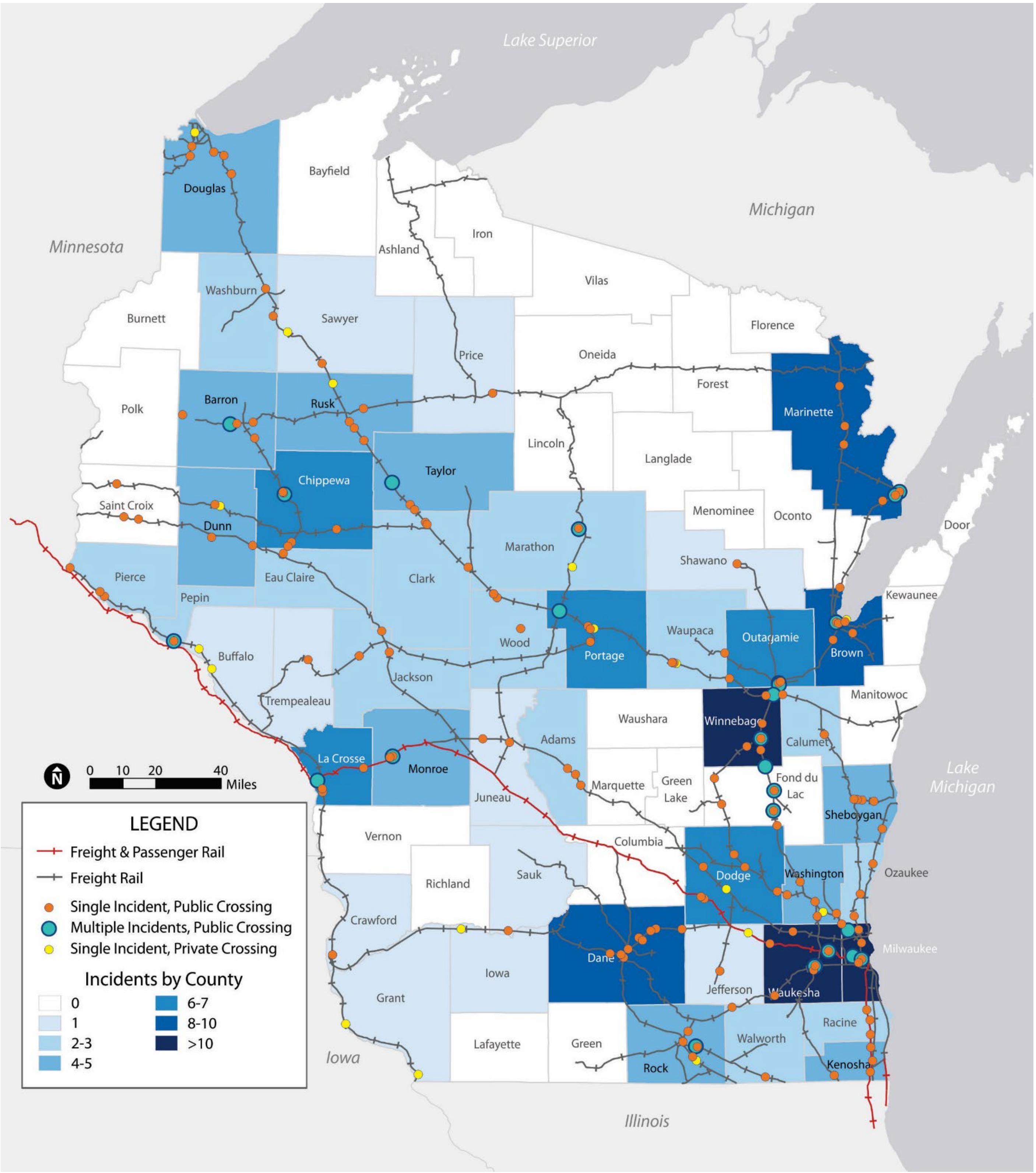
1. Location
2. Crossing Information – warning devices, crossing illumination, travel conditions, and view obstructions
3. Driver Information – transportation mode type (pedestrian, vehicle type, etc.), speed, action, and demographics
4. Train Information – speed, type, hazardous materials
5. Temporal Information – incident year, month, and time of day
6. Incident Severity
7. Cost of Damages

There were 195 incidents at public crossings in Wisconsin from 2016 – 2020, 39 per year on average.

Location

Location was considered a means of establishing safety trends for the highway-rail and pathway crossing infrastructure with focus on the areas with the most history of incidents. The color of each county in Figure 4-6 indicates the total number of incidents at public crossings for that county. Three counties had over ten incidents (Milwaukee, Waukesha, and Winnebago) and three more counties had between eight and ten incidents (Dane, Brown, and Marinette). All six of these counties have high numbers of crossings (over 100) within their county. Wisconsin has a higher number of incidents at fewer crossings when compared with national averages.

Figure 4-6: Incidents at Crossings by County Map



Crossing Information

Track Type

More accidents happen on main track crossings than any other type in Wisconsin, just above the national percentage (91.7 percent WI, 90.4 percent National). There were small variances for the other types. Wisconsin has a higher percentage of industry incidents and a lower percentage of yard incidents.

Table 4-2: Incidents by Track Type

Track Type:	Wisconsin (Count)	Wisconsin (%)	National (%)
Main	178	91.8%	90.4%
Yard	3	1.5%	4.0%
Siding	2	0.0%	0.8%
Industry	11	5.6%	4.8%

Warning Devices

The crossing report noted that signals were installed at 102 of the 194 crossing incident locations. Of the 194 incidents, 50.5 percent of the locations provided a minimum 20-second warning as required by FRA. Four incidents were confirmed to have warning devices that provided no warning, but it was not determined why no warning was provided.

Travel Conditions

Fewer incidents were reported on dry conditions than the national average (67 percent WI, 83.3 percent US).

More incidents happened in snow and slush (18.6% WI, 3.6% US) conditions in Wisconsin than the national average.

Crossing Illumination

The crossing illumination field of the report was filled in for all incidents in Wisconsin for the data that was collected. This indicates the presence of streetlights. Of these, 114 locations were reported as not being illuminated (58.7 percent) which is over the national value of 56.0 percent.

View Obstruction

A low number of incidents in Wisconsin had obscured views listed in the incident report. Five incidents noted obstructed views by the passing train (2), highway vehicles (1), permanent structure (1), or other (1). Though only five incident reports noted obstructed views, WisDOT and OCR observes that many crossings have inadequate vision triangles, which could be a factor in incidents or near misses.

Highway User Information

Highway User Type

Highway users are defined by the different modes and types of vehicles that people operate. User type incidents in Wisconsin slightly vary from the national average percentages for the following modes: truck (higher), truck-trailer (lower), pedestrian (lower). Wisconsin has the 30th lowest percentage of pedestrian incidents among all 50 states. No data was gathered that identified bicycle users.

Highway User	Wisconsin (Count)	Wisconsin (%)	National (%)
Auto	97	50.0%	48.2%
Bus	0	0.0%	0.2%
Motorcycle	1	0.5%	0.4%
Other	8	4.1%	2.9%
Other motor vehicle	11	5.7%	6.4%
Pedestrian	14	7.2%	9.7%
Pick-up truck	15	7.7%	11.9%
School bus	0	0.0%	0.1%
Truck	18	9.3%	4.8%
Truck-trailer	20	10.3%	13.4%
Van	10	5.2%	2.2%

Trucks and buses have unique characteristics that should be considered in crossing design. For example, trucks need longer warning times and storage space. Truck volumes could be considered in prioritizing crossings for upgrade to active warning systems, grade separation, or other improvements.

Passenger Vehicles
132 Incidents (68%)

Trucks
48 Incidents (25%)

Pedestrians
14 Incidents (7%)

Highway User Speed

Many variables impact the highway user speed. A higher number of incident reports in Wisconsin (19.6 percent) did not report the vehicle speed compared to the national average (8.9% percent).

Figure 4-7: Highway User Speed (Percentage)

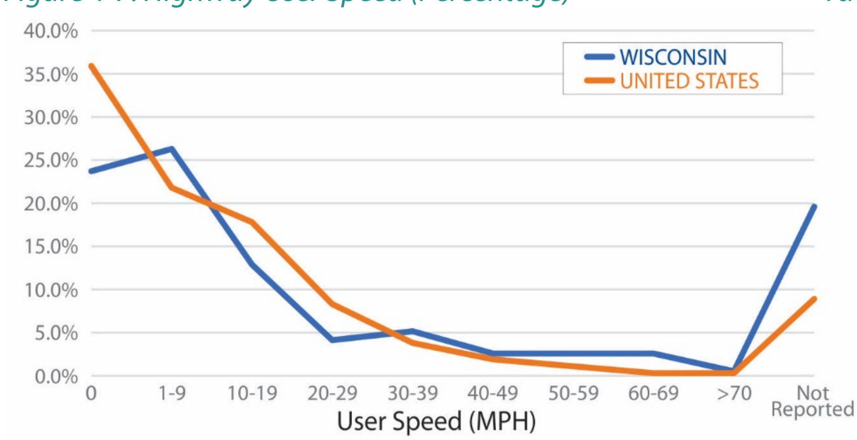


Table 4-3: Highway User Speed Count

Speed (MPH)	Number of Incidents (WI) over 5 years
0	46
1-9	51
10-19	25
20-29	8
30-39	10
40-49	5
50-59	5
60-69	5
Over 70	1

Highway User Position and Action

A large percentage of incidents occurred with the highway user traveling north and south compared to the national average. This can be explained with the large number of main railroad lines traveling east-west across the state and the high number of incidents occurring on main lines.

A larger number of incidents in Wisconsin occurred while the vehicle was moving over the crossing (74.7%, 62.1 US) as opposed to being blocked by crossing gates; stalled, stuck, or stopped on the crossing; or trapped on the crossing by roadway traffic.

A higher percentage of highway users in Wisconsin (42.3%) did not stop at the crossing or stopped and proceeded (8.8%) than the national percentages (30.6%, 5.1% respectively).

Table 4-4: Highway User Action, Incidents in Last 5 Years

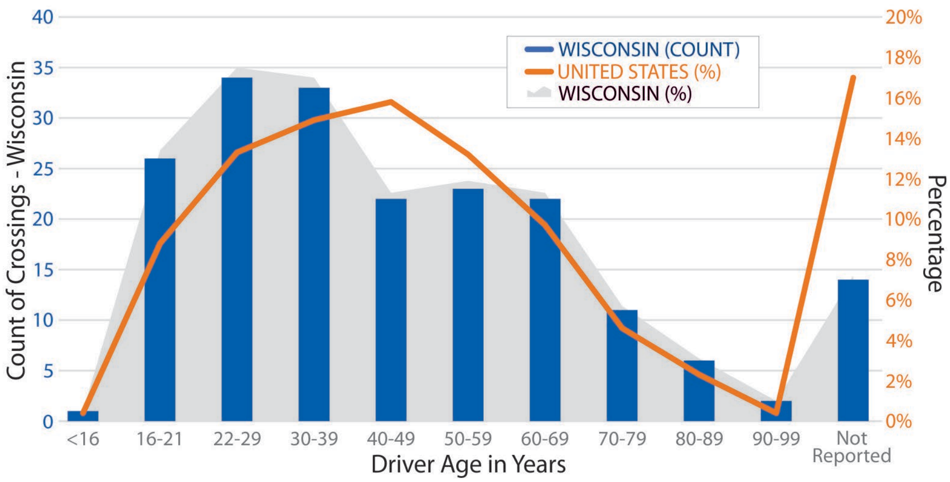
Highway User Action	Wisconsin (Count)	Wisconsin (%)	National (%)
Did not stop	82	42.3%	30.6%
Stopped on crossing	33	17.0%	23.0%
Went around the gate	14	7.2%	18.5%
Other	29	14.9%	14.8%
Went thru the gate	13	6.7%	5.2%
Stopped and then proceeded	17	8.8%	5.1%
Suicide/attempted suicide	4	2.1%	2.3%
Went around/thru temporary barricade	2	1.0%	0.3%

Highway User Demographics

The age range of 22-29 had the highest percentages of incidents. Males drove the vehicles in 145 (74.7 percent) of the incidents in Wisconsin, while females drove the vehicles in 44 (22.7 percent) of the incidents. Five of the incidents did not report the highway user's gender. No data was gathered on the genders of pedestrians and bicyclists.

Driver ages in Wisconsin were younger on average from the national percentages and males had a higher percentage of incidents than the national average of 68.5%.

Figure 4-8: Highway User Demographics, Incidents in Last 5 Years



Gender Split of Incidents

Incident Type

Over 26% (52 incidents) of the highway-rail incidents that happened in Wisconsin involved the rail equipment being struck by the highway user. This is higher than the national average of 19%.

A higher percentage than the national average in Wisconsin were struck by a second train (4.6%, 2.3% US)

Train Information

Train Equipment

The train equipment involved in incidents in Wisconsin varied from the national percentages. Higher percentage of incidents were trains (units pulling), lights locomotives (moving), and car(s) standing.

Hazardous Materials

A higher percentage of incidents in Wisconsin reported transporting hazardous materials in the train than the national average. No incidents were reported to have released hazardous material.

Train Type

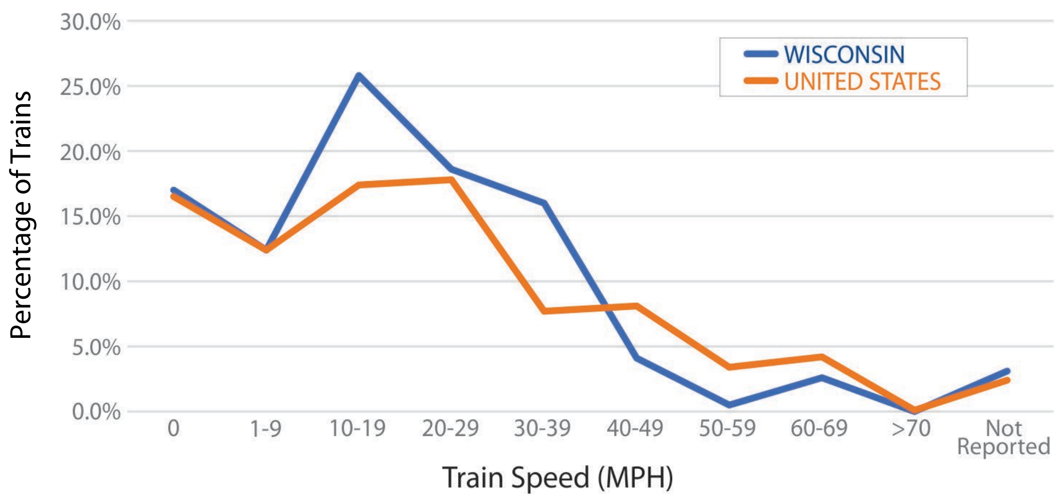
In Wisconsin, a higher number of incidents involved freight trains (86.1 percent) than the national average (71.6 percent), which is statistically significant.

Incidents in Wisconsin (4.1%) were below the national average for incidents involving an Amtrak train (7.0%).

Speed of Train

The speed of the trains involved in incidents varies from those of the national percentages. Rates of incidents in Wisconsin are higher than national percentages at speeds under 40 miles per hour (mph).

Figure 4-9: Train Speed

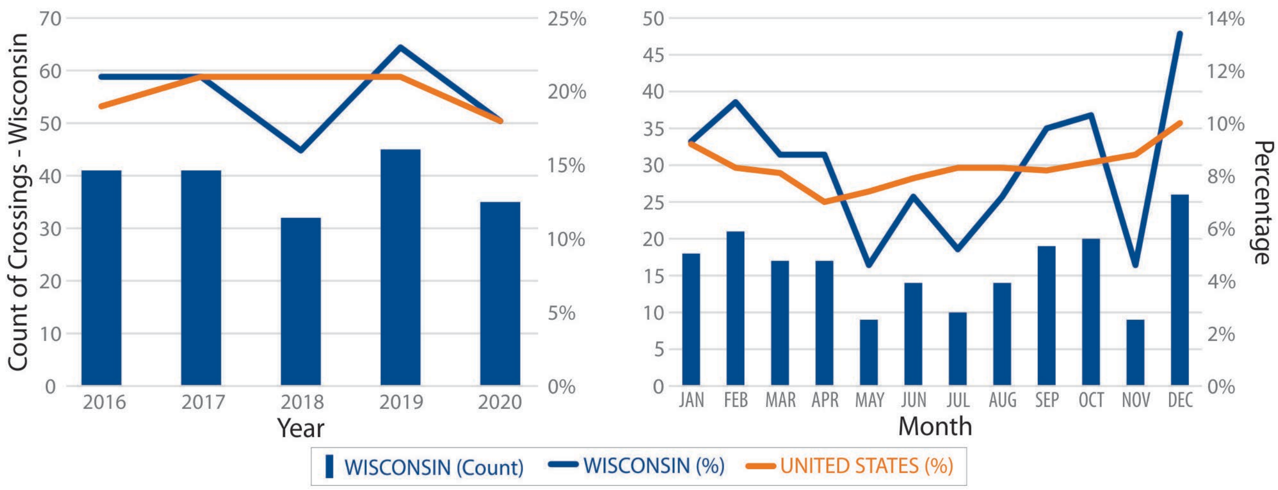


Temporal Information

By Year and Month

The percentage of incidents during the time frame fluctuated for both year and month for compared to the national percentages.

