NDOT Research Report

Report No. 362-16-803

Development of Revised Grade Crossing Hazard Index Model

July 2017

Nevada Department of Transportation
1263 South Stewart Street
Carson City, NV 89712

Disclaimer

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 362-16-803	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Development of Revised Grade Crossing Hazard Index Model: Final Report and Recommended Model		5. Report Date July 2017 6. Performing Organization Code 09389.00
7. Author(s) Christopher Ryan, PE, Andrew Mielke, AICP		8. Performing Organization Report No.
9. Performing Organization Name and Address SRF Consulting Group, Inc. One Carlson Parkway North, Suite 150 Minneapolis, MN 55447-4453		10. Work Unit No. 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Nevada Department of Transportation 1263 South Stewart Street Carson City, NV 89712		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Nevada Department of Transportation (NDOT) plays a key role in addressing highway-rail grade crossing safety issues by allocating federal funding through the Railway-Highway Crossing (Section 1030) Program. This Program requires each state to select eligible projects through a data-driven project selection and prioritization process. NDOT currently relies on the use of a modified version of the New Hampshire Hazard Index formula for this project prioritization. However, NDOT feels that the results of this formula have not accurately reflected actual safety needs of many crossings throughout the state. This report summarizes current grade crossing safety trends in Nevada and at the national level, reviews the strengths and weaknesses of NDOT's current grade crossing safety prioritization procedures, and evaluates potential alternative hazard index models used by other agencies. This report also includes summaries of peer interviews with the Arizona, Oregon, and Utah Departments of Transportation and also includes a summary of feedback received from an Expert Panel consisting of representatives from NDOT, the Federal Railroad Administration, Federal Highway Administration, Union Pacific Railroad, and others. Finally, the report proposes a revised Hazard Index Model for consideration as a replacement for NDOT's current model.

17. Key Words Safety, Transportation Safety, Railroad Grade Crossings, Hazard Index, Risk, Crash Rates	18. Distribution Statement No restrictions. This document is available through the: National Technical Information Service Springfield, VA 22161		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 86	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Development of Revised Grade Crossing Hazard Index Model

Final Report and Recommended Model

FINAL

Nevada Department of Transportation

Prepared by:

SRF Consulting Group, Inc.
ENGINEERS
PLANNERS
DESIGNERS

July, 2017

SRF No. 9389

Table of Contents

Introduction

Highway-rail grade crossing safety in Nevada is the responsibility of both the Nevada Department of Transportation (NDOT) and the Public Utilities Commission of Nevada (PUCN). NDOT has administrative responsibility while regulatory responsibility falls to the PUCN. One of NDOT's primary roles in the grade crossing safety program is to secure federal funding through the Section 130 program and allocate these funds toward safety improvements at high-risk crossings. To aid in project selection, NDOT relies on the use of a hazard index formula to identify crossings that are most in need of safety improvements.

Historically, NDOT has used a modified version of the New Hampshire hazard index formula for this purpose. However, NDOT feels that the results of this formula do not accurately reflect actual safety needs of many crossings throughout the state. One of the key criticisms of the current formula is that factors such as train and traffic volumes are weighted too heavily. As a result, many urban crossings with higher traffic volumes are prioritized over lower-volume rural crossings. NDOT has retained the services of SRF Consulting Group, Inc. to assist with the development of a revised hazard index model that will prioritize grade crossing safety improvements in a manner consistent with the NDOT's goals and strategies.

The components of this final report achieve the following goals and tasks:

- Summarize NDOT's current approach to grade crossing safety prioritization
- Identify the strengths and weaknesses of the current approach
- Review and summarize alternative hazard indices
- Review national trends and best practices for grade crossing safety
- Summarize the characteristics and existing safety issues for Nevada's grade crossings
- Summarize discussion and feedback from the Nevada Rail Safety Expert Panel
- Apply the four evaluation criteria to the proposed hazard index formula factors
- Recommend a final revised Hazard Index Model for NDOT consideration

Miriam Amtrak Crash

A driving force for this review of the hazard index model is the recent grade crossing collision that occurred in June 2011 between a tractor-trail and an Amtrak passenger train near Miriam, Nevada. The crash highlighted variables that may have contributed to the conditions leading up to a serious incident, in this case leading to 6 fatalities and 16 injuries. The crash occurred at a low-volume (900 vehicles per day) rural crossing that was equipped with automatic gates and cantilevered flashing lights. The driver of the northbound tractor-trailer did not react in time to the functioning warning devices and collided with the westbound train. It is the hope that through this hazard index reevaluation process that similar crashes can be prevented in the future.

Review of Existing Crossing Safety Practices

As part of this research effort, the study team conducted a review of existing rail crossing safety issues, including a review of the traditional hazard index models/formulas, a peer state review, and a review of emerging practices.

The literature review also included a range of issues in grade crossing evaluation and safety. The categories studied include, but are not limited to, the following;

- Crash Prediction models and indexes in current use
- Grade crossing safety research, federal, state, and private
- Driver behavior
- Pedestrian and non-motorized vehicle safety at crossings
- Best practices and innovations in passive and active crossing treatments
- Alternative or qualitative crash prediction models

Several significant and relevant themes emerged through this review. Although historically grade crossing collisions were a major source of injuries and fatalities in the mid-twentieth century—in some localities exceeding 15 percent of all severe highway crashes—successful safety programs and applications have reduced this to approximately one percent or less in most areas. These low statistics have resulted in crash prevention models using five or ten-year crash rates to be questionable in their accuracy when used to rank crossings for future capital investments in safety improvements. At the same time, pedestrian injuries and fatalities now consistently outrank vehicular injuries across the country, but with little research or guidance to address this problem. Railroad-related suicides also appear to be trending upwards.

Another trend is an increasing reliance on evaluations of qualitative factors to determine effective treatments at crossings, as well as crash prediction. There is also a recognition in research and practice of the possibility of catastrophic crash and large-scale injury events, resulting from passenger and freight train derailments caused by grade crossing collisions. While the incidence of these major crashes is extremely rare, they have and will continue to happen, and should be a consideration in grade crossing safety programs. This approach is consistent with other "Toward Zero Death" initiatives that many state DOTs have in place.

Current NDOT Hazard Index Model

NDOT currently uses a modified form of the New Hampshire hazard index model to rank highway-rail at-grade crossings. This model is widely used and relatively straightforward in its methodology, but also carries a number of significant weaknesses. In particular, the model does not address the detailed characteristics of the grade crossing site and surroundings, nor does it incorporate the characteristics of the involved road and rail traffic, including the mix of heavy commercial vehicles, vehicle speeds, approach variables, exposure to passengers, trains, and hazardous materials.

Nevada Hazard Index Model

$HI = TADT \times AADT \times PF \times AF$

TADT = Average Daily Train Volume
AADT = Annualized Average Daily Traffic Volume
PF = Protection Factor

Gates:	0.1
Flashing Lights:	0.6
Passive:	1.0

AF = Crash Factor (5-year crash history)

1+ Σ	(# Fatal Crashes)	x 1.00
	(# Injury Crashes)	x 0.10
	(# PDO Crashes)	x 0.05

This model tends to prioritize high conflict (high road and rail traffic volumes) sites to the exclusion of low volume crossings, particularly in rural areas. The model also uses crash frequency and severity as modifying inputs. However, the frequency of grade crossing crashes in recent years has declined to the point that crash history is no longer a good indicator of future crash probability. In Nevada, these factors have tended to direct crossing improvement efforts to southern region crossings located along the Union Pacific main lines, especially around urbanized areas, to the detriment of improvements in other regions. While the current approach is objective, defensible, and easy to explain, it may be missing other important risk factors that could result in a serious crash.