Figure 4-10: Incidents by Year and by Month



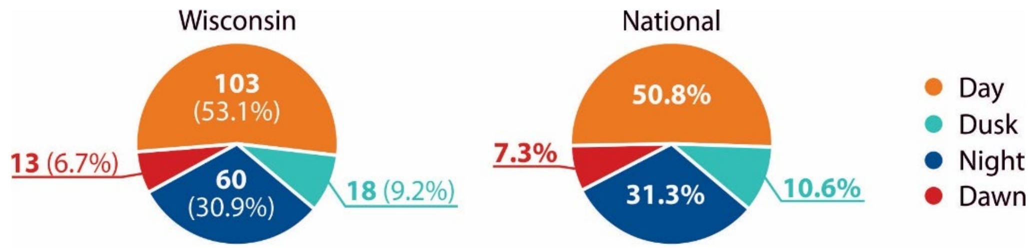
By Time of Day

There was not a clear pattern of incident time of day for Wisconsin compared to the national average. Time periods when the WI average was greater than 0.5 percent different than the national average are shaded grey in the table below. The natural light time periods (dawn, daytime, dusk, and nighttime) were also reviewed for incidents. No significant difference between the Wisconsin average and national average was identified.

Table 4-5: Incident by Time of Day

Time of Day	WI (%) AM	National (%) AM	WI (%) PM	National (%) PM
12:00	1.0%	3.2%	7.2%	5.2%
1:00	2.6%	2.9%	4.6%	5.5%
2:00	3.1%	2.8%	6.2%	5.2%
3:00	2.6%	2.5%	7.2%	6.0%
4:00	3.6%	1.9%	4.6%	5.5%
5:00	3.6%	2.1%	4.1%	5.6%
6:00	2.6%	2.5%	4.1%	5.2%
7:00	2.6%	4.0%	4.1%	4.5%
8:00	2.6%	4.8%	5.2%	4.4%
9:00	5.2%	4.6%	3.6%	4.0%
10:00	5.2%	5.0%	1.5%	3.8%
11:00	7.2%	5.2%	5.7%	3.6%

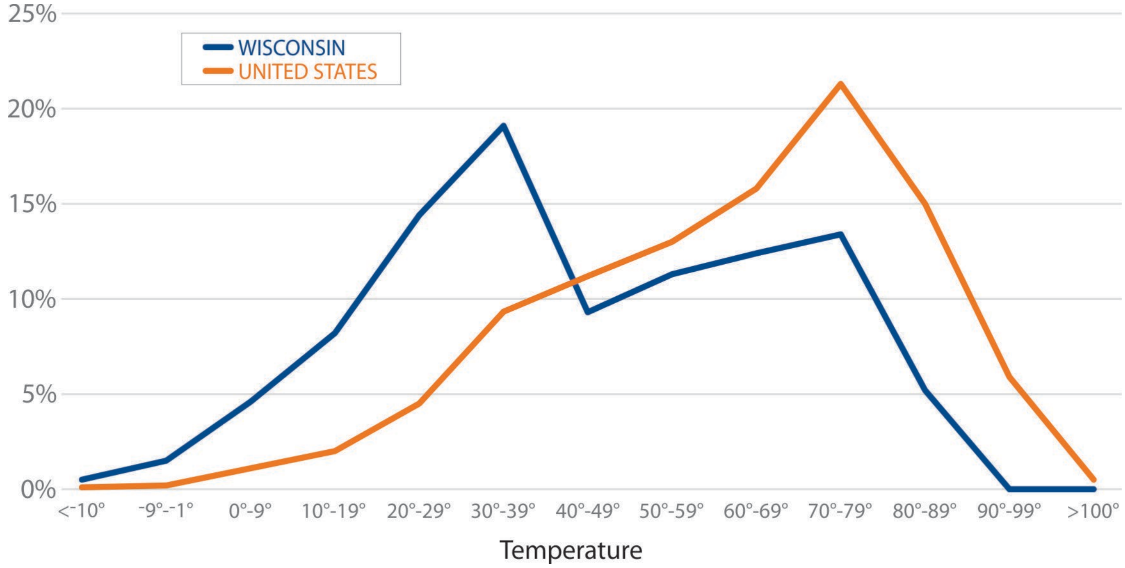
Figure 4-11: Summary of Incidents Occurring at Dawn, Daytime, Dusk, or Nighttime



Temperature

The incidents at temperatures under 40 degrees are more prevalent in Wisconsin, which is expected due to Wisconsin's northern climate.

Figure 4-12: Incidents by Temperature



Incident Severity

Public crossing incidents were reviewed by each type of train and the percentage of those incidents that resulted in a fatality, injury, or property damage only (PDO). In comparison to the national average, a higher percentage of incidents involving passenger trains resulted in a fatality or injury.

PDO incidents occur at a higher rate the slower the train is moving. For trains moving above 60 mph, there is a higher percentage that result in injury or fatalities. Incidents involving pedestrians or bicyclists almost always result in a fatality regardless of the train speed at collision.

*Table 4-6: Percentage of Severity of Incidents by Train Speed Compared to National Average (2016-2020)**

Train Speed at Collision	PDO WI	PDO US	Injury WI	Injury US	Fatality WI	Fatality US
<10 mph	64 %	78 %	33 %	20 %	3 %	2 %
10-20 mph	63 %	68 %	37 %	27 %	-	4 %
21-35 mph	62 %	58 %	23 %	32 %	15 %	10 %
36-49 mph	53 %	53 %	32 %	29 %	15 %	18 %
50-59 mph	49 %	46 %	38 %	25 %	13 %	29 %
>= 60 mph	17 %	36 %	50 %	27 %	33 %	37 %

INJURY INCIDENTS

Wisconsin 32.9%

United States 29.1%

FATAL INCIDENTS

Wisconsin 10.4%

United States 13.4%

Only one of the 21 fatal incidents in Wisconsin during the last five years resulted in more than one fatality during a single incident. Additional information on injury and fatality incidents is covered in Chapter 5 – Risk Analysis.

Cost of Damages

Monetary damages were reported for 185 incidents in Wisconsin. Nine incident reports did not include information on the monetary damages. These costs reflect property damage only as fatalities and injuries are not monetized. The highest percentage of incidents (35.6 percent) had incident estimated damages valued at $1,001 to $5,000. No incidents exceeded $100,000.

Table 4-7: Incident Estimated Damages

Incident Estimated Damages ($)	Wisconsin (Count)	Wisconsin (%)	National (%)
0	15	7.7%	13.9%
$1 - $500	10	5.2%	2.3%
$501 - $1000	4	2.1%	32.0%
$1,001 - $5,000	69	35.6%	26.2%
$5,001 - $10,000	45	23.2%	19.8%
$10,001 - $50,000	28	14.4%	1.3%
$50,001 - $100,000	14	7.2%	0.4%
$100,001 - $500,000	0	0.0%	0.1%
Not Reported	9	4.6%	4.0%

4.5 Multiple-Incident Locations (5 Year Data)

Developing strategies to address crossings with multiple incidents in the past five years is the central focus of the State Action Plan. Crossings with multiple instances of incidents represent an opportunity to determine factors that may lead to a higher probability of incidents. In the past five years of data, there have been 25 public crossings with multiple incidents. Figure 4-13 is a map that shows all the multiple-incident locations documented from 2016-2021. A list of these crossings can be found in Chapter 6.

Figure 4-13: Multiple-Incident Locations Map

Additional details for these reported multiple-incident crossing locations are summarized in Table 4-8 and Table 4-9.

Table 4-8: Count and Percentage of Reported Road Type at Multi-Incident Crossings (2016-2020)

Road Type	Multiple Incidents	Multiple Incident %	Statewide Crossing %
Local	13	54 %	60 %
Minor Collector	1	4 %	4 %
Major Collector	4	17 %	16 %
Minor Arterial	4	17 %	12 %
Other Principal Arterial	2	8 %	5 %
Interstate	-	-	3 %

Table 4-8 shows that 54 percent of all crossings with multiple incidents in the past five years were intersected by local roads. The incident trends seen in multiple-incident crossings appear to follow the distribution of crossing road types in the state. The percentage of minor arterial incidents is slightly higher than the percentage of minor arterial crossings. Results from the statistical analysis on the reported road type at the crossings where multiple incidents occurred are inconclusive. This indicates that the difference between the multiple and statewide incident percentages is not statistically significant.

Table 4-9: Percentage of Multiple Incident Crossings in Urban and Rural Regions

Region Type	Multiple Incidents	Multiple Incident %	Statewide Crossing %
Rural	7	29 %	58 %
Urban	17	71 %	42 %

Urban crossings make up a much higher portion of the multiple-incident locations.

Just over 71% of crossings with multiple incidents are intersected by urban roads but urban crossings only make up 42% of all public crossings in the state.

Results from the statistical analysis on multiple incident crossings in urban and rural regions show the region type is statistically significant and should be examined further.

Table 4-10 shows the averages of the train and crossing information for the multiple-incident locations. This provides a general profile for crossings that have experienced multiple incidents in the past five years and can be a component to consider when identifying future crossing locations of interest.

Table 4-10: Multiple-Incident Incident Statistic Averages

Train Information	Crossing Information
46 mph maximum timetable speed	3,861 roadway AADT
7.4 trains per day during the daytime	2.2 traffic lanes
6.0 trains per day at night	

These multiple-incident locations are considered high priority highway-rail grade crossing locations. More information about the prioritization is in in Chapter 6.

4.6 Single-Incident Locations (3 Year Data)

This SAP identifies crossings that have experienced a single incident within the past three years of complete data. The crossing ID of these crossings was extracted from the FRA accident report form and then matched with information from the crossing inventory to develop a profile of the average crossing involved with at least one incident. Figure 4-14 is a map that shows all the single-incident locations documented from 2018-2021.

Figure 4-14: Single-Incident Locations Map

Of the 4,735 open public crossings in Wisconsin, 103 (or approximately 2.2%) of those crossings experienced at least a single incident from 2018 to 2020. Although there were 103 single incidents at public crossings, only 100 reports provided comprehensive information. Details for these reported crossings are summarized in Table 4-11 and Table 4-12.

Table 4-11: Count and Percentage of Reported Road Type at Crossings (2018-2020)

Road Type	Single Incidents	Single Incident %	Statewide Crossing %
Local	59	59 %	60 %
Minor Collector	4	4 %	4 %
Major Collector	15	15 %	16 %
Minor Arterial	16	16 %	12 %
Other Principal Arterial	6	6 %	5 %
Interstate	-	-	3 %

Table 4-11 shows that 59 percent of all crossings with at least one incident in the past three years were intersected by local roads. Similarly to the multiple-incident locations, the incident trends seen in single incident crossings appear to follow the distribution of crossing road types in the state. The percentage of minor arterial incidents is also slightly higher than the percentage of minor arterial crossings. Results from the statistical analysis on the reported road type at the crossings where single incidents occurred are inconclusive. This indicates that the difference between the single and statewide incident percentages is not statistically significant.

Table 4-12: Percentage of Single Incident Crossings in Urban and Rural Regions

Region Type	Single Incidents	Single Incident %	Statewide Crossing %
Rural	51	51 %	58 %
Urban	49	49 %	42 %

When comparing to the distribution of crossings in the state, urban crossings make up a higher percentage of incidents. The statistical analysis on the type of region where single incidents in Wisconsin occurred is inconclusive. This indicates that the differences between the single and statewide incident percentages in Wisconsin are not statistically significant.

Table 4-13 shows the averages of the train and crossing information for the single-incident locations. This provides a general profile for crossings that have experienced an incident in the past three years and can be one component to consider when identifying future crossing locations of interest.

Table 4-13: Single-Incident Crossing Location Statistic Averages

Train Information	Crossing Information
45 mph maximum timetable speed	2,680 roadway AADT
4.9 trains per day during the daytime*	2 traffic lanes
3.3 trains per day at night*	92% paved

*Average for active crossings (open crossing with at least one train per 24-hour period). Total average for all crossings was 6.9 trains per day for daytime period and 3.7 trains per day at night.

These single-incident locations were considered when determining the priority highway-rail grade crossing locations summarized in Chapter 6.

4.7 Trespasser Incident Locations (5 Year Data)

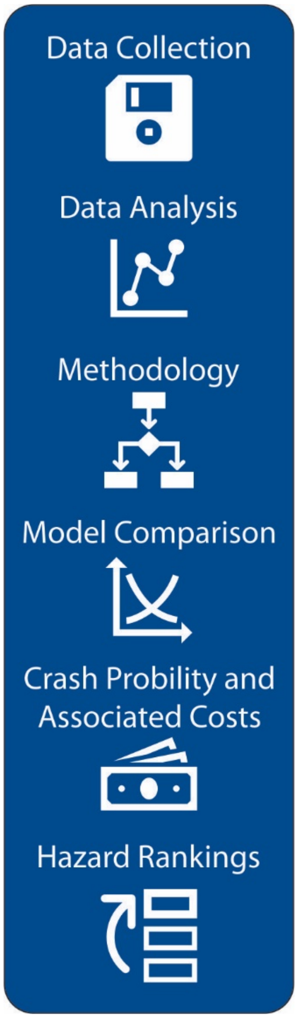
Trespassing prevention is an area of national focus and is a priority within Wisconsin. Figure 4-15 shows the locations of trespassing incidents over a five-year period. There were 56 reported trespasser incidents distributed evenly among the five years. The incident locations are distributed across the state as shown in the figure below. This summary of locations is valuable to identify potential improvements to provide access and safe crossings for bikers and pedestrians.

Figure 4-15: Trespasser Incidents by Location

5. RISK ASSESSMENT

5.1 Introduction and Approach

This chapter is meant to outline the process used to analyze incident statistics and assess risk at crossings within the state of Wisconsin. The following sections summarize the statistical analysis, how the risk and costs are calculated, and the different models that were used in the analysis. Also included are the results of three state-wide scan rankings. Determining the risk associated with individual crossings can aid in developing processes for selecting crossing improvements.



To understand the current trends in rail-grade crossing incidents, crossings with incident history were analyzed. Chapter 4 summarizes the data collection and trend identification effort.

The probability of crossing incidents was also calculated for this analysis. Several probability models were used to calculate the probability of an incident and the probability of a fatal, injury, or property damage only (PDO) incident. The study team used the following models:

1. FRA model, as described in the GradeDec reference manual[1],
2. The 2020 update to the FRA model[2],
3. WisDOT incident prediction model

To properly assess the risk posed at each crossing, the costs associated with an incident was calculated. Two approaches to determine costs were reviewed.

1. National Cooperative Highway Research Program (NCHRP) Report 755, an approach that captures both primary and secondary costs.
2. Current WisDOT BCA Tool. This approach only considers primary costs.

By calculating the probability and expected cost, the risk associated with the crossings could be determined and used to identify at-risk crossings. These were determined to be crossings that had high annual expected costs associated with them. Other metrics were also reviewed, such as the net present value of warning device upgrades to crossings without existing gates and an analysis to identify crossings where consolidation could be investigated further.

In this analysis, not all crossings have the available data that is needed to calculate probability and cost. Data on the expected number of incidents in Wisconsin was taken from the FRA's Web Accident Prediction System and compared to a full list of public at-grade crossings taken from the FRA's inventory form. Comparison of the two data sources saw that 93 percent of the crossings from the inventory form had matching data from the FRA's Web Accident Prediction System.

1 https://railroads.dot.gov/sites/fra.dot.gov/files/2021-09/GradeDecNET%202019%20Reference%20Manual.pdf
2 https://railroads.dot.gov/sites/fra.dot.gov/files/2020-10/GX%20APS-A.pdf

While the data used in this analysis does not show the causes of incidents, the trends identified in this section can be used to develop more targeted programs, such as reaching at-risk demographics or identifying shared characteristics of crossings with previous incidents. These analyzed metrics have been statistically reviewed to determine their significance.

5.2 Data Sources

Using the information from the two databases listed below (also used in Chapter 4 Data Analysis), the initial analysis was conducted by analyzing crossing information from Form 6180.57 and Form 6180.71 to find trends and patterns in the State of Wisconsin's incident history.

FRA Highway-Rail Crossing Inventory (Form 6180.71)

This database is maintained by the Federal Railroad Administration in which data is submitted using Form 6180.71. Information includes location and classification information, railroad information, highway and traffic control information, and physical characteristics.

FRA Highway-Rail Grade Crossing Accident/Incident Report (Form 6180.57),

Contains information on each reported accident at highway-rail and pathway crossings. Information on crossing conditions, vehicle user profile, and incident particulars are reported in this form.

5.3 Statistical Analysis Summary

Identifying statistically significant characteristics associated with the severity of incidents in the state of Wisconsin allows for further investigation into potential causes of these incidents. To do so, a statistical approach was used, analyzing each of the categories related to the incidents by conducting chi-squared or Fisher's exact tests. The results of these statistical tests, shown in Table 5-1, identified any characteristics of incidents that are statistically significant in Wisconsin compared to the nation overall. There was not enough data to determine statistical significance for incidents involving pedestrians and bicyclists.

For this analysis, the assumption was made that any p-value less than or equal to 0.05 was considered significant and anything above that was insignificant. This allows for a deeper understanding of which variables are significant to incidents at these crossings and merits further investigation into the causation.

Table 5-1: Order of Incident Characteristics by Significance

Order	Table Number		P-Value
1	User Action Compared to National Average (2016-2020) **Vehicles did not stop for crossing**	Significant	0.0004998
2	Count of Train Type Involved in Incidents (2016-2020) **Freight train incident count**	Significant	0.0005558
3	Position of Highway User to National Average (2016-2020) **Collision occurred while moving over crossing**	Significant	0.0054970
4	Percentage of Multiple Incident Crossings - Urban and Rural **Higher percentage of urban crossing incident locations**	Significant	0.0070500

1. User action during incidents was considered as a valuable insight to shape future programs to lower incident rates at Wisconsin crossings. Vehicles that did not stop for the crossing make up the highest percentage of incidents at 43 percent. This percentage is higher than the national average and should be further investigated. Results from the statistical analysis on user action during incidents show user action is statistically significant in incidents. The data supports the need for further investigation into the trend of vehicles not coming to stop at public crossings.

2. In Wisconsin, a higher number of incidents involved freight trains (86.1 percent) than the national average (71.6 percent), which is statistically significant and further investigation is warranted. The statistical significance of other train types could not be determined as there are too few incidents involving other train types.

3. There is a higher rate of vehicles moving over the crossings during incidents in Wisconsin (75 percent) when compared to the national average (62 percent). The statistical analysis showed the position of a highway user at the time of the incident is statistically significant. This characteristic is very similar to the "user action" statistically significant characteristic described in list item number one above. A deeper understanding of the factors that lead to vehicles not stopping before the crossing would help WisDOT understand how to address a larger percentage of incidents.

4. Just over 71 percent of crossings with multiple incidents are intersected by urban roads but urban crossings only make up 42 percent of all public crossings in the state. Results from the statistical analysis on multiple incident crossings in urban and rural regions show the region type is statistically significant and should be examined further.

5.4 Risk Assessment Calculation

Two factors inform risk calculation: the **probability** of an event and the **consequence** of the event. Applied to rail crossings, risk is calculated as the probability of an incident multiplied by the cost of the incident. This gives the expected cost for each crossing. By ranking these expected values, the locations with the highest priority can be determined.

NCHRP Report 755[3] categorizes the cost of an at-grade crossing incident in two groups of primary and secondary effects:

- **Primary Effect Costs**: direct, indirect, and intangible costs associated with property damage, injury, and fatal incidents (more visible at the time of the incident).
- **Secondary Effect Costs**: costs accrued to delayed travelers and cargo, and to parties beyond the immediate road and rail travelers and service operators (less visible at the time of the incident).

The simplified expected cost of an incident is the probability of an incident multiplied by the primary effect costs plus the secondary effect costs. Detailed explanation of the risk assessment calculation can be found in Appendix B.

3 https://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_755.pdf

Incident Probability

The U.S. Department of Transportation formulas were used to estimate the **probability of a public at-grade crossing incident occurring** in Wisconsin. This section uses the terms 'accident' for incidents to remain consistent with US DOT terminology outline in the *GradeDec.Net* manual. This report also investigates the updated 2020 FRA accident prediction model and how it calculates the probability of incidents at crossings. The US DOT model includes the accident history at these crossings for the previous five years. The equations used to calculate the FRA models can be found in Appendix B.

2020 FRA Accident Prediction Model

The FRA has released a 2020 update to the accident prediction model and the accident severity model. The 2020 models were both considered in this analysis to calculate incident probabilities. The 2020 FRA accident prediction model calculates **the predicted number of accidents at a crossing**, while the 2020 FRA accident severity model determines the **probability of an incident resulting in a specific severity type** given a collision occurred.

The 2020 accident prediction model is composed of two parts: the Zero-Inflated Negative Binomial (ZINB) regression model and the Empirical Bayes (EB) method. The ZINB regression is used to model count data that displays overdispersion and excess zeroes. The excess zeroes in the data indicate no history of accidents occurring in the past five years at the crossing. The equations used to calculate the 2020 FRA ZINB model can be found in Appendix B.

Comparison of FRA Models

The updated 2020 FRA accident prediction model and severity model were both investigated to determine how the new probability calculations relate to the old FRA model. The new FRA model is composed of the ZINB regression and EB adjustment. Plotting these two models against the old FRA model allows for a comparison to be drawn between the calculations for the probability and costs associated with incidents at crossings. Based on the results, the new FRA model has a lower incident probability outcome than the old FRA accident prediction model.

Although the probability calculations from the updated 2020 FRA accident prediction model are lower than the old FRA model, the outcome of these incidents are more severe in the new model. The new FRA model shows a higher fatality and injury probability calculation than the old FRA model.

5.5 Incident Costs

The probability and expected cost of an incident determine the risk associated with each crossing. Risk assessment is composed of the probability of an incident occurring and the cost associated with that incident. The formula used in this model to calculate risk is defined in Appendix B.

Primary Effect Costs

Primary effect costs are grouped into two categories:

- **Injury Costs**: Inputs from the U.S. Department of Transportation Guidance on Benefit-Cost Analysis (2021)[4] were used in calculating the costs of fatal and injury-causing incidents. These values covered fatalities, three levels of injury severity, an unknown injury status, and costs for non-injury incidents.

4 https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

- **Property Damage Costs**: The property damage cost of an incident was identified based on FRA forms 6180.57 and 8180.54 which collect data on highway-rail and pathway grade crossing accidents and rail equipment accidents respectively. This cost is in addition to the cost for a non-injury incident.

Table 5-2: Statistical Value of Life (US DOT 2021)

	Fatal Injury	Type A Injury	Type B Injury	Type C Injury	Type U* Injury	Non Injury
Comprehensive Cost	$10,900,000	$521,300	$142,000	$72,500	$197,600	$3,700

*Type U injury is used when the injury status is unknown

The other primary cost considered in a rail incident is the property damage costs. For this analysis, vehicle damage cost, rail equipment cost, and rail infrastructure costs were analyzed. Where possible, averages were taken based on the severity of the incident. The rail equipment and rail infrastructure costs in Table 5-3 are estimations due to a damage threshold that does not require rail equipment accidents to be reported if the monetary damage is below a certain amount. For incidents without any reported damages, it was assumed that damage equal to half of that years reporting threshold was incurred.

Table 5-3: Vehicle and Rail Property Damage Costs (2016-2020)

Incident Type	Vehicle Damage	Rail Equipment	Rail Infrastructure
Fatal	$5,755	$6,007	$1,859
Injury	$10,174	$13,832	$2,167
PDO	$7,580	$5,375	$2,018

Secondary Effect Costs

The secondary effect costs can be defined as the costs accrued by delayed travelers and cargo, and to the parties beyond the immediate road and rail travelers and operators. Three primary elements of secondary effect costs according to NCHRP Report 755 are outlined in Table 5-4.

Table 5-4: Secondary Effect Costs

Cost Component	Description
Delay and Rerouting Costs	Added operating costs and the monetary cost of the delay to the operators and passengers of the vehicles, trucks, and trains affected by the incident.
Supply Chain Transport Cost	Supply chain delay cost includes the cost to the shippers from the additional time spent in transit. This also encompasses penalty fees and other miscellaneous costs incurred during the delay.
Supply Chain Inventory Cost	Additional inventory carrying cost impacted by the incident to cover depreciation in value or replacement of affected goods.

These secondary costs are driven by the closure of the at-grade crossing caused by the incident. Closures of at-grade crossings will cause passenger vehicles and trucks to spend time and resources finding an alternate route to their destination. This also increases the logistical costs of the cargo being transported.

This analysis utilized NCHRP Report 755 recommended closure times for freight trains, which are reflective of additional time needed for the investigation of more severe incidents. The same closure times have been used for injury and PDO incidents. The rerouting time applied in this analysis is based on the Mid-America Transportation Center study to avoid multiple rerouting times based on the severity of incidents. The study uses an average of four hours for closure time and an average detour time of 15 minutes for an at-grade crossing incident. It should be noted that it is possible to calculate rerouting time for individual crossings if future detailed analysis is warranted.

Roadway Vehicle Delay and Rerouting Costs

Vehicle delay and rerouting costs are derived from the operational cost and value of passenger and operator costs due to the increase in time spent traveling. Delay and rerouting costs are comprised of the operating cost of vehicles that are affected by the closure, and the value of time that passengers lose. The basis for these costs requires equations for:

- the number of passenger vehicles affected by the closure
- the number of trucks affected by the closure
- vehicle rerouting cost
- value of passenger time
- cost of truck rerouting
- value of truck driver time

All equations for determining the values above can be found in Appendix B.

Rail Delay Costs

Rail delay can be measured by estimating various costs including the cost of idling, the value of the train operators' time, and the value of the train passengers' time.

The basis for these costs requires equations for:

- cost of train Idling
- value of train operator time
- value of train passenger time

Truck Supply Chain Costs

Supply chain transportation and inventory costs are identified to measure the additional costs to transport inventory and stock outage/safety stock costs resulting from the delay caused by the at-grade crossing incident. NCHRP 755 attempts to explain the driving forces behind the supply chain costs, however, it does not clearly describe how this information can be applied to an analysis of an incident for calculating supply chain costs.

This report uses the approach provided by an FHWA (Winston and Shirley)[5] report to measure the congestion costs to shippers as a percentage of cargo value. This report assumes the following congestion costs for freight:

- 0.2% cargo value per hour for bulk
- 0.6% cargo value per hour for perishables
- 0.4% cargo value per hour for all other

5 https://www.fhwa.dot.gov/policy/otps/060320d/060320d.pdf

Truck supply chain cost depends on the value of the cargo carried by the truck. Due to the lack of visibility on truck cargo carried on different roadways, and average value approach is used to estimate the supply chain costs for both the value of the cargo and the time value of the cargo.

The Freight Analysis Framework (FAF5 – 2021) was used to estimate the dollar per ton value of the truck cargo. FAF5 uses a base year of 2017 and so these values were adjusted for inflation.

Rail Supply Chain Costs

Rail supply chain costs are dependent on the number of railcars in the train, the average cargo weight of each railcar, and the average value per ton for cargo carried by the trains. Several sources were used in the development of these inputs:

- The average number of rail cars was calculated by taking the average number of cars attached to trains involved in incidents in Wisconsin from 2011-2020. Through this method, it was determined that the average train involved in an incident contains 61.3 cars.
- To determine the average ton per rail car, values from the public waybill sample was used. It was determined that the average car moving through Wisconsin has a tonnage of 91.1 (2019). This includes all cars terminating and originating in Wisconsin, and all those that most likely passed through Wisconsin.
- The average value per ton of cargo carried by rail was determined by using the FHWA's Freight Analysis Framework – Version 5 (FAF5). Using this method, it was estimated that the average value per ton was $1,268. The calculations used to determine the average supply chain cost per train per hour can be found in Appendix B.

Table 5-5 summarizes the value of time, operational costs and other factors used in the report to calculate the cost of secondary effects:

Table 5-5: Secondary Cost Parameters

Parameter	Value	Source
Vehicle Delay and Rerouting Costs		
Value of Passenger Time	17.90 $ / Hour	US DOT – 2021 BCA Guidance
Vehicle Operation Cost	29.96 $ / Hour	
Avg. Number of Vehicle Passengers	1.67 Passengers	
Truck Delay and Rerouting Cost		
Value of Truck Drivers Time	30.80 $ / Hour	US DOT – 2021 BCA Guidance
Truck Operating Costs	37.79 $ / Hour	ATRI – Operational Costs of Trucking (2020)[6]
Rail Delay and Rerouting Costs		
Value of Passenger Time	17.90 $ / Hour	US DOT – 2021 BCA Guidance
Value of Locomotive Engineer Time	49.40 $ / Hour	
Value of Transit – Rail Operator Time	50.00 $ / Hour	
Train Idling Costs	14.48 $ / Hour	NCHRP-755 (adjusted for inflation)

6 https://truckingresearch.org/wp-content/uploads/2020/11/ATRI-Operational-Costs-of-Trucking-2020.pdf

5.6 Differences Between Models

WisDOT uses a variation of the FRA probability model to calculate accident probability and costs. The WisDOT model was investigated to determine how the probability and cost calculations compare to the FRA model. It is important to point out the similarities between the two models, as well as identifying the areas where they differ. Understanding the approaches and inputs provided in each model will help when determining the expected costs of an incident at public crossings in Wisconsin.

FRA Model

The incident cost model based on FRA probability calculations is composed of various inputs for determining the expected cost of incidents. The model evaluates crossing information to find the probability of an incident occurring and the expected costs associated with that incident in the State of Wisconsin.

WisDOT Model

The incident cost model used by WisDOT is composed of various inputs for determining the expected cost of incidents. Some of the data collected for this model came from WisDOT collected inventories provided by Grade Crossing Safety Engineers and Region Railroad Coordinators. The WisDOT incident cost model also uses data from the WisDOT Major Highway Projects Program which provides the economic costs of incidents associated with several injury types and the cost of a fatality from a incident.

The input values for WisDOT and FRA models are not the same since the Wisconsin DOT model uses specific Wisconsin state data for the primary costs values and the FRA model uses the Benefit-Cost Analysis Guidance for Discretionary Grant Programs. Understanding the FRA and WisDOT's approach will help identify comparisons in the models.

WisDOT Probability Calculation

WisDOT uses the US DOT formula to estimate the probability of an incident at crossings in the state of Wisconsin. The WisDOT model then adjusts the economic parameters in the incident calculations. A constant is included for each warning device (passive, flashing lights, and flashing lights and gates) throughout the model to normalize the predicted accidents in a year with actual counts.

WisDOT Cost Calculation

To calculate the costs associated with the reported incidents in Wisconsin, a formula with the following variables and terminology was used.

- Economic Cost of Fatality: value of a statistical life (VSL)
    - Incident Adjustment Factor for Fatality: incidents to fatalities = 1.143
- Fatal Incidents: predicted number of fatal accidents per year at the grade crossing
    - Incident Adjustment Factor for Injury: incidents to injuries = 1.481
- Injury Incidents: predicted number of injury accidents per year at the grade crossing
    - Injuries (at train speeds):
        - If maximum train speed < 25mph, economic cost of injury C incident value
        - If maximum train speed > 25mph, economic cost of injury A incident value
        - If maximum train speed = 25mph, economic cost of injury B incident value
        - Otherwise "ERROR"
- Economic Cost of PDO: PDO incident value
- PDO Incidents: predicted number of PDO accidents per year at the grade crossing

The WisDOT incident costs model consists of only primary costs. Secondary costs were not observed in the calculation for the expected train incident costs. The primary costs being used in the Wisconsin DOT model are the economic costs of incidents, including the injury or property damage costs.

WisDOT Comparison

After reviewing the approaches of the WisDOT and FRA models to calculate the expected incident costs of an incident at public crossings in Wisconsin, differences were identified and summarized in Table 5-6.

Table 5-6: FRA and WisDOT Model Comparison

Comparison	Similarity	Difference
Input Data Sources	Data came primarily from the Federal Railroad Administration and GradeDec.Net	FRA data: U.S. Department of Transportation WisDOT data: Additional state-specific data from Grade Crossing Safety Engineers, Region Railroad Coordinators, and data from the WisDOT Major Highway Projects Program
Department of Transportation (DOT) Formulas	The same US DOT formula for the predicted number of accidents at the crossing are used in both models	FRA and WisDOT used different exposure calculations
Exposure Calculation	Both models account for all trains at crossings throughout the day and night	FRA calculation uses a time-of-day correlation factor to account for day and night trains WisDOT calculation uses a weighted factor of exposure to account for day and night trains
Incident Probabilities	The same variables are used in both models to calculate incident probabilities	FRA uses the predicted number of accidents at crossing by severity category US DOT formula WisDOT uses conditional probability formulas
Primary Costs	Inputs for economic costs of incidents are the same	Input values are different due to WisDOT using state-specific data. See Table 5-7 for input values.
Secondary Costs	-	Secondary costs were incorporated into the FRA model, but not included in the WisDOT model (as observed)

Table 5-7: US DOT and WisDOT Model Inputs Comparison

Input Values for Cost Calculation	US DOT Input Values[7]	WisDOT Input Values[8]
Cost of Fatal Incident	$10,900,000	$9,200,000
Cost of Injury A	$521,300	$2,674,133
Cost of Injury B	$142,000	$1,364,246
Cost of Injury C	$72,500	$54,360
Cost of Property Damage Only (PDO)	$3,700	$2,912

5.7 Wisconsin Statewide Scan Rankings

As part of the risk analysis, Wisconsin's crossings were evaluated through separate state-wide scans focusing on three different variables:

1. Annual expected incident cost of crossing
2. Net present value (NPV) of warning device improvement benefit
3. Candidates for possible crossing consolidation

Each statewide scan provides valuable information on specific crossings. While the central focus of the SAP is crossings with multiple incidents, information in these scans can be used to help achieve the strategies and objectives defined in Chapter 7. It should be noted that none of the crossings identified in these statewide scans are also multiple-incident locations.

Two of the rankings were developed to incorporate possible improvements.

Annual expected incident cost of crossing

The first ranking was calculated based on expected annual incident cost. The current FRA and GradeDec probability formulas were used to determine the expected number of incidents per year, as well as the probability of severity for these incidents. Primary and secondary costs for fatal, injury, and PDO incidents were determined using previously described cost calculations, and then multiplied against the probabilities of each severity type to determine the expected annual incident cost. The annual expected cost for these locations ranged from $124,286 to $239,164. A map of locations and list with crossing details including expected cost can be found in Appendix C.

NPV of warning device improvement benefit

The second ranking of crossings was calculated based on Net Present Value (NPV) of warning device improvement benefits. The NPV was calculated by subtracting the cost of installing a warning device from present value of benefits installing warning device over its useful life. The benefit of warning device installation was calculated by multiplying the initial expected annual incident cost by an incident modification factor that corresponded with upgrading it to gates. This new value was subtracted from the initial expected annual incident cost to derive the total benefit a warning device upgrade would have. The cost of 2-quad gate installation was then subtracted from the benefit to calculate the NPV.