A review of current practices and hazard indices in other states points to the fact that no single hazard index model is sufficient or appropriate for all regions, states, or local areas. The unique characteristics and goals of the Nevada's highway-rail crossings should be methodically identified and reviewed to develop a hazard index model that will address the most critical needs of the system and provide a structure for future safety investment. The following factors should be considered through this review:

- Improved and expanded data on crossing conditions and traffic
- Identification of heavy or slow vehicle use, such as heavy commercial trucks, industrial equipment and farm implement traffic
- Speed, frequency, and commodities carried on trains, especially hazardous materials
- Road conditions impact on safety, including road geometry, angle and grade of crossings, road surfaces, sight lines, nearby road signals and intersections, potential weather conditions (snow, ice, drifts, fog), and congestion
- Exposure to passenger trains, commercial buses, and school buses

- Type and condition of existing passive or active safety devices, including modernized safety measures, advance warning installations, and interconnection with traffic signal systems
- Surrounding land use and impacts of crossing and rail operations
- Weighting of safety factors and/or categorization of classes of crossings
- Criteria for improving passive crossing to active protection
- Understandable and documented processes for safety evaluations
- Transparent and responsive communications with local officials, regulators, railroads, and the public on processes and projects

The goal of incorporating these considerations is to establish an improved replacement for the current accident prediction models, increase buy-in and support from legislators and the public, and materially reduce the occurrences of crashes at crossings.

Traditional Methods for Crossing Improvement Prioritization

The Federal Highway Administration's (FHWA) Railroad-Highway Grade Crossing Handbook provides an overall framework designed for states to use to meet Highway Safety Improvement Program (HSIP) funding guidelines. The framework provides guidance on various aspects on the subject, but particularly focuses on methodologies for hazard identification and crash predictions. The Handbook notes that, "a systematic method for identifying crossings that have the most need for safety and/or operation improvements is essential to comply with requirements of the FAPG [Federal Aid Policy Guide], which specifies that each state should maintain a priority schedule of crossings improvements."

The Handbook suggests the use of a hazard index or prediction formula as a means of objectively identifying and prioritizing grade crossing improvements. Four models or formulas are suggested by the Handbook: The New Hampshire Hazard Index, The USDOT Accident Prediction Model, the Peabody-Dimmick Crash Prediction Formula, and the NCHRP Report 50 Formula. Each of these approaches is summarized below.

The Handbook also suggests that those crossings with the highest hazard index be investigated further in the field. In addition to these crossings, FHWA regulations state that site investigations should take place at crossings where, "the potential danger to large numbers of people at crossings used on a regular basis by passenger trains, school buses, transit buses, pedestrians, bicyclists, or by trains and/or motor vehicles carrying hazardous materials be one of the considerations in establishing a priority schedule. Some states incorporate these considerations into a hazard index, thus providing an objective means of assessing the potential danger to large numbers of people."

New Hampshire Hazard Index

The Handbook cites this index as a commonly used tool for states. The index is largely driven by traffic volumes, train volumes, and the existing warning devices. The basic formula is often modified to include additional factors such as speeds, sight distances, geometric factors, frequency of hazardous materials, and roadway functional class. This model is currently used by NDOT with a modification factor for crash history.

New Hampshire Hazard Index

HI = V x T x PF

V = Average daily traffic volume
T = Average daily train volume
PF = Protection factor

Gates:	0.1
Flashing Lights:	0.6
Passive:	1.0

USDOT Accident Prediction Model

This model combines three calculations to produce a prediction of the likelihood of a crash occurring at a crossing. The baseline calculation includes a number of factors for various characteristics such as exposure index (train volume x traffic volume), train speed, number of tracks, number of highway lanes, and highway pavement type. The second calculation uses the results of the baseline calculation and recent crash history to create a collision prediction. The final calculation factors in a normalizing constant, adjusted periodically to match the formula to current collision trends. A major shortcoming in this model is its reliance on the past as an indicator of the future. Overall, grade crossing collisions are at an all-time low, negating the usefulness of some of the models underlying assumptions.

USDOT Accident Prediction Model Formula

a = K x EI x MT x DT x HP x MS x HT x HL

a = Initial collision prediction, collisions per year at the crossing
K = Formula constant
EI = Factor for exposure index (highway traffic x train traffic)
MT = Factor for number of main tracks
DT = Factor for number of through trains per day during daylight
HP = Factor for highway paved (yes or no)
MS = Factor for maximum timetable speed
HT = factor for highway type
HL = factor for number of highway lanes

$$B = \frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right)$$

B = Second collision prediction, collisions per year at the crossing
a = Initial collision prediction from basic formula
N = Number of observed collisions
T = Years of observation for collisions
T_0 = Formula weighting factor,

$$T_0 = \frac{1.0}{(0.05 + a)}$$

Peabody-Dimmick Crash Prediction Formula

Developed in 1941 by the U.S. Bureau of Public Roads this formula predicts the expected number of crashes for five years. The formula is based on data collected in the 1930s at 3,563 rural crossings in 29 states.

Peabody-Dimmick Formula

$$A_5 = 1.28\frac{\left(V^{0.170}\right)\left(T^{0.151}\right)}{P^{0.171}} + K$$

A5 = Expected number of accidents in five years
V = Annual average daily traffic
T = Average daily train traffic
P = Protection coefficient
K = Additional parameter

NCHRP Report 50 Accident Prediction Formula

> **NCHRP Report 50 Accident Prediction Formula**
>
> Accident Frequency = A x B x Trains/Day
>
> A = Factor based on highway vehicles/day
> B = Factor based on warning devices and urban/rural classification

In 1984, the National Cooperative Highway Research Program (NCHRP) Report 50 proposed an accident prediction formula for rail-vehicle crashes and another for non-train related crashes. The formula for train crashes is relatively simple and uses coefficients found on tables in the report as the variables in the formula.

Texas Priority Index

> **Texas Priority Index**
>
> PI = V x T x (S x 0.1) x PF x A^1.15 x 0.01
>
> V = Average daily traffic volume
> T = Average daily train volume
> S = Train speed
> PF = Protection factor
>
> | | |
> |---|---|
> | Gates: | 0.10 |
> | Cantilever Flashing Lights: | 0.15 |
> | Mast Mounted Flashing Lights | 0.70 |
> | Passive: | 1.00 |
>
> A = Train crashes in 5 years (Default = 1)