[7] The Benefit-Cost Analysis Guidance for Discretionary Grant Programs
[8] WisDOT Major Highway Projects Program

These costs were based on the number of traffic lanes at each crossing. It should be noted that the crossings all currently have flashing lights or passive warning devices, as crossings with existing gates were excluded from the ranking. Further investigation of expected benefits is possible if more information is uniformly available of gate type, medians, existence of overhead cantilevers with flashing lights, etc. A map of locations and list with crossing details including NPV can be found in Appendix C.

Rail Corridor Segments with Potential Consolidation Opportunities

Rail corridors were analyzed to determine if there were opportunities to evaluate consolidation. The corridor must have at least one crossing that meets three primary assumed conditions to be considered for consolidation:

1. The first assumed condition was that consolidating crossings will have no migrated incidents at other locations.
2. The second assumed condition was that possible detours of 5, 10, and 15 minutes are available.
3. The third assumed condition was that emergency services will not be negatively affected.

For rail corridor segments that met the assumptions listed above, a cost comparison was calculated to determine if there was a good candidate for consolidation of crossings. This calculation involved determining the operating costs and lost value of operator time caused by a consolidation and did not include the cost of the physical infrastructure work required. If the 20-year cost of consolidation was less than the 20-year expected incident cost, the rail corridor was flagged for consolidation consideration. The calculations were performed under three scenarios based on the possible length of rerouting time: 5-minute, 10-minute, and 15-minute detours.

6. PRIORITY HIGHWAY-RAIL GRADE CROSSING LOCATIONS

Chapter 4 and Chapter 5 provided information on the various safety challenges at at-grade crossings that are facing the state. When determining priority locations and safety challenges, the decision should be driven by empirical evidence and not speculation. This section summarizes which of the at-grade crossing locations WisDOT determined to be the priority and central focus of the SAP.

WisDOT decided that the priority for the SAP would focus on the crossing locations that had more than one incident over the past five years. Crossings with multiple incidents indicate a pattern of potential safety concerns and should be prioritized. Figure 4-13 shows a map of these crossing locations.

Table 6-1: Priority Highway-Rail Grade Crossing Locations (Multiple-Incident Locations)

Crossing ID	Road Name	City	County	Status
079961D	First Street	Pepin	Pepin	deficiencies identified
179791M	Washington Avenue	Oshkosh	Winnebago	deficiencies identified
179919F	Locust Street	Appleton	Outagamie	deficiencies identified
179939S	Memorial and College Avenue	Appleton	Outagamie	upgrade complete or programmed
181594Y	State Street	Marinette	Marinette	deficiencies identified
182045H	5th Avenue	Wausau	Marathon	deficiencies identified
186014X	13th Avenue	Bloomer	Chippewa	deficiencies identified
281845S	Hinkle Street	Green Bay	Brown	deficiencies identified
386506F	Greves Street	Milwaukee	Milwaukee	deficiencies identified
386632A	Seventh Street	Menasha	Winnebago	deficiencies identified
386974A	91st Street	Milwaukee	Milwaukee	upgrade complete or programmed
386979J	124th Street	Milwaukee	Milwaukee	upgrade complete or programmed
387972P	La Prairie Town Hall	Janesville	Rock	upgrade complete or programmed
390502K	70th Street State	Wauwatosa	Milwaukee	deficiencies identified
390521P	Brookfield Road	Brookfield	Waukesha	deficiencies identified
390877X	Hazelwood Avenue	Sparta	Monroe	deficiencies identified
390935R	Avon Street / Hagar Street	La Crosse	La Crosse	deficiencies identified
392754T	Main Street / Morgan Avenue	Junction City	Portage	deficiencies identified
689913X	Grand Avenue	Waukesha	Waukesha	deficiencies identified
689916T	Carroll Street	Waukesha	Waukesha	deficiencies identified
690119Y	Arndt Street	Fond Du Lac	Fond du Lac	deficiencies identified
690132M	Lone Elm Avenue	Vandyne	Fond du Lac	deficiencies identified
691156E	18th Street	Barron	Barron	deficiencies identified
697269F	County Road B	Gilman	Taylor	deficiencies identified
910730L	Country Meadows Road	Marinette	Marinette	upgrade complete or programmed

Table 6-1 lists priority location information for the 25 locations with multiple incidents. Also listed is the table is the status of crossings. Rows shaded in grey indicate that crossing has been upgraded or is currently programmed for improvements.

The team performed comprehensive site visits at all 25 of the priority locations to gather current information, document observations, and identify deficiencies. This effort provides valuable information as WisDOT determines the next steps to address the safety challenges at these sites.

7. ACTION PLAN

7.1 Introduction

This section of the SAP outlines and links goals and objectives to the safety challenges listed in the previous section, including tactical actions to be taken to meet the objectives and accomplish the goals.

The SAP Project Team has developed a list of improvement strategies and crossing treatments to improve safety. With the understanding that all sites are unique, consideration must be taken to address the specific characteristics and needs of the crossing.

7.2 Safety Improvement Approaches

Education and Outreach

- Target highway user demographics that were identified in Chapter 4 – drivers ages 16-39 with a focus on male drivers.
- Warning messages or signs at high incident frequency locations
- Work with Operation Lifesaver to expand public outreach efforts
- Local official outreach (presentations, work session, conferences)
- Continue and improve agencies' coordination on education

Legislative or Policy Approaches

- Review law enforcement training requirements and mandates
- Review driver's education class requirements and driver instruction best practices
- Evaluate the capacity and sustainability of available funding sources

Operational Changes

- Data collection and database improvements
- Update existing systematic approach to analysis, evaluation, prioritization, and programming
- SAP implementation

Innovative Solutions

- Train-activated warning enhancements
- Evaluation and potential adoption of new technologies to improve program efficiency, coordination, messaging, analysis, and system monitoring.

Highway Components

- Signing, pavement marking, and roadway lighting maintenance improvements
- Evaluate crossing consolidation with highway improvement projects

Geometric Crossing Improvements

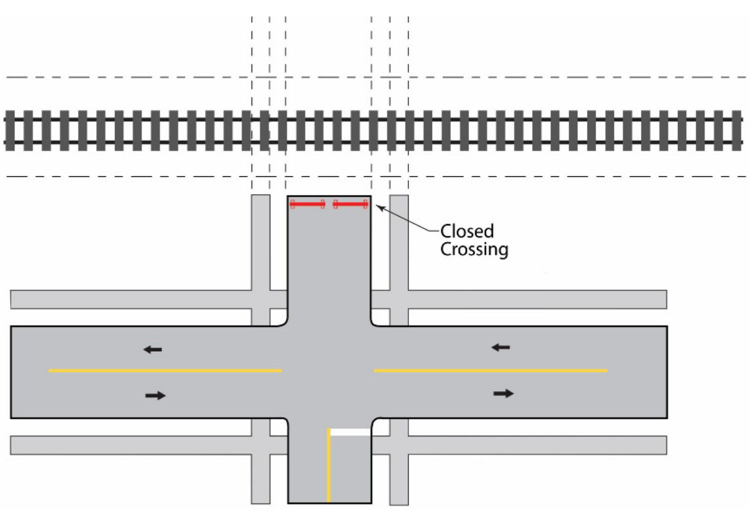
A variety of crossing treatments were developed to provide a toolbox of options that can be reviewed for potential crossing improvement projects.

- Crossing Consolidations
- Grade Separation
- Four-Quadrant Gates
- Non-Traversable Medians
- Channelization Devices and Delineators
- Improved Geometrics
- Vision Triangle Clearing
- Upgrade to Active Warning Devices

Crossing Consolidation

A highly effective way to improve crossing safety is consolidating crossings within a segment of road and improving remaining crossings that are to remain at grade. Consolidation of a crossing eliminates an at-grade crossing and should be considered when there are no significant impacts to traffic, safety, and access. A benefit to the railroad is the cost savings by avoiding maintenance costs of surfaces and grade crossing warning devices. Closure of a crossing with the addition of a turnaround (e.g. cul-de-sac) allows vehicles to turn around if needed but may require additional right of way. Other costs can vary significantly by location.

COST — **Costs can vary significantly**

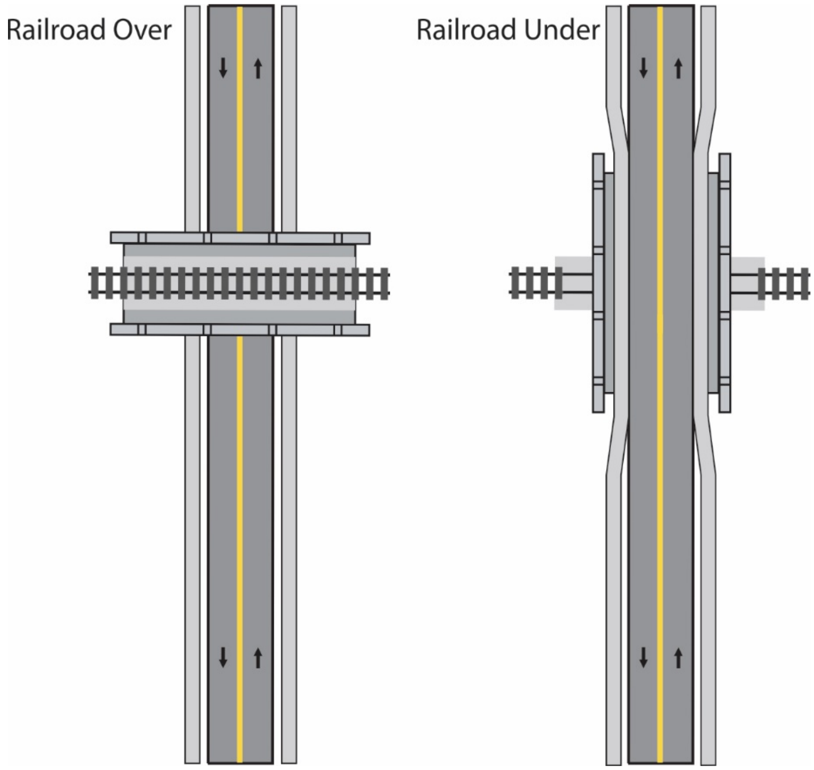


Grade Separation

A grade separated crossing improves safety by eliminating conflict points at an at-grade crossing and eliminates traffic delays caused by occupied crossings. Removing at-grade crossings can increase speed for both trains and cars. Grade separation can be costly, complicated, and may require additional right of way to construct the necessary structures.

COST

Costs can vary significantly

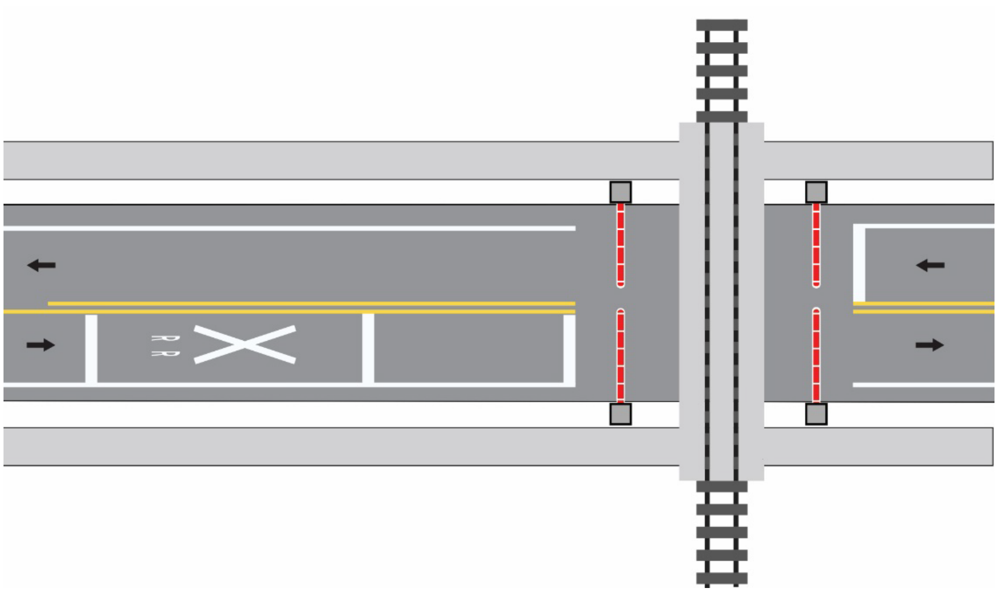


Four Quadrant Gates

Four-quadrant gates include four separate gate mechanisms that block both sides of tracks from both directions of traffic when a train is present. There are two entrance and two exit gates as part of the four-quadrant system. Exit gates begin to drop several seconds after the entrance gates to avoid entrapping vehicles between the closed gates. This improvement option has the advantage of causing minimal impact to access to adjacent properties.

COST

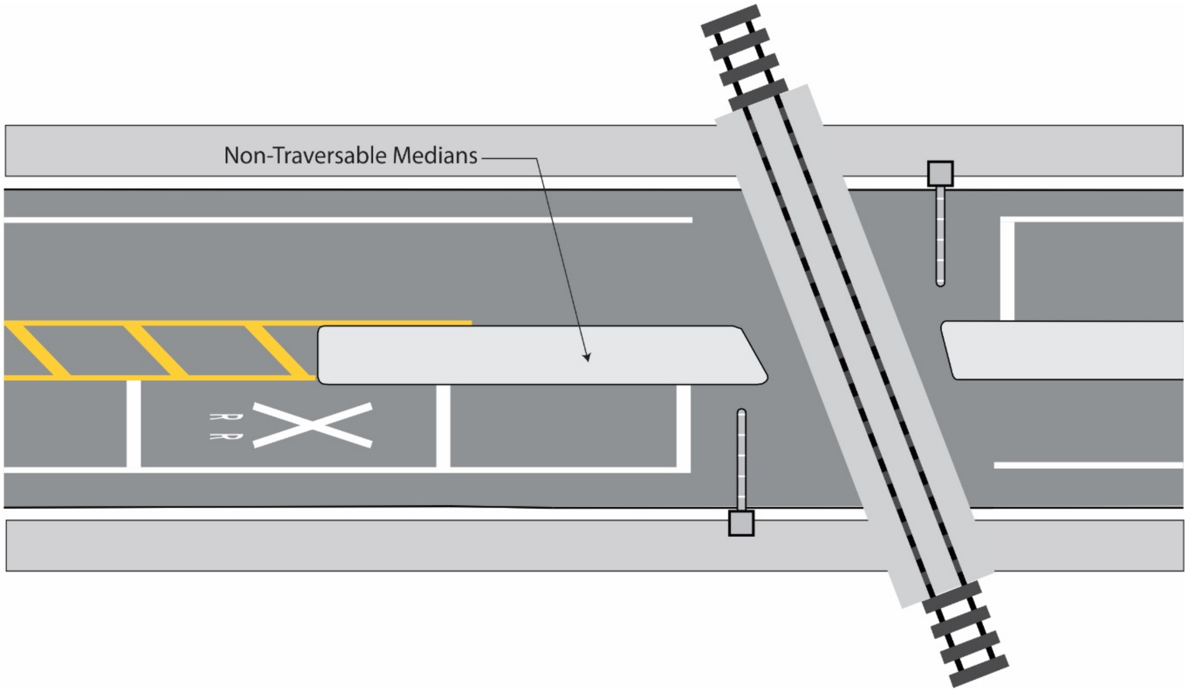
$300,000 - $500,000



Non-traversable Medians

Non-traversable medians prevent motorists from circumventing lowered gate arms. Accesses should be closed or relocated if they are within the extents of the median. When no other access options exit, private accesses may remain within the extents of the median but would be limited to right-in/right-out (RIRO) access. Non-traversable medians are generally four feet wide but may vary depending on roadway width limitations. In some cases, crossing improvements may be difficult or impossible due to the configuration of roadways, accesses, and other factors. Cost estimates for medians range depending on the need for roadway widening, access modifications, drainage, and other associated modifications.

COST **$20,000 - $100,000**

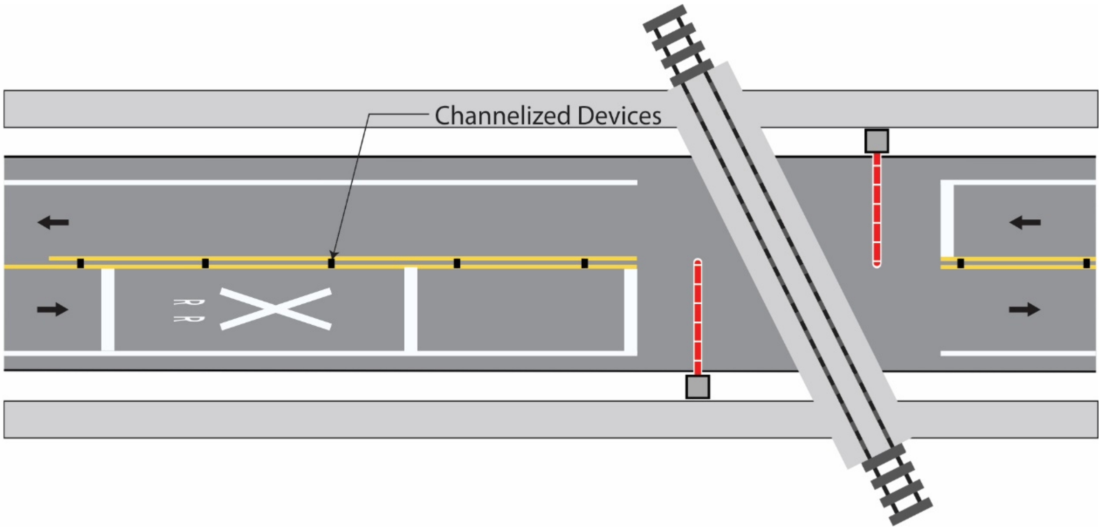


Channelization Device and Delineators

Channelization improvement options function similarly to non-traversable medians and are frequently used in place of non-traversable medians where cost, narrow roadway width, or other roadway conditions must be considered. Costs for these improvements are estimated at $50 per linear foot ($6,000 for two 60-foot medians, assuming no other roadway or drainage work). While they are easy to install, they require regular replacement especially in the winter with snow removal and contribute annual roadway maintenance costs.

COST

$50 per linear foot

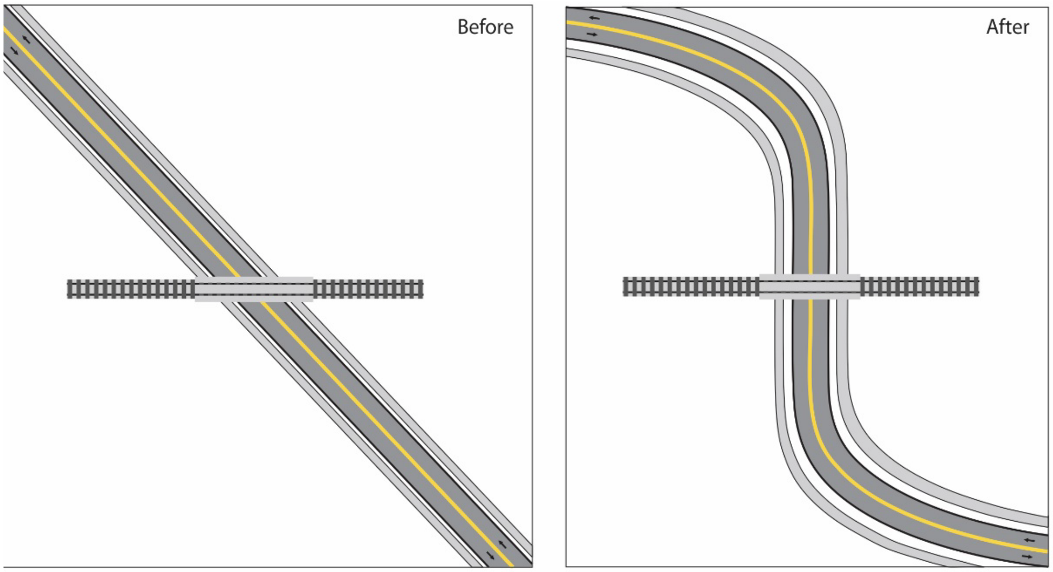


Improved Geometrics

Reconfigure the roadway geometrics to improve crossing safety. This can include relocation of nearby roadway intersection or straightening a skewed approach to achieve a crossing as close to 90 degrees as possible. Improving the geometrics at a crossing can be costly depending on necessary roadway reconstruction and may require additional space.

COST **Costs can vary significantly**

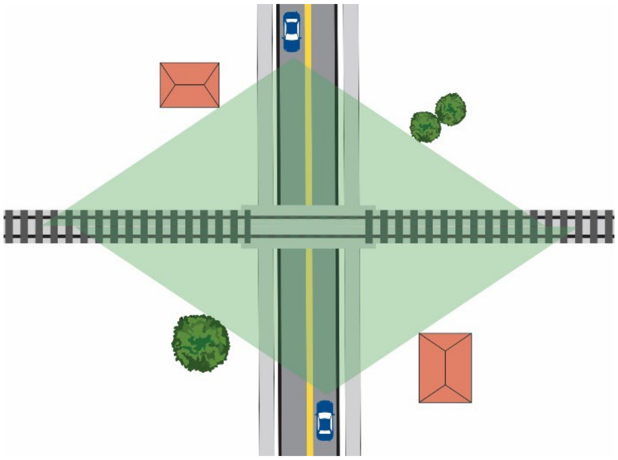
Example of Improving a Skewed Approach



Clear Vision Triangles

Encourage clearing of vision triangles consistent with State Statute 195.29(6). Though only five incident reports noted obstructed views, WisDOT and OCR observe that many crossings have inadequate vision triangles which could be a factor in incidents or near misses. Costs can vary from basic vegetation clearing to expensive real estate acquisition if structures are within the vision triangle.

COST **Costs can vary significantly**



Upgrade to Active Warning Devices

Upgrade a crossing with passive warning devices (Stop signs, cross buck signs, or lights only) to active warning devices such as bells, flashing lights, and automatic gates. Costs vary depending on treatment type. At some intersections, it may be necessary to coordinate the traffic signals with the active warning devices.

Installation of crossing warning devices cost approximately $200,000-$325,000 per crossing in addition to an annual maintenance fee that would be required.

Preemption should also be considered if crossing is nearby to traffic signals

COST

$200,000 - $325,000
+ annual maintenance fee

7.3 Action Plan – Goals, Objectives, and Strategies

Action steps were developed for the ten statewide goals that were defined in Chapter 1. As mentioned earlier, the goals are numbered for organizational purposes and numbering does not reflect priority. Objectives indicate how goals will be stratified, and the strategies are the specific tasks or steps that can be undertaken by rail-highway safety stakeholders to achieve the objectives. The goals include both short-term and long-term strategies. Where applicable, the intended time frame is stated. It is important to note that each goal has a different scale and scope. Some goals are broad which require more objectives and strategies. Others have a much narrower focus which requires fewer strategies.

For reference, below is the list of the ten defined goals:

1. Reduce the number and rate of incidents at railroad grade crossings
2. Reduce the number of severe incidents at locations with reoccurring incidents within the last five years
3. Efficiently deliver and manage projects in highway improvement, OCR safety, WisDOT safety and crossing surface repair programs
4. Implement and maintain safety improvements at interconnected crossing systems
5. Maintain a program to repair deficient railroad crossing surfaces on the STH network
6. Evaluate rail corridors for potential crossing consolidations
7. Improve data collection and analysis on railroad crossings
8. Implement design improvements at railroad grade crossings when undertaking highway improvement projects
9. Engage statewide stakeholders in education and enforcement
10. Reduce trespassing

Goal 1: Reduce the number and rate of incidents at railroad grade crossings.

Objectives:

- In partnership with OCR, continue to manage and improve the OCR Safety Program for installation of warning devices to maximize the benefit of Section 130 funding and designated state funding.
- Continue to manage and improve the WisDOT Safety Program for installation of warning devices and/or elimination of hazards that maximizes the benefit of Section 130 funding.
- Address deficiencies in railroad warning devices and surfaces at crossings where highway improvement projects are being implemented.
- Identify the needs of bicyclists and pedestrians at complex, multiple, or skewed rail crossings and at grade crossings with high volumes of pedestrian travel or near school zones or other pedestrian generators.

Strategies/Action Steps – Current Practice:

- Continue program stability by maintaining a four-year program of projects for both OCR and WisDOT Safety programs. Partner with OCR as appropriate.
- Continue to identify projects that are advanceable in order to accommodate changes in project schedules or unexpected balances becoming available.
- Actively monitor the program through monthly coordination meetings with OCR and monthly internal program coordination meetings.
- Monitor program monthly to ensure projects are programmed with a remaining balance for each state fiscal year of less than the approximate cost of an average project (approximately $200,000).
- Assess safety and crossing surface deficiencies at at-grade crossings within limits of planned highway improvement projects.
- Monitor deliverability of projects in the current fiscal year and next two years and build the program's fourth year as the year goes on. During the current fiscal year, year 4 of the program is filled.
- Commit to an advanceable project programming list strategy including an early May assessment of project status and program balances. Advance projects as necessary to deliver a full program that maximizes the use and benefit of Section 130 Funds.
- Manage an obsolete equipment replacement program (50% railroad and 50% Section 130 funds) to upgrade obsolete equipment. WisDOT solicits obsolete equipment candidates regularly from the railroad companies and works with the OCR to program these projects in both the OCR Safety and WisDOT Safety programs.

Strategies – Proposed Initiatives:

- Initiate a statewide analysis of crossing locations that exceed defined exposure rates to justify potential grade separations.
- Work to ensure that construction of grade separations is considered when highway projects are studied and scoped.
- Advocate for authority to spend additional federal Section 130 funds or state funds to implement high-benefit rail crossing safety improvements.
- Share information and data with OCR to expand their project selection process by providing a specific list of top candidate crossings to OCR.

Goal 2: Reduce the number of severe incidents at locations with reoccurring incidents within the last five years

Objectives:

- Analyze crossings with multiple incidents in five years and analyze causal factors and treatments that can be applied system wide. Multiple incident locations are listed in Table 6-1 and Figure 4-13 .
- Develop methodologies to correct deficiencies statewide that are identified through the analysis of the multiple-incident crossings.

Strategies/Action Steps – Current Practice:

- Conduct crossing reviews with a crossing Diagnostic Team including WisDOT Engineers, OCR investigators, local jurisdictions, and railroads to evaluate crossings with reoccurring incidents.

Strategies/Action Steps – Proposed Initiatives:

- Annually revisit a refreshed list of crossings with multiple severe incidents within the past five years.
- Identify which of the multiple-incident crossings have projects in WisDOT's six-year program and ensure safety improvements are addressed in those projects as appropriate.
- Develop a system to categorize safety deficiencies and potential safety treatments.
- Monitor the statewide rail system to identify priority crossings with the identified deficiencies to apply the safety treatments within available funding.
- In concert with WisDOT's Bureau of Transportation Safety, coordinate with EMS and police services agencies to identify locations with recurring incidents to understand effective improvement strategies.

Goal 3: Efficiently deliver and manage projects in highway improvement, OCR safety, WisDOT safety, and crossing surface repair programs

Objectives:

- Define and keep up-to-date procedures in the Facilities Development Manual and internal policy and procedural manuals to execute the delivery of railroad projects.
- Inform stakeholders of roles to carry out the crucial process steps in railroad coordination.
- Identify and assign necessary staff resources that are available to deliver the projects.

Strategies/Action Steps – Current Practice:

- Refine and improve process for tracking and documenting railroad signal and surface projects. WisDOT will track completion and maintain documentation of executed agreements, work start notices, construction inspection, and approved invoices.
- Ensure timely review of project completion and associated invoices to work toward project completion and financial closure.
- Maximize use of Section 130 funds by managing project closure and prompt de-obligation of unused funds.
- On a quarterly schedule, review FHWA's list of inactive railroad projects. WisDOT evaluates all projects for ability to close associated purchase orders and project IDs.

Strategies/Action Steps – Proposed Initiatives:

- Focus on current practices and revisit at next SAP update.
- Promote railroad company and region railroad coordinator education and outreach to ensure project delivery by keeping railroad coordination policy and guidance documents up-to-date with respect to changes in WisDOT policy, railroad policy and applicable laws.

Goal 4: Implement and maintain safety improvements at interconnected crossing systems

Objectives:

- For existing interconnected systems – follow OCR's requirements and FRA's guidance on annual joint inspections at preempted crossings, including the roadway authority and railroad company
- For installation of new systems during the design of interconnected preempted systems, conduct a thorough engineering analysis following Manual for Uniform Traffic Control Devices (MUTCD) requirements to ensure proper functioning of the interconnected system

Strategies/Action Steps – Current Practice:

- Identify and program improvements to interconnected systems in WisDOT's Safety Program using Section 130 funds (state appropriation 287).
- Ensure that on new projects, all current standards for clearance time are thoroughly determined and calculated with the railroad.

Strategies/Action Steps – Proposed Initiatives:

- On non-state-owned traffic signals, provide technical resources to assist local entities performing annual inspections.
- Seek funding to provide resources for annual joint inspection efforts.
- Program projects through Section 130 engaging all responsible parties including the highway and railroad authorities.
- Request exemption requirements, annual inspection requirements, and event recorders on WisDOT's petitions to OCR.
- Support development and attendance at WisDOT-tailored training on preempted crossings.

Goal 5: Maintain a program to repair deficient railroad crossing surfaces on the state highway network

Objectives:

- For railroad crossings on the State Trunk Highway network not within connecting highway limits, maintain and execute a Crossing Surface Repair program to fund crossing replacements on crossings where improvement projects are not programmed.

Strategies/Action Steps – Current Practice:

- On an every-other-year cycle, evaluate all 140 eligible crossings on the State Trunk Highway Network using standardized criteria, unique to crossing surface type.
- Continue to refine the evaluation criteria for grading of eligible crossings.
- Evaluate and prioritize crossing surfaces that are eligible for program funding. Strive to use all current year available dollars in the program.
- Due to the nature of crossing surface deterioration, maintain a full 2-year program, i.e. the current year and following year.

Strategies/Action Steps – Proposed Initiatives:

- Create a database to track installation dates and crossing surface type to gather data regarding longevity of newly installed crossings and help determine anticipated life of a crossing and predict when crossings will need to be replaced again.

Goal 6: Evaluate Rail Corridors for Potential Crossing Consolidations

Objectives:

- Promote evaluation of rail corridors for opportunities to consolidate crossings. Facilitate crossing closures in conjunction with highway improvement projects and railroad crossing safety upgrades when appropriate.

Strategies/Action Steps – Current Practice:

- Work with railroad companies to consider incentive payments for consolidating crossings and inform the local government of available federal matching incentive funding.
- When considering highway and roadway improvement, always consider whether the crossing meets closure criteria identified in FRA's Railroad Highway Crossing Handbook.

Strategies/Action Steps – Proposed Initiatives:

- Determine whether upgrades to adjacent crossings are necessary and will help facilitate the consolidation of crossings.
- In coordination with OCR, consider crossings within a corridor to help identify closure candidates.
- During highway improvement project development, involve local stakeholders and railroad companies and educate the locals on safety benefits of crossing consolidation and the steps to analyze and perform consolidations.
- Participate in OCR closure dockets by offering engineering-based testimony and exhibits.

Goal 7: Improve data collection and analysis on railroad crossings

Objectives:

- Achieve compliance with FRA's requirement to submit roadway information for all state public railroad highway crossings on a three-year cycle.
- Update crossing data in the Railroad Crossing Inventory System on the same three-year cycle.

Strategies/Action Steps – Current Practice:

- RCIS data is generated from railroad crossing inventories and from the FRA database. WisDOT's statewide benefit/cost analysis and individual analysis use data from RCIS. Develop process to ensure data in RCIS is as current as possible.
- Use the compiled data to identify and prioritize projects.

Strategies/Action Steps – Proposed Initiatives:

- Develop and use data to search for deficiencies in equipment condition or adequacy.

Strategies/Action Steps – Proposed Initiatives, 2-3 years:

- Review state system used to identify deficiencies in signage, pavement marking, warning devices and grade crossing surface
- Develop a process to determine AADT on all public crossings and enter into the database. Initiate this improvement by expanding the regular 3-year counting program to include counts at railroad crossings.
- Improve automation system from data collection to storage in RCIS to uploading to FRA, integrating GIS mapping capabilities and database capabilities. Also develop and provide the ability to import inventory information straight from the field to the database.
- Identify and correct mismatches between FRA, OCR, and WisDOT signal data.
- Build a list of projects that could use improvements to geometrics and develop a strategy on how to fund and deliver these projects.
- In conjunction with OCR, formulate strategies to collect and use inventory data to identify deficiencies and prioritize potential efforts on pavement marking, signs, vision triangle deficiencies and bike/pedestrian deficiencies.

Goal 8: Implement design improvements at railroad grade crossings when undertaking highway improvement projects

Objectives:

- Apply the desirable standards for roadway design when WisDOT is undertaking improvement projects near grade crossings

Strategies/Action Steps – Current Practice:

- Conduct site visits with WisDOT Engineers, OCR investigators, local jurisdictions, railroads, and other appropriate stakeholders to evaluate candidate crossings for geometric improvements.
- ADA requirements are routinely addressed in improvement projects, including installation of detectable warning fields at crossings with sidewalks or shared use paths. Design features that are evaluated include re-alignment of walkways and bikeways, pavement marking and signage, dedicated warning devices, and replacement of existing signs with high-visibility signs.
- Where improvement projects are being developed, identify and incorporate enhancements that would make pedestrian and bike movements safer; i.e. realignments, auxiliary warning devices, etc.
- As a policy, WisDOT recommends installation of lights and gates with 12" lenses. The incremental increased cost of gates versus a lights-only installation is outweighed by the benefit of adding gates.

Strategies/Action Steps – Proposed Initiatives:

- Use inventory data to identify areas where signage improvements could be implemented. Develop strategies to identify and fund statewide sign replacements. Use the data to quantify the inventory presence/absence of bike and pedestrian accommodations.
- Use data from the crossing inventories to determine where there are opportunities for improvement in pedestrian and bike access and safety.
- Build list of projects that could benefit from improved geometrics and implement those improvements within programmed improvement projects, as appropriate.

Goal 9: Engage statewide stakeholders in education and enforcement

Objectives:

- Support advocacy organizations and local governments in the effort to provide public safety educational messages.

Strategies/Action Steps – Current Practice:

- Coordinate and support Wisconsin Operation Lifesaver education and outreach efforts.
- Participate in Rail Safety Week annually

Strategies/Action Steps – Proposed Initiatives:

- Work with local municipalities on education and enforcement in areas where trespassing is particularly prevalent.
- For enforcement, create a toolbox of trainings for local enforcement agencies and provide educational material (brochures from FRA and OLI website) about emergency notification signs.
- Use toolkit of public outreach tools such as lesson plans for teachers. Explore templates from other states. Provide public services announcements to local units of government, newspapers, etc.
- Partner with Operation Lifesaver to provide educational opportunities identifying partnerships and educating stakeholders about railroad safety.