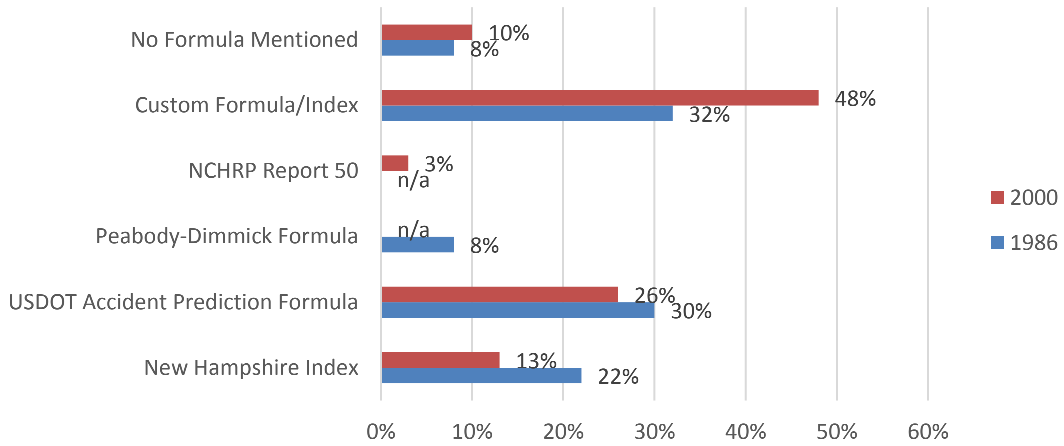
While not specifically mentioned in the FHWA Railroad-Highway Grade Crossing Handbook, the Texas Priority Index is another hazard index formula that is used by many states. Similar to other formulas and indices, it is driven primarily by traffic and train volumes, existing crossing warning devices, and recent crash history. The formula is very similar to a modified New Hampshire Index with additional factors for train speed and crash history. It also distinguishes between flashing lights that are mast-mounted and those that are cantilever-mounted. Interestingly, while the number of train crashes is a factor in the index, it only affects the final number if there are two or more crashes recorded within the past five years. One crash or no crashes in that time period will have the same result.

Use of the Traditional Methods by State DOTs

In 2014, the Tennessee Department of Transportation (TDOT) completed their Highway-Rail Grade Crossing Identification and Prioritizing Model Development study. The document discusses the content and merits of seven nationally recognized crash prediction models. As part of that analysis, the study reviewed previous surveys of state DOTs regarding their use of hazard indices or accident prediction formulas. The first survey, conducted in 1986, included responses from 45 states. The second survey, conducted in 2000, included responses from 31 states. The results of the surveys are summarized in Figure 1.

The results show that in both surveys, the greatest proportion of respondents noted the use of a custom formula or index for crossing improvement prioritization. This is followed by use of the USDOT Accident Prediction Formula and the New Hampshire Index (including both baseline and modified forms). The change in response for custom formula/index between 1986 and 2000 appears to indicate a growing trend towards a customized state-specific approach to crossing safety. The study also found that many of the modified and/or custom formulas included additional qualitative and quantitative variables such as school bus volumes, heavy vehicle traffic, vehicle speeds, and physical risk characteristics.

Figure 1. Hazard Index/Formula Employed by State DOTs



SOURCE: TDOT HIGHWAY-RAIL GRADE CROSSING IDENTIFICATION AND PRIORITIZING MODEL DEVELOPMENT STUDY

Most recently, a 2015 article from the Transportation Research Record, Macroscopic Models for Accident Prediction at Railroad Grade Crossings: Comparisons with U.S. Department of Transportation Accident Prediction Formula looked at how effective the USDOT Accident Prediction Model is today, three decades after its creation. The paper used historic data from Illinois to evaluate its current accuracy measured in terms of the cumulative accident frequency and the accuracy for ranking high-accident locations. Results highlight advantages of a model built with recent data to predict the overall accident trends and the absolute accident frequencies.

Peer State Interviews

As part of the existing resource review, the study team completed informational interviews with rail safety leads at three peer state DOTs. The peer states included Arizona, Oregon, and Utah. These were selected based on the following similarities: western states; large rural areas; and significant trucking activities related to natural resource extraction. In addition to reviewing the type of hazard index employed by each of the peers, the interviews also included a discussion of other issues such as pedestrian safety considerations, stakeholder involvement, and general design criteria. A summary of the feedback received from each state is included below.

Arizona

The Arizona Department of Transportation (ADOT) currently uses the Texas Priority Index as their primary model for prioritizing crossing improvements. However, in recent years they have begun to review potential alternatives to this approach, as they feel— similar to Nevada— that their current hazard index results do not align with state priorities and goals. They have begun to explore means of incorporating other factors, such as school bus usage, hazardous materials, train speeds, and urban/rural distinctions into their approach.

Stakeholder involvement is a critical component of ADOT's project selection. They regularly put out calls for projects from cities, counties, ADOT district engineers, and the railroads to identify the crossings that are most in need of safety improvements. The hazard index is applied to these recommended crossings and is used to provide context in the broader discussion with all stakeholders to determine the official priority list. ADOT feels that this degree of stakeholder involvement at the state and local levels helps foster public support for the final project selections.

Oregon

The Oregon Department of Transportation (ODOT) uses a custom accident prediction model for crossing improvement prioritization. The Jaqua model, developed in 1969 by the Oregon Public Utility Commissioner (Clarence E. Jaqua), employs three major factors: an exposure factor, a hazard rating, and a protection factor. Each of the three factors is multiplied together to calculate the final index value.

- The exposure factor is an estimate of the maximum number of collisions possible based on crossing occupancy time estimates for both vehicles and trains. Distinct exposure factors are developed for freight trains, passenger trains, and for switching movements. These are then summed into a total exposure index for each crossing.
- The hazard rating accounts for grade crossing characteristics that could adversely affect crossing safety. These include number of tracks, sight line obstructions, train speed, crossing geometry, and other site-specific distractions or features.
- Similar to other models, the protection factor assigns a value based on the presence of warning devices such as gates, flashing lights, and stop signs.

ODOT also applies some discretion when applying the Jaqua model. Crossings that are lower on the final priority list may be improved first if there is an immediate opportunity such as a roadway reconstruction project or if forecast future conditions indicate a greater need (e.g., bus route changes, increased truck traffic, adjacent crossing closures).

Utah

The Utah Department of Transportation (UDOT) uses the FRA's Web Based Accident Prediction System (WBAPS) to generate a list of the top 50 crossings in the state that should be considered for safety improvements. This system is based on the USDOT Accident Prediction Formula described earlier. However, this list is used only as a starting point for discussion. Much more emphasis is based on the recommendations made during UDOT's individual crossing reviews. These crossing reviews are completed annually for each crossing. UDOT considers many site-specific safety issues such as restricted sight lines, highly skewed intersections, and even local weather conditions. UDOT uses a prescribed scoring system for identifying issues at each crossing, but this system is flexible and the professional judgement of the crossing review teams is used to make the final decisions for crossing improvements. UDOT feels that this approach has fostered positive public and political support and the recommendations from the crossing review teams are highly valued. The policies and applications of this approach are reviewed regularly by the agency's Expert Advisory Panel.

UDOT noted two additional issues that have been reviewed more closely in recent years. The first is the issue of pedestrian safety, specifically at crossings on the rapidly expanding light rail and commuter rail transit systems on the Wasatch Front and in the Salt Lake Valley. In 2013, UDOT developed a Pedestrian Grade Crossing manual to review best practices for pedestrian considerations and to recommend when and where to install specific pedestrian safety treatments. The second issue is traffic signal preemption at intersections near grade crossings. Signal preemption can have a significant impact on grade crossing safety and the recently published UDOT manual Preempting Traffic Signals near Railroad Crossings in Utah provides an overview of common issues and tools for identifying the need for and implementing signal preemption systems.

Moving Beyond the Traditional Approach

Many of the traditional hazard index model approaches have focused on the key factors of highway/rail volumes, existing warning devices, and crash history. Many recent projects and ongoing research has identified a number of other issues that should be considered when evaluating highway-rail grade crossing safety. A summary of some of these themes and ideas is provided below.