Strategies/Action Steps – Proposed Initiatives, 2-3 years:

- Support law enforcement outreach through OLI.
- Support educational endeavors such as public education of what to do when seeing a “do not stop on tracks” sign. Include corridor specific data when available.
- Educational endeavor on meaning of exempt signs. Target audience could be drivers’ education and/or bus companies.

Goal 10: Reduce Trespassing

Objectives:

- Quantify the presence or absence of bike and pedestrian accommodations
- Consider the needs of bicyclists and pedestrians at grade crossings with:
  - high volume of pedestrian travel
  - frequent and/or high-speed trains
  - wide, complex, multiple, or skewed rail crossings
  - near school zones or pedestrian generators such as parks or business areas
- Maximize state resources to implement safe crossing solutions for pedestrians and bicyclists.
- Identify the needs of pedestrians to access adjacent lands, while minimizing trespassing incidents on railroad property.

Strategies/Action Steps – Current Practice:

- Review proposed law changes that may make rails or rail crossings less safe for individuals and motorists. Provide expertise to decision-makers.
- Address access issues and to provide safe crossings for pedestrians and bikers with highway improvement and safety projects when possible.
- Conduct ongoing education and outreach with Operation Lifesaver to communicate the importance of education and enforcement of rail trespassers.

Strategies/Action Steps – Proposed Initiatives:

- Help facilitate locally led projects to provide access and safe crossings for bikers and pedestrians.
- Partner with Wisconsin DNR, OLI, railroads, and outdoor recreational and sportsman groups for education on trespassing.
- Monitor and implement suggestions from FRA's National Strategy to Prevent Trespassing on Railroad Property - https://railroads.dot.gov/national-strategy-prevent-trespassing.

8. NEXT STEPS

8.1 Introduction

This purpose of this plan is to provide implementable strategies and action steps to improve rail safety throughout Wisconsin. And for that plan to be implemented, responsibility must be assigned to specific parties.

8.2 Designated Official Monitoring and Communication

WisDOT designates Lisa Stern, Chief of Railroads and Harbors to oversee implementation and evaluation of the SAP.

- WisDOT will review this document on an annual basis
- Assign the strategies outlined in the goals and objectives sections to specific groups or persons within WisDOT and work with other stakeholders to meet set goals and objectives.
- When a priority location is programmed for a project, WisDOT will use Chapter 7 to compare and consider the various improvement alternatives when scoping the project
- Coordinate with railroad maintenance departments to determine if any crossing surfaces identified as a priority are scheduled for routine maintenance.

8.3 Measurement and Reporting

The data collected during the development of this document will prove more valuable as additional data is collected over time. WisDOT will continue to collect crossing data on an annual basis which will be assessed and reviewed to determine if the various objectives outlined in Chapter 1 are being met.

8.4 Next Steps

Use the approved SAP as reference document for the Connections 2050 Long-Range Transportation Plan Update, the Wisconsin Rail Plan 2050 update, and other broad transportation planning documents. Determine a process to monitor the progress of the SAP. Continue to track and document data for future updates to the SAP.

Wisconsin should regularly check in on progress of actions listed in the SAP to obtain information on the status of the action items. This monitoring process should produce information that can be shared with the responsible State agencies and rail safety stakeholders. As the SAP reaches its objectives, success should be shared with all stakeholders to maintain momentum and affirm commitments to the goals, objectives, and actions in the SAP. Conversely, if goals, strategies, or objectives need adjustment or are not on track to be met by a specified time goal, then discussion should take place to determine the reasons, with revisions being made as necessary.

WisDOT will review the planning process of developing this SAP and work with stakeholders to decide whether changes and improvements are necessary. WisDOT will assess feedback for future iterations of the SAP considering the data collected and results. As the SAP achieves its objectives, a new planning cycle will build upon that success and the new baseline of grade crossing safety.

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APPENDIX A. Glossary of Terms

Abandonment. The relinquishment of interest (public or private) in a ROW or activity thereon with no preservation of rights to reclaim or use again for the original purposes.

Accident/Incident/Collision/Crash. Any impact between railroad on-track equipment and a highway user at a grade crossing (GX) or pathway crossing (PX). Accident is used in relation to FRA forms and process, otherwise the word incident is used in this document.

Active Crossing. A grade crossing which includes an Active Grade Crossing Warning System as described below.

Active Grade Crossing Warning System. The flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of rail traffic at grade crossings.

Advance Preemption. The notification of approaching rail traffic that is forwarded to the highway traffic signal controller unit or assembly by the railroad equipment in advance of the activation of crossing warning devices.

Advance Preemption Time. The period of time that is the difference between the required maximum highway traffic signal preemption time and the activation of the railroad warning devices.

Americans with Disabilities Act (ADA) of 1990. A civil rights law that prohibits discrimination based on disability. Refers to the ADA of 1990 (PL 101-336) and the ADA Amendments Act of 2008 (PL 110-325).

Anchors. Rail-fastening devices used to resist the longitudinal movement of rail due to train operations and maintain proper expansion allowance for temperature changes at joint gaps.

Annual Average Daily Traffic (AADT). The total volume of traffic passing a point or segment of a highway facility in both directions for one year divided by the number of days in the year. Normally, periodic daily traffic volumes are adjusted for hours of the day counted, days of the week, and seasons of the year to arrive at average annual daily traffic.

Apportionment. An administrative distribution of funds based on a prescribed formula provided in law by a governmental unit to another governmental unit for specific purposes and for certain periods.

Appropriation. The act of a legislative body that makes federal-aid highway funding available for obligation and expenditure with specific limitations as to amount, purpose, and duration.

Ballast. Material placed on a track roadbed to hold the track in alignment and elevation. It consists of crushed stone, generally 1 to 2 inches in size, angular, rough-surfaced, clean, free of sand, loam, clay, flat, elongated, soft or disintegrated pieces, and other deleterious substances.

Bar Signals (LRT). An illuminated signal configured in the shape of a bar, normally positioned to appear in a vertical, angled, or horizontal orientation. These are used as aspects to convey a signal indication. Bar signals are typically used on LRT systems. LRT bar signals are white, monochrome bar signals that are separated in space from motor vehicle signals.

Benefit-Cost Ratio. The economic value of the project benefits (e.g., reduction in fatalities, injuries, and property damage, reduced delay, reduced fuel and operating costs, reduction in emissions, etc.) divided by the cost of the project.

Blank-Out Sign. A sign that displays a single predetermined indication only when activated. When not activated, the sign legend should not be visible.

Cantilevered Signal Structure (Cantilever). A structure that is rigidly attached to a vertical pole and used to provide overhead support of signal units; the term Cantilever refers to a Cantilevered Signal Structure with one or more flashing-light units attached.

Channelization Device. A traffic separation system made up of a raised longitudinal channelizer with vertical panels or tubular delineators. These devices can serve several purposes such as being placed between opposing highway lanes designated to alert or guide traffic in a particular direction, or as a fencing system used to separate modes (e.g., channelize pedestrians).

Clear Storage Distance. The distance available for vehicle storage measured between six (6) feet from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway.

Clearing Sight Distance. The distance measured along the track which a road user must be able to see to decide whether it is safe to cross based upon the speed of an approaching train and the acceleration characteristics of the highway vehicle.

Clear Zone. The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non- recoverable slope, and/or a clear run-out area.

Constant Warning Time Detection. A means of detecting rail traffic that provides road users with relatively uniform warning times prior to the approach of through trains that neither accelerate nor decelerate after having been detected.

Crossing Angle. The angle 90 degrees or less between the intersection of the centerlines of the railroad tracks and the roadway.

Design Vehicle. The longest vehicle permitted by statute of the road authority (State or other) on that roadway.

Diagnostic Team. A group of knowledgeable representatives of the parties of interest (such as the railroad, road authority, State regulatory agency, where applicable) in a highway-rail crossing or group of crossings who evaluate conditions at the crossing(s) to identify safety issues.

Dynamic Envelope. The clearance required for the train and its cargo overhang due to any combination of loading, lateral motion, or suspension failure.

Dynamic Exit Gate Operating Mode. A mode of operation where the exit gate operation is based on the presence of vehicles within the minimum track clearance distance.

Easement. A right to use or control the property of another for a designated purpose. Examples include:

Drainage easement. An easement for directing the flow of water.

Planting easement. An easement for reshaping roadside areas and establishing, maintaining, and controlling plant growth thereon.

Sight line easement. An easement for maintaining or improving the sight distance.

Slope easement. An easement for cuts or fills.

Economic Analysis. A determination of the cost-effectiveness of a project by comparing the benefits derived and the costs incurred in a project.

Entrance Gate. An automatic gate that can be lowered across the lanes approaching a grade crossing to block road users from entering the grade crossing.

Exit Gate. A crossing gate that is used on the departing lanes of traffic to block users from entering a highway rail crossing.

Exit Gate Clearance Time. For four-quadrant gate systems, the amount of time provided to delay the descent of the exit gate arm(s) after entrance gate arm(s) begin to descend.

Exit Gate Management System. A system using a detector or detectors with processing logic to identify the presence of vehicles within the minimum track clearance distance and used to control the operation of the exit gates or for train control purposes.

Exit Gate Operating Mode. For four-quadrant gate systems, the mode of control used to govern the operation of the exit gate.

Fail-Safe. A design practice applied to a system or device such that the result of failure either prohibits the system or device from assuming or maintaining an unsafe state or causes the system or device to assume a state known to be safe regardless of actual prevailing conditions.

False Activation. A condition under which crossing warning devices are activated but there is no train approaching the crossing.

Flagger (Flagging). A person who actively controls the flow of vehicular traffic into and/ or through a temporary traffic control zone using hand-signaling devices or an Automated Flagger Assistance Device (AFAD). In the railroad context, a railroad flagger is a person who is authorized by the railroad to provide warning of the approach of a train or the presence of roadway workers along the right-of-way, and who may be authorized to control rail traffic through a construction zone along a railroad.

Flashing-Light Signals. A warning device consisting of two red signal indications arranged horizontally that are activated to flash alternately when a train is approaching or present at a highway-rail grade crossing.

Functional Classification. Designation of a transportation system into classes or systems by the nature of the service they provide in serving travel needs.

Grade. The rate of ascent or descent of a roadway, expressed as a percent, or the change in roadway elevation per unit of horizontal length.

Grade Crossing (Crossing). The general area where a highway and a railroad and/or light-rail transit route cross at the same level, within which are included the tracks, highway, and traffic control device for traffic traversing that area.

Grade Separation. A crossing of two roadways, or a roadway and railroad tracks, at different levels that do not physically meet.

Guardrails. A safety barrier intended to deflect an errant vehicle back to the roadway, and prevent an errant vehicle from striking a roadside obstacle that is more hazardous than the guardrail itself.

Highway (Street or Road). A general term for denoting public way for purposes of travel, including the entire area within the ROW.

Highway-Rail Grade Crossing. A location where a highway, road, or street and the railroad ROW cross at the same level, within which are included the railroad tracks, highway, and traffic control devices for highway traffic traveling over the railroad tracks.

Highway User. Includes all automobiles, buses, trucks, motorcycles, bicycles, farm vehicles, pedestrians, and all other modes of surface transportation, motorized and un-motorized.

Interconnection (Preemption Interconnection). The electrical connection between the railroad crossing warning system and the highway traffic signal controller assembly for preemption to coordinate traffic signals and warning devices.

Locomotive. A piece of on-track equipment other than hi-rail, specialized maintenance, or other similar equipment:

Locomotive Cab or Cab Car. The space in a locomotive unit, diesel or electric multiple- unit (DMU/EMU), or push-pull passenger "cab coach" containing the operating controls and providing shelter and seats for the engine crew.

Locomotive Horn. An air horn, steam whistle, or similar audible warning device mounted on a locomotive or control cab car. The terms "locomotive horn," "train whistle," "locomotive whistle," and "train horn" are used interchangeably in the railroad industry.

Main (Track). A track which is used for through trains operating between stations and terminals as distinguished from a siding which branches from a main line track and is of limited length.

Manual on Uniform Traffic Control Devices (MUTCD). The *Manual on Uniform Traffic Control Devices*, approved by the Federal Highway Administration, is the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with 23 U.S.C 109(d) and 402(a). For the purpose of the MUTCD applicability, "open to public travel" includes toll roads and roads within shopping centers, airports, sports arenas, and other similar business and/or recreation facilities that are privately owned but where the public is allowed to travel without access restrictions. Except for gated toll roads, roads within private gated properties where access is restricted at all times are not included in this definition.

Maximum Highway Traffic Signal Preemption Time. The maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the ROW transfer and queue clearance, including separation time.

Median. The area between two roadways of a divided highway measured from edge of traveled way to edge of traveled way, excluding turn lanes. The median width may be different between intersections, interchanges, and opposite approaches of the same intersection.

Minimum Track Clearance Distance (MTCD). For standard two-quadrant warning devices, the minimum track clearance distance is the length along a highway at one or more railroad or light rail transit tracks, measured from the highway stop line, warning device, or 12 feet perpendicular to the track center line, to 6 feet beyond the track(s) measured perpendicular to the far rail, along the center line or edge line of the highway, as appropriate, to obtain the longer distance. For Four-Quadrant Gate systems, the minimum track clearance distance is the length along a highway at one or more railroad or light rail transit tracks, measured either from the highway stop line or entrance warning device, to the point where the rear of the vehicle would be clear of the exit gate arm. In cases where the exit gate arm is parallel to the track(s) and is not perpendicular to the highway, the distance is measured either along the center line or edge line of the highway, as appropriate, to obtain the longer distance.

Minimum Warning Time (MWT). The least amount of time the active crossing warning system is designed to remain activated prior to the arrival of a train at a highway-rail grade crossing.

Passive Crossing. A crossing where warnings and traffic control is provided by passive devices such as signs and pavement markings where no Active Grade Crossing Warning System is present.

Pathway. A general term denoting a public way for purposes of travel by authorized users outside the traveled way and physically separated from the roadway by an open space or barrier and either within the highway ROW or within an independent alignment. Pathways include shared-use paths or trails but do not include sidewalks along the roadway traveled way.

Pathway Crossing. Where a pathway and railroad or LRT tracks cross at the same level, within which are included the track, pathway, and traffic control devices for pathway traffic traversing that area.

Pathway Grade Crossing. A pathway that crosses railroad tracks at grade, which is dedicated for the use of non-vehicular traffic, and which is not associated with a road or highway.

Pavement Markings. Markings set into the surface of, applied upon, or attached to the pavement for regulating, warning, or guiding traffic.

Preemption Clearance Interval. The part of a traffic signal sequence displayed as a result of a preemption request when vehicles are provided the opportunity to clear the railroad or LRT tracks, or a busway prior to the arrival of the train, or bus for which the traffic signal is being preempted.

Preemption. The transfer of normal operation of traffic signals to a special control mode that interrupts the normal sequence of traffic signal phases to accommodate train operation at or adjacent to the traffic signal-controlled intersection.

Pre-signal. Traffic control signal faces that control traffic approaching a grade crossing in conjunction with the traffic control signal faces that control traffic approaching a highway- highway intersection beyond the tracks. Supplemental near-side traffic control signal faces for the highway-highway intersection are not considered pre-signals. Pre-signals are typically used where the clear storage distance is insufficient to store one or more design vehicles.

Priority. Modification of the normal highway traffic signal operation process to assign who has the right-of-way in the intersection to accommodate train operation at or adjacent to a traffic signal-controlled intersection.

Private Crossing. A location where a private highway, road, or street, including associated sidewalks or pathways, crosses one or more railroad tracks.

Public Crossing. A highway-rail or pedestrian grade crossing where a roadway or a pathway, under the jurisdiction of and maintained by a public authority, intersects with the railroad tracks at the same level. No approach may be on private property, unless State law or regulation provides otherwise.

Queue Clearance Time. The time required for a stopped design vehicle that is stopped inside the minimum track clearance distance to start up, move through, and clear the entire minimum track clearance distance. If pre-signals are present, this time must be long enough to allow the vehicle to move through the intersection or to clear the tracks if there is sufficient clear storage distance. If a four-quadrant gate system is present, this time must be long enough to permit the exit gate arm to lower after the design vehicle is clear of the minimum track clearance distance.

Queue Cutter Signal. A traffic control signal that is located just upstream from a crossing where traffic has been observed to queue across the crossing due to a downstream condition. Queue cutters are intended to prevent vehicular queueing across tracks at a crossing and are activated either by detection of a traffic queue getting close to the crossing, or by the approach of a train. A queue cutter signal is not operated as a part of a downstream intersection traffic control signal but is an independently controlled traffic control signal with interconnection to the adjacent crossing warning signal system.

Quiet Zone. A segment of a rail line, within which is situated one or a number of consecutive public highway-rail crossings at which locomotive horns are not routinely sounded per 49 CFR Part 222. (May include private and pedestrian crossings.)

Right-of-Way (ROW). A general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes. Alternately, "right-of-way" is also a

term that confers to a road user or train the priority to proceed in preference to other vehicles or pedestrians, depending upon the rules of the road and traffic control devices in use.

Right-of-Way Transfer Time. The maximum amount of time needed by the traffic signal system to change from its current signal indication to present the track clearance green indication. This includes any railroad or highway traffic signal control equipment time to react to a preemption call and any required traffic control signal green, pedestrian walk and clearance, yellow change, and red clearance intervals for conflicting traffic.

Roadway. The portion of a highway improved, designed, or ordinarily used for vehicular travel and parking lanes, but exclusive of the sidewalk, berm, or shoulder even though such sidewalk, berm, or shoulder is used by persons riding bicycles or other human-power vehicles.

Road User. Vehicle operators, pedestrians including persons with disabilities, or bicyclists within a road or highway.

Separation Time. The portion of highway traffic signal preemption time during which the minimum track clearance distance is clear of vehicular traffic prior to the arrival of the train.

Shoulder. The portion of the roadway adjacent to the traveled way that is primarily intended for accommodation of stopped vehicles for emergency use and for lateral support of base and pavement surface courses.

Sidewalk. That portion of a street between the curb line or the lateral line of a roadway, and the adjacent property line or on easements of private property that is paved or improved and intended for use by pedestrians.

Simultaneous Preemption. Notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly and railroad active crossing warning devices at the same time.

Stopping Sight Distance. The length of highway required to safely stop a vehicle traveling at a given speed.

Swing Gate. A self-closing fence-type gate designed to swing open away from the track area and return to the closed position upon release.

Timed Exit Gate Operating Mode. A mode of operation where the beginning of exit gate descent is based on a predetermined time interval.

Traffic Control Device. A sign, signal, marking, or other device used to regulate, warn, or guide traffic.

Train. One or more locomotives coupled with or without cars that operates on railroad or LRT tracks and to which State law requires that all other traffic must yield the ROW at highway-rail grade crossings.

Traveled Way. The portion of the roadway for the movement of vehicles, exclusive of shoulders.

Trespassing. Walking, loitering, or being present upon the track of any railroad by unauthorized persons not at designated crossing locations, as further clarified in state statute 192.32.

Volume. The number of vehicles passing a given point during a specified length of time.

Warrants. A threshold condition based upon average or normal conditions that, if found to be satisfied as part of an engineering study, shall result in analysis of other traffic conditions or factors to determine whether a traffic control device or other improvement is justified. Warrants are not a substitute for engineering judgment. The fact that a warrant for a particular traffic control device is met is not conclusive justification for the installation of the device.

Wayside Equipment. The signals, switches, and/or control devices for railroad operations housed within one or more enclosures located along the railroad ROW.

Wayside Horn. A stationary horn located at a highway-rail crossing or pathway crossing, designed to provide, upon the approach of a locomotive or train, audible warning to oncoming motorists of the approach of a train.

APPENDIX B. Risk Assessment Calculations and Equations

Collision Probability

Equation 1: Expected Cost of an Incident - Primary Effect Costs

$$\begin{aligned} &Expected\ Cost\ of\ a\ Crash \\ &\quad = [Probability\ of\ a\ Crash] * [Probability\ of\ Property\ Damage] \\ &\quad * [Cost\ of\ Property\ Damage] + [Probability\ of\ a\ Crash] \\ &\quad * [Probability\ of\ Injury] * [Cost\ of\ Injury] + [Probability\ of\ a\ Crash] \\ &\quad * [Probability\ of\ Fatality] * [Cost\ of\ Fatality] \end{aligned}$$

Taking these secondary effects into account, the expected cost of an at-grade crossing collision becomes the equation shown in Equation 2.

Equation 2: Expected Cost of Incident - Primary and Secondary Effect Costs

$$\begin{aligned} &Expected\ Cost\ of\ Crash \\ &\quad = [Probability\ of\ a\ Crash] * [Probability\ of\ Property\ Damage] \\ &\quad * [Cost\ of\ Property\ Damage] + [Probability\ of\ a\ Crash] \\ &\quad * [Probability\ of\ Injury] * [Cost\ of\ Injury] + [Probability\ of\ a\ Crash] \\ &\quad * [Probability\ of\ Fatality] * [Cost\ of\ Fatality] + [Probability\ of\ a\ Crash] \\ &\quad * [Cost\ of\ Secondary\ Effects] \end{aligned}$$

Equation 3: Simplified Cost of Incident

$$\begin{aligned} &Expected\ Cost\ of\ a\ Crash \\ &\quad = [Probability\ of\ a\ Crash] * ([Primary\ Effect\ Costs] \\ &\quad + [Secondary\ Effect\ Costs]) \end{aligned}$$

The rest of this section will elaborate on estimation of collision probabilities as well as measuring primary and second costs of the collision.

The US DOT formula includes a normalizing constant for each warning device at a crossing (passive, flashing lights, and flashing lights and gates), represented as *Adj* in Equation 4. The formula used to calculate the predicted number of incidents at a crossing is as follows:

Equation 4: Predicted Number of Accidents at the Crossing US DOT Formula

$$a = k \times EI \times DT \times MS \times MT \times HL \times HP$$

$$T_o = \frac{1}{0.05 + a}$$

$$NA = \frac{(a * T_o) + N}{T_o + 5} * Adj$$

Variable	Type of Grade Crossing		
	Passive	*Flashing Lights*	*Lights and Gates*
k	0.0006938	0.0003351	0.0005745
EI	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.37}$	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.4106}$	$\left[\frac{Expose + 0.2}{0.2}\right]^{0.2942}$
DT	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1781}$	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1131}$	$\left[\frac{dthru + 0.2}{0.2}\right]^{0.1781}$
MS	$e^{0.0077 * ms}$	1	1
MT	1	$e^{0.1917 * tracks}$	$e^{0.1512 * tracks}$
HL	1	$e^{0.1826 * (lanes - 1)}$	$e^{0.142 * (lanes - 1)}$
HP	$e^{-0.5966 * (paved - 1)}$	1	1
Adj	0.5086	0.3106	0.4846

Where:

- T_o: formula weighting factor based on the initial collision prediction
- a: initial collision prediction, incidents per year at the crossing
- *k*: regression coefficient
- EI: factor for exposure index based on product of highway and train traffic
- DT: factor for number of through trains per day during daylight
- MS: factor for maximum timetable speed
- MT: factor for number of main tracks
- HL: factor for number of highway lanes.
- HP: factor for highway paved (yes or no)
- *NA*: predicted number of accidents per year at the grade crossing
- *N*: number of accidents in previous five years at grade crossing
- *Adj*: coefficient to normalize predicted accidents in year with actual counts
- *Expose*: daily exposure with time-of-day correlation, see Equation 5
- *dthru*: number of day through trains per day
- *ms*: maximum timetable speed at crossing, miles per hour
- *tracks*: number of main tracks
- *lanes*: number of highway lanes
- *paved*: if highway is paved, paved = 1; if unpaved then paved = 2

Equation 5: Daily Exposure with Time-of-Day Correlation

$$Expose = 1.35 * EF * AADT * TV$$

Where:

- *Expose*: base year daily exposure with time-of-day correlation, effective daily exposures
- *EF*: time-of-day exposure correlation factor
- *AADT:* average annual daily traffic on the highway at the crossing
- *TV:* average daily trains at the crossing

The calculation for daily exposure was outlined in the *GradeDec.Net* manual. This formula takes in the average annual daily traffic that occurs at crossings and the time-of-day correlation of traffic to determine the daily exposure in this model.

The time-of-day correlation factor in Equation 5 is important in understanding the foundation of the formula. This formula uses the time-of-day correlation factor, derived by Equation 6, between train and highway vehicle types at crossings to determine the impact of the daily exposure. The percentage for daily exposure is then compared to what it would be if the time-of-day correlation was equivalent to the national average's correlation. The US DOT model uses the results of a surveyed expert, as noted in the FRA Grade Dec 2019, to determine the percentage of daily exposure for the correlation calculation. The value 1.35, represented in Equation 5, indicates there is 35% more daily exposure for the time-of-day correlation between train and highway vehicle types at crossings than the national average's correlation.

Equation 6: Time-of-Day Exposure Correlation Factor

$$EF = \frac{\sum_i \left(\sum_k \alpha_k a_{ik} \ \sum_j \beta_j b_{ij}\right)}{Max\left(\sum_i \sum_k (\alpha_k a_{ik})^2, \sum_i \sum_j \left(\beta_j b_{ij}\right)^2\right)}$$

Where:

- *EF*: time-of-day exposure correlation factor
- *i*: an index designating the hour of the day
- *j*: an index of highway vehicle type
    - Auto
    - Truck
    - Bus
- *k*: an index of train types
    - Passenger
    - Freight
    - Switch in the corridor model or through and switch in the regional model
- a_{ik}: the share of daily trains of train type k at the crossing in the ith time-of-day period
    - $\sum_i a_{ik} = 1$
- b_{ij}: the share of daily traffic of vehicle type j in the ith hour of the day
    - $\sum_i b_{ij} = 1$
- α_k: the share of train type k of total trains
    - $\sum_i \alpha_k = 1$
- β_j: the share of vehicle type j in daily highway traffic

- $\sum_i \beta_j = 1$

When evaluating the time-of-day exposure correlation factor, the numerator in Equation 6 calls for the sum of all train and highway vehicle types for the designated hour of the day. First, it takes the sum of the share of each train type multiplied by the share of daily trains for each train type in the designated time-of-day period and evaluates it for each train type. Similarly, it takes the sum of the share of each highway vehicle type multiplied by the share of daily traffic for each vehicle type in the designated time-of-day period and evaluates it for each highway vehicle type. These two sums are then evaluated for each hour of the day to determine the total train and highway vehicle types at crossings. The denominator in Equation 6 calls for the maximum between the squared sum value of all the train and highway vehicle types for the designated hour of the day. From here, the time-of-day correlation was determined and incorporated in calculating the daily exposure with time-of-day correlation for the model.

Fatality Probability

The predicted number of fatal accidents per year at the grade crossing, denoted as FA, is estimated using Equation 7.

Equation 7: Predicted Number of Accidents at Crossing for Fatal Accidents

$$FA = \frac{NA}{1 + KF * MS * TT * TS * UR}$$

Where:

- *FA*: predicted number of fatal accidents per year at the grade crossing
- *NA*: predicted number of accidents per year at the grade crossing (from Equation 4)
- *KF*: formula constant = 440.9
- MS: factor for maximum timetable speed
- *TT*: factor for through trains per day
- *TS*: factor for switch trains per day
- *UR:* factor for urban or rural crossing

The model takes the total number of fatal accidents divided by the total number of accidents resulting in a fatality, injury, or property damage only (PDO) to calculate the fatality probability.

Casualty Probability

The predicted number of casualty accidents per year at the grade crossing, CA, is calculated as follows:

Equation 8: Predicted Number of Accidents at Crossing for Casualty Accidents

$$CA = \frac{FA}{1 + KC * MS * TK * UR}$$

Where:

- *CA:* predicted number of casualty accidents per year at the grade crossing
- *FA*: predicted number of fatal accidents per year at the grade crossing (from Equation 7)
- *KC:* formula constant = 4.481
- MS: factor for maximum timetable speed

- *TK:* factor for number of tracks
- *UR:* factor for urban or rural crossing

Injury Probability

The predicted number of injury accidents per year at the grade crossing, denoted IA, is calculated in Equation 9:

Equation 9: Predicted Number of Accidents at Crossing for Injury Accidents

$$IA = CA - FA$$

Where:

- *IA:* predicted number of injury accidents per year at the grade crossing
- *CA:* predicted number of casualty accidents per year at the grade crossing (from Equation 8)
- *FA*: predicted number of fatal accidents per year at the grade crossing (from Equation 7)

The model calculates the injury probability by taking the total number of injury accidents divided by the total number of accidents resulting in a fatality, injury, or PDO.

PDO Probability

The predicted number of PDO accidents per year at the grade crossing, PA, is calculated as follows:

Equation 10: Predicted Number of Accidents at Crossing for PDO Accidents

$$PA = NA - FA - IA$$

Where:

- *PA:* predicted number of PDO accidents per year at the grade crossing
- *NA*: predicted number of accidents per year at the grade crossing (Equation 4)
- *FA*: predicted number of fatal accidents per year at the grade crossing (Equation 7)
- *IA:* predicted number of injury accidents per year at the grade crossing (Equation 9)

The model takes the total number of PDO accidents and divides it by the total number of accidents resulting in a fatality, injury, or PDO to calculate the PDO probability.

2020 FRA Probability Model

The assumptions for the 2020 FRA ZINB model are the following:

- Each crossing has a probability greater than zero of being a no-risk crossing
- Each crossing has an expected number of annual accidents
- Accident counts for the population of crossings conform to a negative binomial distribution (the standard deviation of accidents for the population is greater than the mean, indicating overdispersion)

The ZINB count model calculates the predicted number of accidents at crossings. This formula does not include crossings that contain excess zeroes in the accident history for the last five years.

Equation 11: The ZINB Count Model

$$N_{CountPredicted} = e^{[\beta_0+\beta_1*Expo+\beta_2*D_2+\beta_3*D_3+\beta_4*RurUrb+\beta_5*XSurfID2s+\beta_6*AADT+\beta_7*MaxTtSpd]}$$

Where:

- $N_{CountPredicted}$: predicted accidents of count model
- $Expo$: exposure, equal to average annual daily traffic times daily trains (AADT*Daily Train Count)
- D_2: if warning device type is lights = 1, 0 otherwise
- D_3: if warning device type is gates = 1, 0 otherwise
- $RurUrb$: if rural = 0, if urban = 1
- $XSurfID2s$: timber = 1, asphalt = 2, asphalt and timber or concrete or rubber = 3, concrete and rubber = 4
- $lAadt$: average annual daily traffic
- $lMaxTtSpd$: maximum timetable speed (integer value between 0 and 99)

The ZINB zero-inflated model calculates the probability that the grade crossing is an "excess zero," indicating crossings with an effectively zero crossing accident risk.

Equation 12: The ZINB Zero-Inflated Model

$$P_{InflatedZero} = \frac{z}{1+z}$$

$$z = e^{[y_0+y_1*TotalTrains]}$$

Where:

- $P_{InflatedZero}$: probability that the grade crossing is an "excess zero"
- $TotalTrains$: total number of daily trains
- y_0: estimated coefficient for the intercept
- y_1: estimated coefficient for lTotalTime

The ZINB combined model determines the predicted number of accidents at crossings, including those with excess zeroes.

Equation 13: The ZINB Combined Model

$$N_{Predicted} = N_{CountPredicted} * (1 - P_{InflatedZero})$$

Where:

- $N_{Predicted}$: predicted accidents after accounting for excess zeroes
- $N_{CountPredicted}$: predicted accidents of count model (from Equation 11)
- $P_{InflatedZero}$: probability that the grade crossing is an "excess zero" (from Equation 12)

The Empirical Bayes (EB) method is incorporated into the 2020 accident prediction model to account for the accident history at the crossings and correct for any bias in the ZINB regression calculation. The EB adjustment will make the expected value of accidents at crossings either closer to zero or the actual value depending on the accident history. The formula below calculates the expected number of accidents at the crossing.

Equation 14: The Empirical Bayes Adjustment Formula

$$N_{Expected} = w * N_{Predicted} + (1 - w) * N_{Observed}$$

Where:

- w: The Empirical Bayes weighting factor (from Equation 15)
- $N_{Expected}$: the adjusted number of predicted accidents
- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure (from Equation 13)
- $N_{Observed}$: the number of observed accidents over a five-year period

The weighting factor in Equation 15 accounts for the accident history at the crossing. This weighted factor allows for a better approximation of the expected number of accidents at crossings.

Equation 15: The Empirical Bayes Weighting Factor Formula

$$w = \frac{1}{1 + \frac{V[N_{Predicted}]}{N_{Predicted}}}$$

Where:

- w: weighting factor
- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure (from Equation 13)
- $V[N_{Predicted}]$: the variance of crossings predicted number of accidents (from Equation 16)

The variance of the predicted number of accidents at the crossings is calculated as follows:

Equation 16: The Variance of Crossing's Predicted Number of Accidents Formula

$$V[N_{Predicted}] = N_{Predicted} * 1 + [N_{Predicted} * \left(P_{InflatedZero} + \frac{1}{\theta}\right)$$

Where:

- $N_{Predicted}$: number of predicted accidents from the ZINB regression procedure (from Equation 13)
- $P_{InflatedZero}$: probability that the grade crossing is an "excess zero" (from Equation 12)
- $\frac{1}{\theta}$: the inverse of the overdispersion parameter α from the ZINB regression
    - $\theta = 0.7716$; as defined in the 2020 Probability Guidelines

2020 FRA Accident Severity Model

As previously mentioned in this report, the updated 2020 accident severity model was considered in this analysis to calculate incident probabilities across each severity category (fatal, injury and PDO) at grade crossings.

The 2020 accident severity model determines the probabilities that given an accident at the grade crossing, the accident will result in a fatality, injury, or PDO. In a probability distribution, each probability represents the likelihood of an event occurring, where each probability is composed of a value between zero and one. The sum of these probabilities will always equal to one. The following formula is used to verify that the probabilities calculated for each category of severity sum to one.

Equation 17: Constraint that Severity Probabilities Sum to 1

$$1 = P(acctype = fatal \mid A) + P(acctype = injury \mid A) + P(acctype = PDO \mid A)$$

Where:

- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A (from Equation 20)
- $P(acctype = injury \mid A)$: the probability of an injury accident given an accident A (from Equation 21)
- $P(acctype = PDO \mid A)$: the probability of a PDO accident given an accident A (from Equation 22)

The 2020 accident severity model uses multinomial logistic regression, which is used to predict the probability of an accident type occurring at a crossing based on the severity type. This model uses the accident type "fatal" as the reference level in the regression analysis.