Alternative Factors and Approaches

Minnesota Crude-by-Rail Study

The Bakken oil crude boom in the Upper Mississippi Valley dramatically increased crude-by-rail traffic in Minnesota. In response, the Minnesota DOT (MnDOT) completed the 2014 Report on the Improvements to Highway-Rail Grade Crossings and Rail Safety. This study evaluated crude oil unit train routes and recommended a prioritized list of crossing improvements based on a customized formula. In response to public concern regarding the potential impact to adjacent areas from crude-by-rail collision or other incidents, the study included factors beyond those typically included in the traditional approaches described above. Factors incorporated into the study include:

- Traffic and train volumes and speeds
- Population in hazmat evacuation zones (Schools, senior communities, etc.)
- Makeup of vehicle traffic including heavy truck and school bus
- Physical conditions at crossing

The study evaluated not only the crude oil train routes in the state, but all 4,500 grade crossings. A four-category, 20-variable evaluation process was developed and applied to prioritize grade crossing safety and accident exposures. The highest priority crossings were evaluated by an expert team consisting of MnDOT rail project managers, rail engineers, and railroad personnel. The analysis was confirmed by site visits, meetings with local safety representatives, railroad near-miss reports, and actual traffic counts and vehicle type/mix data. The output of this process was reported to the Legislature in a plain-language report and shared with the public and affected communities through several dozen public forums. The process successfully evaluated heavy truck routes, bus routes, traffic conflicts, conditions and geometrics, community impacts of actual crossing collisions, rail operations, and produced a listing of both funded and future projects to improve crossing safety.

MnDOT Rail Grade Crossing Safety Project Selection

Using some of the lessons learned from the crude-by-rail study, MnDOT completed a Statewide Grade Crossing Study in 2016 with the purpose of identifying the crossing characteristics most important to predicting grade crossing safety. The study reviewed national literature and the use of action prediction models and alternatives. The risk factors found to have the highest correlation with crashes included:

- Roadway and train volumes
- Roadway and railroad speed limits
- Number of mainline tracks
- Crossing angle
- Distance to nearby intersections
- Distance to nearest crossings
- Sight distance limitations

The report suggested the use of threshold values to determine the importance of a risk factor. These thresholds were developed separately for crossings with active and passive warning devices. For example, if roadway ADT exceeded 2,500 at an active crossing, it would receive one point for that factor. If ADT were below 2,500, the crossing would receive zero points. For passive crossings, this ADT threshold was set at 150. The total number of thresholds was 10 for active crossings and 9 for passive crossings. Crossings meeting more thresholds were considered higher priority for safety improvements.

Alternative Improvement Options at Passive Crossings

In the 1990s, researchers recognized that current prioritization methodologies favored investment in urban, high AADT crossings. Because of this, many high-volume crossings had been improved, while many rural passive crossings were neglected. An article in Transportation Research Record 1368: Innovative Passive Device Studies and Demonstrations Currently Being Conducted in the United States and Canada looked at how improved passive crossing protection (advance warning, high-reflectivity, angled reflectivity) can help reduce collisions.

Specifically, it looked at creating a comprehensive review of fragmented studies on the effectiveness of various improvements such as new retroreflective materials, retroreflective trackside objects, an alternative passive warning sign, and the use of variable aspect signs. The study also reviewed a Texas study to enhance the effectiveness of standard crossbuck signs, an FHWA human factors study, a Canadian study of new sign systems at passive crossings using intermediate signs, and a before and after study of the effects of an Operation Lifesaver media blitz on driver behavior at crossings. The article found positive impacts to grade crossing safety resulting from the implementation of these improved passive warning devices.

More recently, the FRA evaluated the use of LED technology at passive crossings (2016). The study used a pilot project to appraise the effect of crossbuck replacement and advance warning signs with LED lights. The study found the improvements yielded a 1.5 to 2.5 percent speed reduction on average for crossing approaches.

Limitations of Crash History as a Predictive Measure

Applying Safety Treatments to Rail-Highway At-Grade Crossings (Cooper & Ragland) looked at the effectiveness of the California hazard mitigation index. Among its findings was the challenge of using historic data to predict the future, and the challenge of determining what defines a dangerous crossing. While these are challenges nationally, the study makes note of California's innovative use of factors such as crossing angle, proximity to highway intersection, and crossing in their hazard calculation.

Heavy Commercial Vehicle Collisions

The size and weight of vehicles involved in grade crossing collisions can play a critical role in the severity of the outcome. Studies of these collision dynamics have found that collisions involved heavy commercial vehicles are more likely to results in derailment. Heavy vehicles such as tractor trailers are also much more likely to become stuck on a crossing due to severe grade changes.

In 1995, the Amtrak Silver Star struck a tractor-trailer that had been lodged on a rural high-vertical hump at a passive grade crossing in South Carolina. The NTSB investigation found that probable cause of this accident was the motor carrier's failure to provide to the driver appropriate guidance to respond to emergency situations. This led to the truck driver's failure both to understand that the substandard profile of the Boogaloo Road grade crossing was incompatible with the truck he was operating, and to notify the appropriate railroad and emergency personnel of the blocked crossing." (HAR-96-01)

The project team searched the FRA databased in October 2016 to identify grade-crossing collision-related train derailments that resulted in injuries and/or fatalities. The team found that 16 grade crossing crashes between 2010 and 2016 resulting in derailments, all involving heavy commercial trucks or semi-tractor trailers, accounting for a total of 16 fatalities, 222 injuries, and two hazmat evacuations.

In April 2016, the Journal of Vehicle Dynamics published a European report that described a modeling simulation that quantifies derailment potential of heavy truck and passenger train collisions at crossings including effects of truck weight, train speed, angle of impact, and train dynamics, illustrates significant effects of oblique impacts and higher train speeds. The study used two scenarios to evaluate these impacts; a heavy truck hitting the front and middle passenger cars of a train set. The study found that it is "easier to cause wheelset derailment when the front passenger car is laterally collided with the road truck rather than the middle car."

Driver Behavior

Issues of driver behavior and inattentiveness play a major role in recent crash trends. These factors should be considered when determining grade crossing improvement options.

In 2012-13, FRA conducted three studies that looked at how driver behavior affects grade crossing safety. The first study looked at how signal detection theory could affect driver stopping behavior. Particular, it defined the reliability of motorist behavior as a function of expected train arrival time of train and noted that the variability of waiting times was the most important factor in compliance. The second FRA report, observed 3,171 commercial vehicle grade crossing events. The study found that drivers were engaged in activities other than driving 21 percent of the time and drivers failed to look left and right 41 percent of the time. Similarly, the last study employed 41,215 event observations to quantify types and extent of behaviors that impact safety at crossings (for all vehicle types). Major findings included 46.7 percent of drivers engaging in activities secondary to driving, 35 percent failed to look left or right at passive crossings.

In 2014, this research was cited by a Canadian Railway Crash Report (ROOC0159) that recognized the need for treatment consistency, management of driver expectations, responses and actions, cites NTSB and independent research in drivers' lack of attention and low expectation of train approach if active visual cues (train siting or signal) are not present.

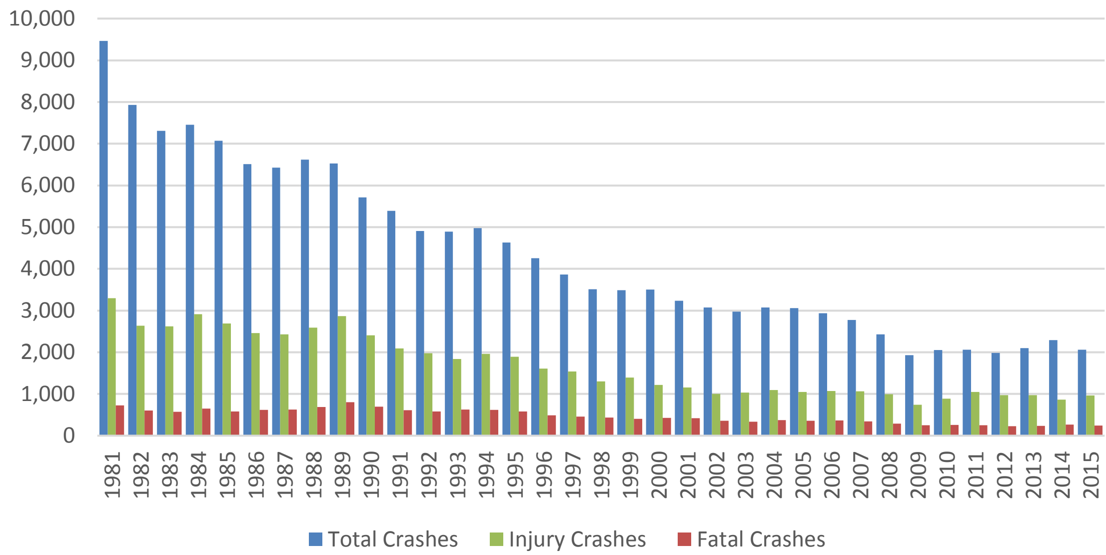
Existing Crossing and Crash Summary

Grade Crossing Safety Trends

At-grade crossings have always been a significant safety concern for both public highway users and the railroads. Local authorities, railroads, states, and federal regulators have made steady progress over the past few decades to improve the safety for at-grade crossings. Great strides have been made in this regard through the implementation of crossing closures and consolidations and the deployment of Intelligent Transportation Systems (ITS) solutions. These efforts locally and nationally have contributed to a steady decline in crash rates since the 1950s.

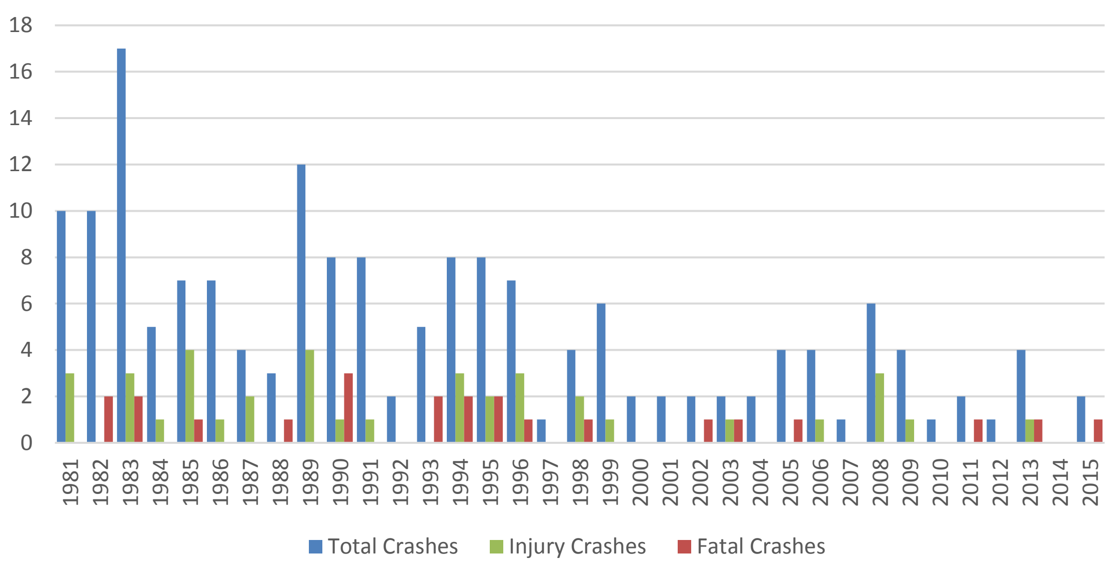
Figure 2 below highlights this national trend in decreasing highway-rail crashes. The figure summarizes crash data from the Federal Railroad Administration (FRA) for the past 25 years. Since 2009, the number of annual crashes has held relatively steady at 2,000 per year. This decrease has been consistent for fatal, injury, and property damage-only (PDO) crashes. Figure 3 shows this information for the State of Nevada alone. The general reduction in crash frequency mirrors the trend at the national level. Note that the figures include crashes for both public and private crossings. The locations of Nevada's public highway-rail grade crossings are shown in Figure 4.

Figure 2. Reported Nationwide Highway-Rail Collisions



SOURCE: FEDERAL RAILROAD ADMINISTRATION OFFICE OF SAFETY ANALYSIS

Figure 3. Reported Nevada Statewide Highway-Rail Collisions



SOURCE: FEDERAL RAILROAD ADMINISTRATION OFFICE OF SAFETY ANALYSIS

Figure 4. Public Highway-Rail Grade Crossings in Nevada

Nevada Grade Crossing and Safety Characteristics

The following section provides an overview of the various characteristics found at public highway-rail grade crossings throughout the state of Nevada. The characteristics reviewed include items such as highway and railroad traffic volumes and speeds, urban or rural designations, existing warning devices, and crossing geometry. This review uses two distinct approaches to generate a better understanding of the characteristics most important to crash prediction. Each of the approaches relied on the use of crash and near miss data. The crash data used in this evaluation is based on information provided in the FRA's accident/incident inventory and was collected for the past 10 years. Data for near misses was based on Unsafe Motorist Reports provides by UP Railroad. This evaluation uses near miss data collected over the past three years. Each data source presents unique benefits and challenges.

- Crash data provides an objective quantifiable value with additional detail such as factors involved in the collision and a summary of highway and train vehicle types. The major disadvantage is that the number of crashes is so low that it can often be difficult to determine strong correlations. In the past 10 years, only 18 crashes were recorded at the crossings reviewed in this analysis.
- Near misses occur must more frequently than actual crashes and therefore provide many more data points for consideration. However, more subjectivity is involved since the requirements for what is considered a "near miss" may change depending on the practices of individual train operators.

The first evaluation approach compares the proportion of crossings within each characteristic to the proportion of crashes and near misses within the same characteristic. If the proportion of crashes or near misses exceeds the proportion of crossings, this indicates that the characteristic is correlated with higher numbers of crashes.

The second approach calculates the crash rate for varying statistics to determine how each characteristic affect the crash rate between train and highway users. A review of the crash rates in conjunction with overall crash proportions may provide additional insight. The crash rates used in this evaluation are calculated as the number of incidents per one million exposure index (highway ADT x Train ADT) points. In order to maintain similar scales of analysis, the crash rate is calculated using a 10-year total, while the near miss rate is calculated using an annual average based on three years of data.