The calculation for the probability of an injury relative to a fatal accident is as follows:

Equation 18: Accident Severity Model - Injury Relative to Fatal

$$ln\left(\frac{P(acctype=injury \mid A)}{P(acctype=fatal \mid A}\right) = \beta_{20} + \beta_{21} * lMaxTdSpd + \beta_{22} * lTrains + \beta_{23} * RurUrb + \beta_{24} * D_2$$

Where:

- $P(acctype = injury \mid A)$: the probability of an injury accident given an accident A (from Equation 21)
- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A (from Equation 20)
- $lMaxTdSpd$: the natural log of the maximum (rail) timetable speed at the crossing
- $lTrains$: the natural log of the total number of daily trains at the crossing
- $RurUrb$: variable taken from FRA Form 71; 1 if the crossing is in a rural (non-urban) environment, 0 if in Urban environment
- D_2: has value 1 if warning device type is lights, 0 otherwise

The calculation for the probability of a PDO relative to a fatal accident is shown below:

Equation 19: Accident Severity Model - PDO Relative to Fatal

$$ln\left(\frac{P(acctype=PDO \mid A)}{P(acctype=fatal \mid A}\right) = \beta_{30} + \beta_{31} * lMaxTdSpd + \beta_{32} * lTrains + \beta_{33} * RurUrb + \beta_{34} * D_2$$

Where:

- $P(acctype = PDO \mid A)$: the probability of a PDO accident given an accident A (from Equation 22)
- $P(acctype = fatal \mid A)$: the probability of a fatal accident given an accident A (from Equation 20)
- $lMaxTdSpd$: the natural log of the maximum (rail) timetable speed at the crossing
- $lTrains$: the natural log of the total number of daily trains at the crossing
- $RurUrb$: 1 if the crossing is in a rural (non-urban) environment, 0 if in Urban
- D_2: has value 1 if warning device type is lights, 0 otherwise

Taking Equation 18 and Equation 19, the individual probabilities for fatality, injury, and PDO given a collision can be calculated. The accident severity formulas used in the model are the following:

Equation 20: Accident Severity Forecast Formulas - Fatal

$$Pr(Y_i = fatal \mid A) = \frac{1}{1 + \sum_{k=1}^{3} e^{\beta_k * X_i}}$$

Equation 21: Accident Severity Forecast Formulas - Injury

$$Pr(Y_i = injury \mid A) = \frac{e^{\beta_2 * X_i}}{1 + \sum_{k=2}^{3} e^{\beta_k * X_i}}$$

Equation 22: Accident Severity Forecast Formulas - PDO

$$Pr(Y_i = PDO \mid A) = \frac{e^{\beta_3 * X_i}}{1 + \sum_{k=3}^{3} e^{\beta_k * X_i}}$$

Where:

- Subscript k: indicates accident type: fatal = 1, injury = 2, PDO = 3
- Subscript i: indicates a grade crossing
- Subscript j: indicates the explanatory variable to which the β element corresponds (0 to 4)
- X_i: vector of crossing traits that explain accident severity from Table 5.1 of the New Model for Highway-Rail Grade Crossing Report
- Y_i: variable indicating accident type (fatal, injury or PDO)
- $\beta's$: vectors of coefficient estimates based on multimodal logistic regressions found in Table 5.1 of the New Model for Highway-Rail Grade Crossing Report
- β_{2j}: coefficient estimate vector for the probability of injury accident relative to fatal
- β_{3j}: coefficient estimate vector for the probability of PDO accident relative to fatal

Supply Chain Costs

Truck Supply Chain Costs*

- Value per ton (truck, adjusted for inflation) = $974
- Tons per Truck = 23.5
- Average Truck Value = [tons] * [value per ton] = 23.5 * 974 = $22,887

Average Supply Chain Cost per Truck per Hour = 22,887 * 0.4% = $92

Rail Supply Chain Costs*

- Carloads: 25,830,507
- Tons: 2,352,992,493
- Tons/Carload = 91.1
- Dollar per ton of rail, and multiple mode and mail (2017 - adjusted for inflation) = $1,268
- Average Railcar Value = [tons] * [value per ton] = 91.1 * $1,268 = $115,532
- Average Rail Supply Chain Cost per Rail Car per Hour = 115,532 * 0.4% = $462
- Average Rail Supply Chain Cost per Train per Hour = 462 * 61 = 28,340

*Explanations of cost sources are provided in Chapter 5.5.

WisDOT Accident Prediction Model

The US DOT formula used to calculate the predicted number of incidents at a crossing is as follows:

Equation 23: Predicted Number of Accidents at the Crossing – US DOT Formula

$$a = k \times EI \times DT \times MS \times MT \times HL \times HP$$

$$T_o = \frac{1}{0.05 + a}$$

$$NA = \frac{(a * T_o) + N}{T_o + 5} * Adj$$

Where:

- a: initial collision prediction, incidents per year at the crossing
- *k*: regression coefficient taken from the WisDOT model
  - *Passive Crossing = 0.0006938*
  - *Crossings with Flashers = 0.0003351*
  - *Crossings with Gates/Flashers = 0.0005745*
- EI: factor for exposure index based on product of highway and train traffic*
- DT: factor for number of through trains per day during daylight*
- MS: factor for maximum timetable speed*
- MT: factor for number of main tracks*
- HL: factor for number of highway lanes*
- HP: factor for highway paved (yes or no)*
- *NA*: predicted number of accidents per year at the grade crossing
- *N*: number of accidents in previous five years at grade crossing
- *Adj*: coefficient to normalize predicted accidents in year with actual counts
  **Factors developed using FRA inventory and/or internal WisDOT crossing data*

The Wisconsin DOT calculates daily exposure differently from the US DOT formula that is outlined in the report. WisDOT exposure is weighted to account for the projected traffic that occurs during the day and night at these crossings. Equation 24 shows the formula WisDOT uses to calculate exposure.

Equation 24: Daily Exposure

$$\begin{aligned} Exposure = [&Most\ Recently\ Recorded\ Traffic\ Projection * \%AADT \\ &* (Day\ Through\ Trains + Day\ Switch\ Trains)] + [Traffic\ Projection * (1 - \%AADT) \\ &* (Night\ Through\ Trains + Night\ Switch\ Trains)] \end{aligned}$$

Where:

- *%AADT*: percentage of average annual daily traffic in day hours

The incident probabilities in the WisDOT model follow the same US DOT formulas mentioned previously in this document. The formulas used to calculate the probability of a fatality, casualty, injury and PDO are represented in Equation 7, Equation 8, Equation 9, and Equation 10, respectively. This process was repeated for passive devices, flashing light devices, and flashing light and gate devices.

To calculate the costs associated with the reported incidents in Wisconsin, the following formula and terminology was used in the WisDOT model:

Equation 25: Train Incident Costs

$$Train\ Crash\ Costs = Economic\ Cost\ of\ Fatality * (Crash\ Adjustment\ Factor\ for\ Fatality * Fatal\ Crashes) + (Crash\ Adjustment\ Factor\ for\ Injury * Injury\ Crashes) + \left[\left(\frac{Total\ Through\ Trains}{Total\ Trains}\right) * Injuries\ (at\ train\ speeds)\right] + \left[\left(\frac{Total\ Switch\ Trains}{Total\ Trains}\right) * Injuries\ (at\ train\ speeds)\right] + Economic\ Cost\ of\ PDO * PDCrashes$$

Where:

- ***Economic Cost of Fatality***: value of a statistical life (VSL)
- ***Incident Adjustment Factor for Fatality***: incidents to fatalities = 1.143
- ***Fatal Incidents***: predicted number of fatal accidents per year at the grade crossing
- ***Incident Adjustment Factor for Injury***: incidents to injuries = 1.481
- ***Injury Incidents***: predicted number of injury accidents per year at the grade crossing
    - ***Injuries (at train speeds)***:
        - If maximum train speed < 25mph, economic cost of injury C incident value
        - If maximum train speed > 25mph, economic cost of injury A incident value
        - If maximum train speed = 25mph, economic cost of injury B incident value
        - Otherwise "ERROR"
- ***Economic Cost of PDO***: PDO incident value
- ***PDO Incidents***: predicted number of PDO accidents per year at the grade crossing

Roadway Vehicle Delay and Rerouting Costs

Equation 26: Affected Vehicles

$$Affected\ Vehicles = \big(AADT * (1 - ADTT\%)\big) * \left(\frac{Closure\ Time}{24}\right)$$

Equation 27: Affected Trucks

$$Affected\ Trucks = (AADT * ADTT\%) * \left(\frac{Closure\ Time}{24}\right)$$

It is important to note that in Equation 26 and Equation 27:

- *AADT*: Average Annual Daily Traffic
- *ADTT%:* Average Daily Truck Traffic (as a percentage of the total traffic)
- *Closure Time*: amount of time crossing is closed to traffic, values from NCHRP Report 755 for different types of crashes

By establishing an estimate for the affected passenger vehicles and affected trucks, the roadway vehicle delay and the rerouting costs can be calculated. For the following equations, rerouting time is expected to be in hours.

Equation 28: Vehicle Rerouting Cost

$$Vehicle\ Re-routing\ Cost = [Number\ of\ Affected\ Vehicles] * [Re-routing\ Time] * [Cost\ of\ Vehicle\ Operation]$$

Equation 29: Value of Passenger Time

$$Value\ of\ Passenger\ Time = [Number\ of\ Affected\ Vehicles] * [Avg.Number\ of\ Passengers\ per\ Vehicle] * [Rerouting\ Time] * [Value\ of\ Passenger\ Time]$$

Truck delay and rerouting costs are comprised of the operating cost of rerouting the affected trucks and the cost of the operator's time during the rerouting period. The following equations utilize the same rerouting time as passenger vehicles assuming trucks and passenger vehicles will be able to use the same route.

Equation 30: Cost of Truck Rerouting

$$Cost\ of\ Truck\ Re-routing = [Affected\ Trucks] * [Rerouting\ Time] * [Truck\ Operating\ Cost]$$

Equation 31: Value of Truck Driver Time

$$Value\ of\ Truck\ Driver\ Time = [Affected\ Trucks] * [Rerouting\ Time] * [Truck\ Driver's\ Hourly\ Wage]$$

Rail Delay Costs

Rail Delay can be measured by estimating various costs including the cost of idling, the value of the train operators' time, and the value of the train passengers' time:

Equation 32: Cost of Train Idling

$$Cost\ of\ Train\ Idling = [Delay\ Time] * [Train\ Idling\ Cost](for\ each\ effected\ train)$$

Equation 33: Value of Train Operator(s) Time

$$Value\ of\ Train\ Operator(s)Time = [Delay\ Time] * [Number\ of\ Train\ Operators] * Value\ of\ Train\ Operator(s)\ Time](for\ each\ affected\ train)$$

Equation 34: Value of Train Passenger(s) Time

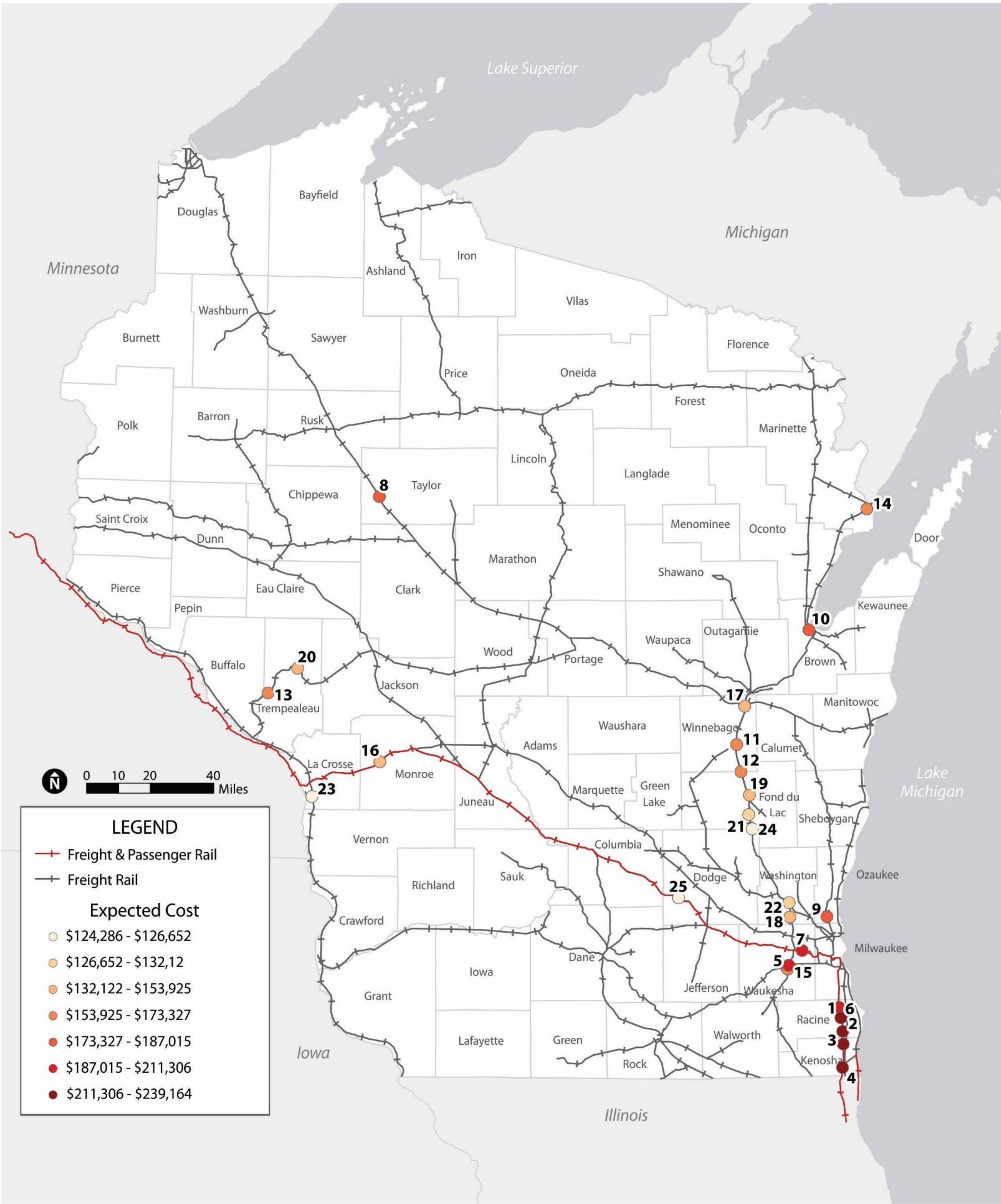
$$Value\ of\ Train\ Passengers\ Time = [Delay\ Time] * [Avg.Number\ of\ Passengers\ per\ Train] * [Value\ of\ Train\ Passengers\ Time]$$

APPENDIX C. Wisconsin Statewide Scan Rankings

Rankings of Crossings based on Expected Costs and Improvement Costs

Rank	Crossing ID	County	Annual Expected Cost	Current Warning Device
1	387995W	RACINE	$241,373	Gates
2	388003U	RACINE	$222,507	Gates
3	388022Y	KENOSHA	$222,436	Gates
4	388035A	KENOSHA	$221,772	Gates
5	689913X	WAUKESHA	$214,275	Gates
6	387990M	RACINE	$203,077	Gates
7	390521P	WAUKESHA	$202,873	Gates
8	697269F	TAYLOR	$189,203	Gates
9	692245A	WAUKESHA	$181,970	Gates
10	281435T	BROWN	$178,867	Passive
11	179791M	WINNEBAGO	$175,611	Gates
12	690132M	FOND DU LAC	$173,486	Gates
13	281828B	TREMPEALEAU	$172,027	Passive
14	910730L	MARINETTE	$171,428	Passive
15	689904Y	WAUKESHA	$163,255	Gates
16	390877X	MONROE	$155,799	Passive
17	689818C	WINNEBAGO	$155,153	Passive
18	692267A	WASHINGTON	$150,286	Gates
19	690119Y	FOND DU LAC	$148,192	Gates
20	281794J	TREMPEALEAU	$148,100	Passive
21	690090D	FOND DU LAC	$133,547	Gates
22	692277F	WASHINGTON	$129,875	Gates
23	079884F	LA CROSSE	$128,197	Gates
24	692318H	DODGE	$125,724	Gates
25	390633N	DODGE	$125,476	Gates

Crossing Locations for Rankings based on Expected Costs and Improvement Costs



Crossing Ranking based on NPV of Gate Improvements

Rank	Crossing ID	County	Net Present Value	Current Warning Device
1	689818C	WINNEBAGO	$78,740	Passive
2	390631A	DODGE	$31,043	Passive
	392819J	MARATHON	$12,986	Flashing Lights
3	692293P	WASHINGTON	$12,467	Flashing Lights
5	281828B	TREMPEALEAU	$5,144	Passive
7	386506F	MILWAUKEE	($31,003)	Passive
6	689939A	CLARK	($31,477)	Passive
8	696383C	KENOSHA	($39,828)	Passive
9	392921P	LINCOLN	($41,729)	Passive
12	931771Y	WOOD	($46,243)	Passive
10	387660G	MILWAUKEE	($46,484)	Passive
11	388081B	MILWAUKEE	($46,484)	Passive
13	697361F	WASHBURN	($67,409)	Passive
14	697351A	WASHBURN	($67,409)	Passive
15	281440P	BROWN	($68,023)	Passive
16	910730L	MARINETTE	($68,389)	Passive
17	251873N	DOUGLAS	($69,423)	Flashing Lights
18	390877X	MONROE	($84,947)	Passive
19	697248M	CLARK	($86,137)	Passive
20	693769P	PORTAGE	($88,344)	Flashing Lights
22	281794J	TREMPEALEAU	($93,102)	Passive
21	079956G	BUFFALO	($94,108)	Passive
23	697337E	SAWYER	($99,499)	Passive
24	697256E	TAYLOR	($101,139)	Passive
25	690129E	FOND DU LAC	($110,333)	Passive

This list is based on certain input factors and projected benefits and not incident history. Any predictive increase in incidents could substantially affect the priority list. Additional study is required to capture other conditions and to determine the actual benefits.

Crossing Locations for Rankings based on NPV Gate Improvements