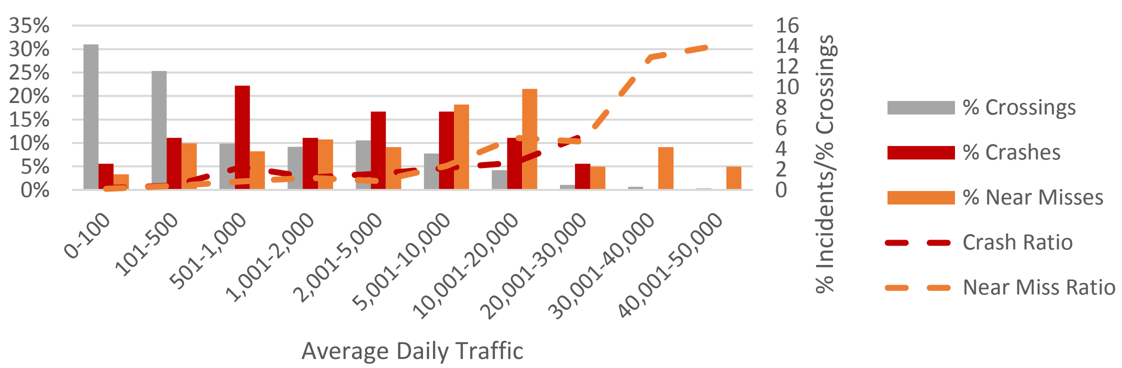
The following pages discuss the results of this evaluation on a number of grade crossing factors. Some factors that were reviewed, but were not included due to inconclusive results (or insufficient data for meaningful results) include:

- Roadway Functional Classification
- Sight Distance Issues
- Crossing Illumination
- Crossing Angle
- School Bus Usage
- Roadway Vertical Curvature
- Number of Highway Lanes
- Number of Railroad Tracks
- Number of Passenger Trains

Highway Average Daily Traffic (ADT)

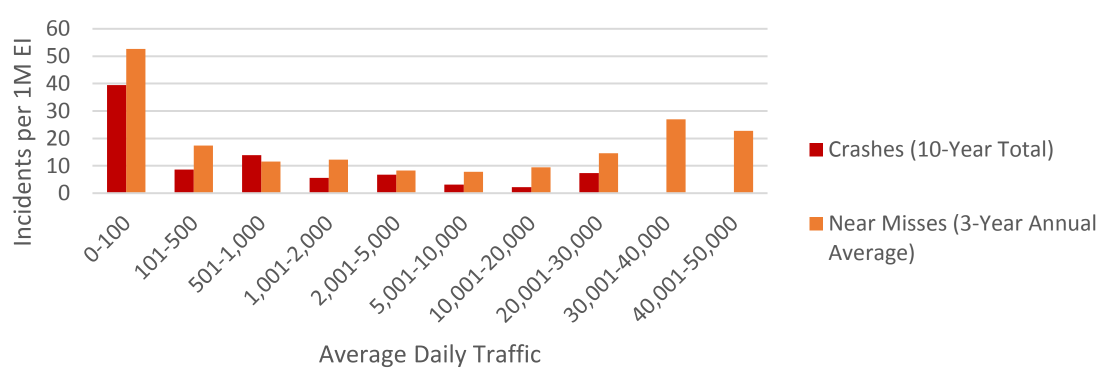
While low-volume crossings with 500 ADT or less comprise roughly 55 percent of all crossings, only 17 percent of crashes and 13 percent of near misses occur at these crossings. In contrast, only 6 percent of the crossings have ADT greater than 10,000, yet these crossings account for 40 percent of the observed near misses and 17 percent of the recorded crashes. The results (Figure 5) indicate that highway traffic correlates strongly with higher numbers of crashes and near misses. This correlation is strongest between 0 and 1,000 ADT and then between 5,001 and 50,000 ADT. **This result suggests that highway ADT should be a key factor in any proposed hazard index model for Nevada.**

Figure 5. Crossing, Crash, and Near Miss Proportions by Average Daily Traffic



A review of the incident rates results in additional potential considerations (Figure 6). The rates for both crashes and near misses are highest for crossings with ADTs of 100 or less. This result may be explained by driver and/or train operator complacency. That is, if a crossing is known to have very low volumes, drivers and train operators may give less attention compared to higher-volume crossings. However, even though the incident rates are much higher, crossings with ADTs of 100 or less still account for only one crash and four near misses. The crash and near miss rates are lowest at crossings with ADT between 5,000 and 20,000. The rates begin to increase once more when ADT increases beyond these levels.

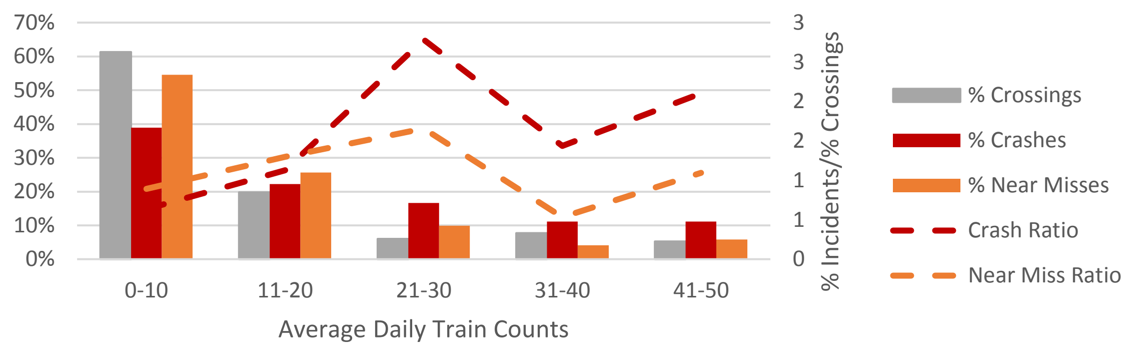
Figure 6. Crash and Near Miss Rates by Average Daily Traffic



Average Daily Train Counts

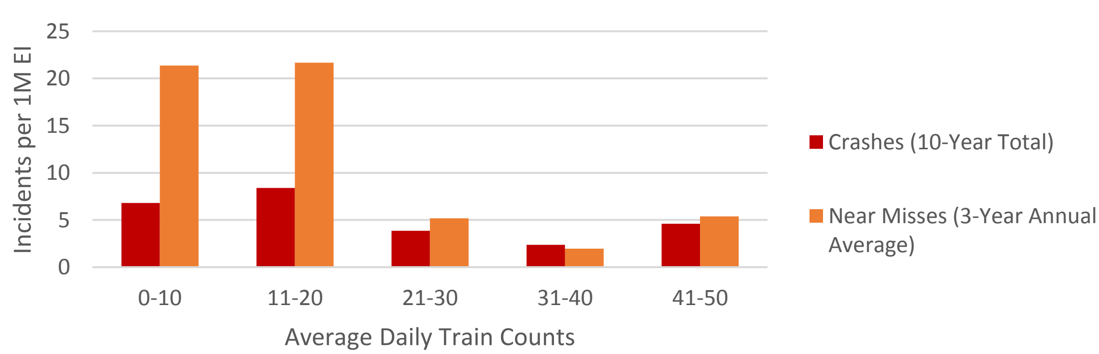
The evaluation of daily train counts shows similar correlations as for highway ADT (Figure 7), however, the correlation does not appear to be as strong. More than 60 percent of the crossings experience on average of 10 or fewer trains per day, yet these crossings account for less than 40 percent of the crashes. As the daily train counts increase, there is a general trend of increasing crash and near miss ratios. Of note is the drop in both ratios between the 21-30 train per day grouping and the 31-40 train per day grouping. However, following this drop, the trend continues upward. **This result suggests that daily train counts should be considered as a potential factor in the proposed hazard index, but should be weighted less than highway ADT.**

Figure 7. Crossing, Crash, and Near Miss Proportions by Average Daily Train Counts



A review of the crash and near miss rates at this crossing shows a similar result to highway ADT (Figure 8). Incident rates for both crashes and near misses are highest at train volumes between 0 and 20 trains per day. One potential explanation for this result is the lower rates of gate utilization at lower-volume crossings. For crossings with 0-20 trains per day, less than half of the crossings are equipped with gates. For crossings with 21 or more trains per day, more than two-thirds of the crossings are equipped with gates.

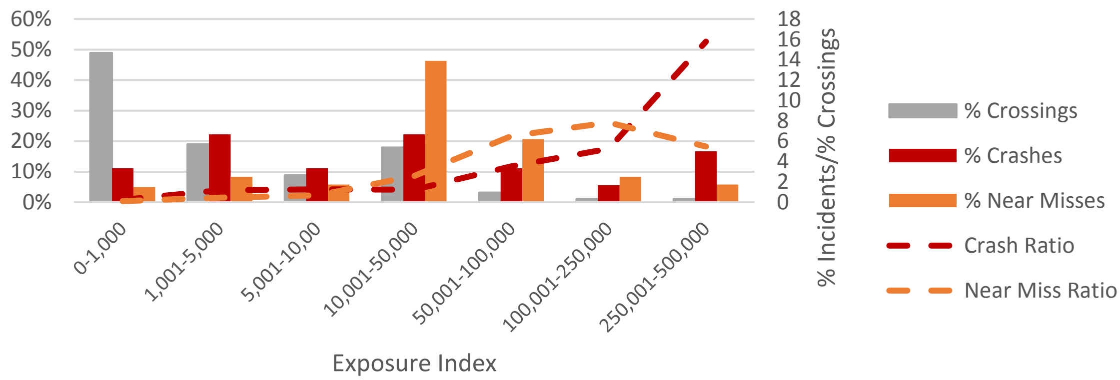
Figure 8. Crash and Near Miss Rates by Average Daily Train Counts



Exposure Index (Highway ADT x Average Daily Train Counts)

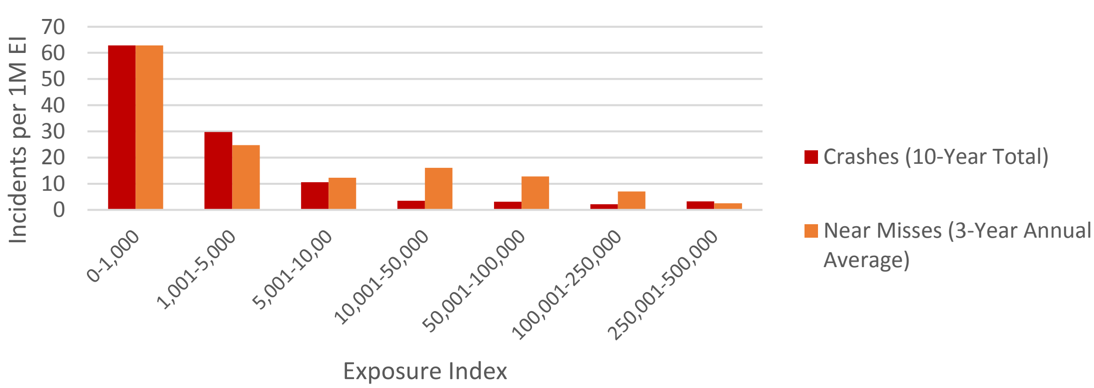
The exposure index is calculated by multiplying the crossing's highway ADT with the average daily train count. Given the positive correlations between these variables and crashes/near misses, it is no surprise that the product of these variables also results in a positive correlation (Figure 9). Nearly 50 percent of crossings have an exposure index of 1,000 or less, yet account for only 10 percent of crashes and 5 percent of near misses. At the other end of the spectrum, crossings with exposure indices over 250,000 comprise only one percent of the crossings, yet account for 17 percent of the crashes and six percent of the near misses throughout the state. **These results suggest that the use of exposure index should be considered for the potential hazard index, and may be a more useful and consistent measure than considering highway and rail volumes independently.**

Figure 9. Crossing, Crash, and Near Miss Proportions by Exposure Index



A review of the crash and near miss rates shows a steady downward trend in incident rates as the exposure index increases (Figure 10). Despite the larger raw numbers of incidents at crossings with high exposure indices, the rates of these incidents are some of the lowest in the state. This suggests that while the exposure index will be a key factor in the proposed hazard index, the weight given to this factor should not increase linearly, but should be adjusted to increase more slowly at higher exposure index values. This could be achieved by using the square root of the exposure index rather than the raw value.

Figure 10. Crash and Near Miss Rates by Exposure Index



Highway Speed

The review of highway speed shows inconsistent results (Figure 11). The ratio of crashes and near misses increases to peaks at 30-35 mph and 40-45 mph, but then drops before spiking again at 70+ mph crossings. These results indicates that highway speeds do not have a direct impact on the overall crash rates at Nevada crossings. Additional review of the average exposure index at each posted highway speed category shows a result that almost perfectly mirrors the ratios for crashes and near misses with peaks at 30-35 mph, 40-45 mph, and 70 mph (Figure 12). This indicates that exposure index is driving the results more so than highway speed.

Figure 11. Crossing, Crash, and Near Miss Proportions by Highway Speed

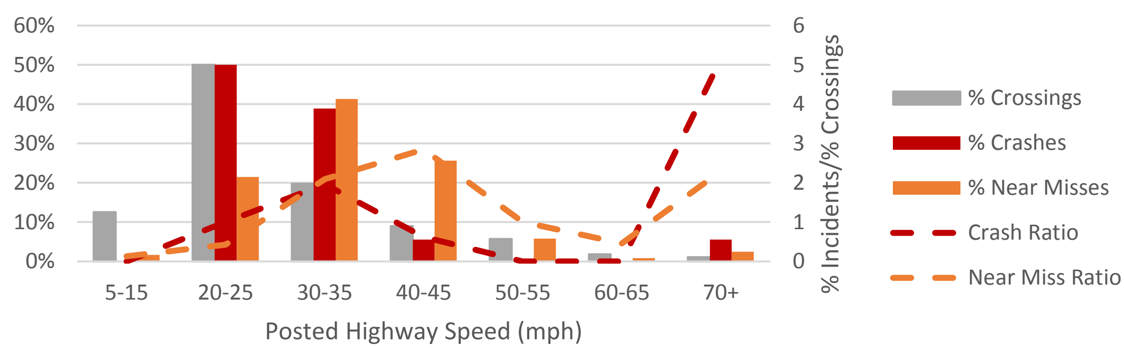
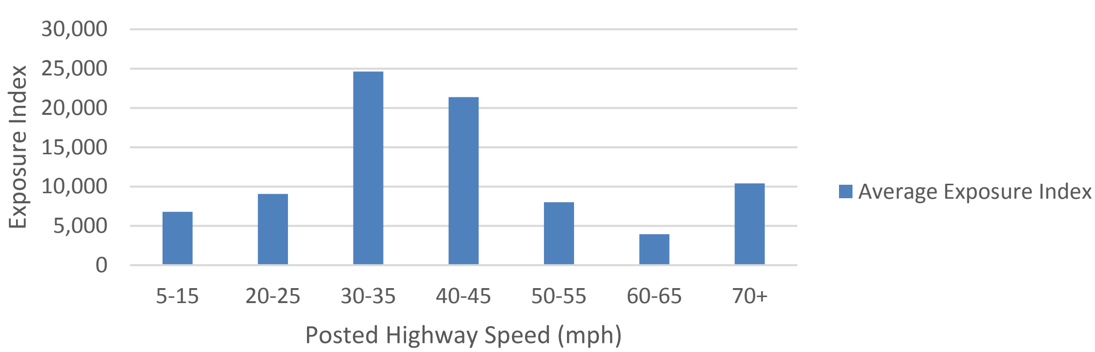
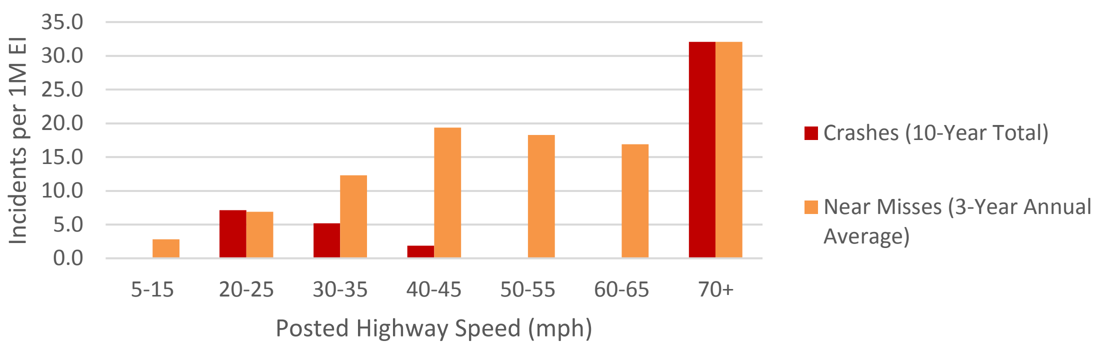


Figure 12. Average Crossing Exposure Index by Highway Speed



A review of the crash and near miss rates helps to provide a look at the role of highway speed independent from highway and train volumes. This results show a general upward trend as highway speed increases (Figure 13). **This trend is particularly strong for near misses, and indicates that highway speed should be considered as a factor in the proposed hazard index.**

Figure 13. Crash and Near Miss Rates by Highway Speed

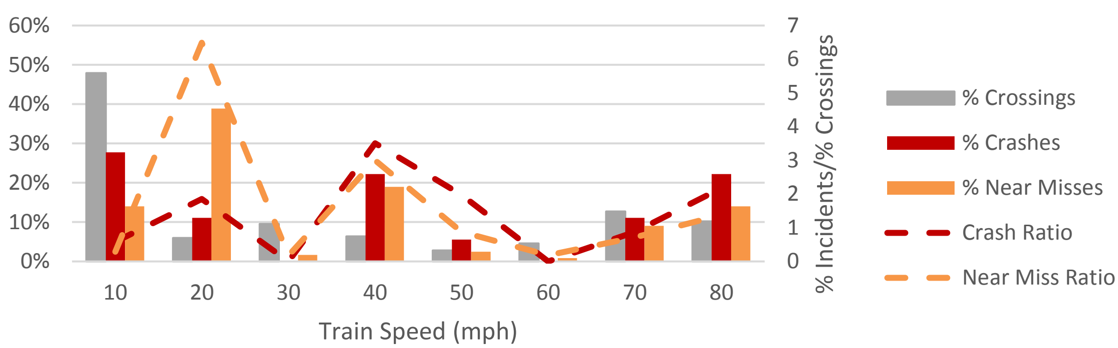


Train Speed

One potential issue with the use of train speed as a factor is that the maximum timetable speed listed for each crossing may or may not correspond to the actual train speeds at the crossing. While actual highway speeds are likely to be close to the posted speed limit, actual train speeds will depend on factors such as the type of load being carried and whether the train is approaching or departing a yard. In addition, while the crossing data does provide a value for average train speed, the maximum speed is more appropriate since the actual train speed may change over time.

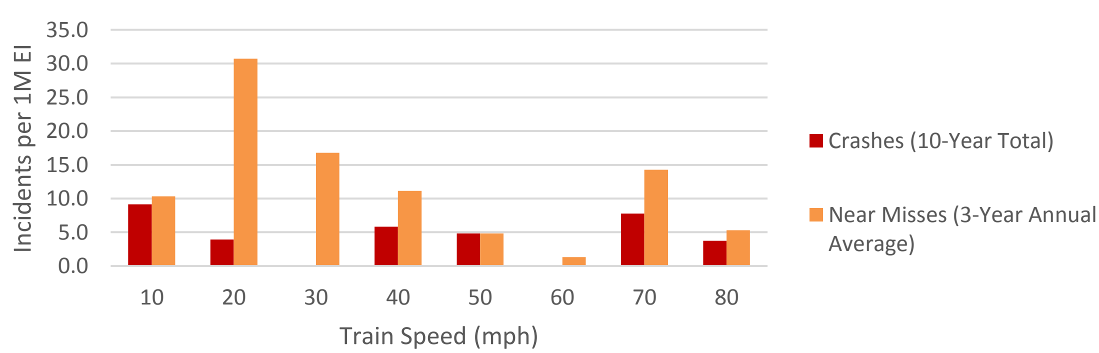
Maximum train speed does not seem to have a clear correlation to crashes or near misses (Figure 14). There appear to be disproportionate jumps in crashes and near misses at maximum timetable speeds of 20, 40, and 60 mph, but there is not a consistent trend in one direction or the other.

Figure 14. Crossing, Crash, and Near Miss Proportions by Train Speed



A review of the crash and near miss rates by train speed shows a similar lack of correlation (Figure 15). Rates of crashes are all in the approximate range of 4 to 9 incidents per million exposure index points. The rates of near misses show more variability with a maximum rate at crossings with train speeds of 20 mph. However, there is no clear trend linking these rates to trains speed. **These results indicate that train speed should not be considered as a factor in the proposed hazard index.**

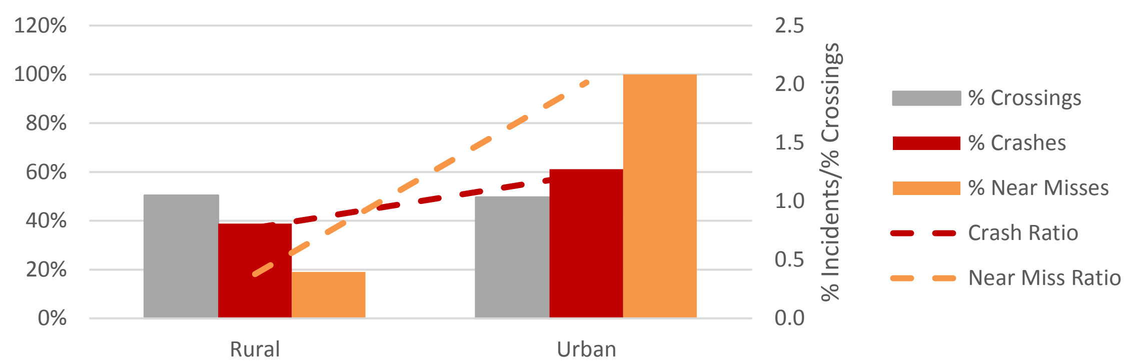
Figure 15. Crash and Near Miss Rates by Train Speed



Urban/Rural

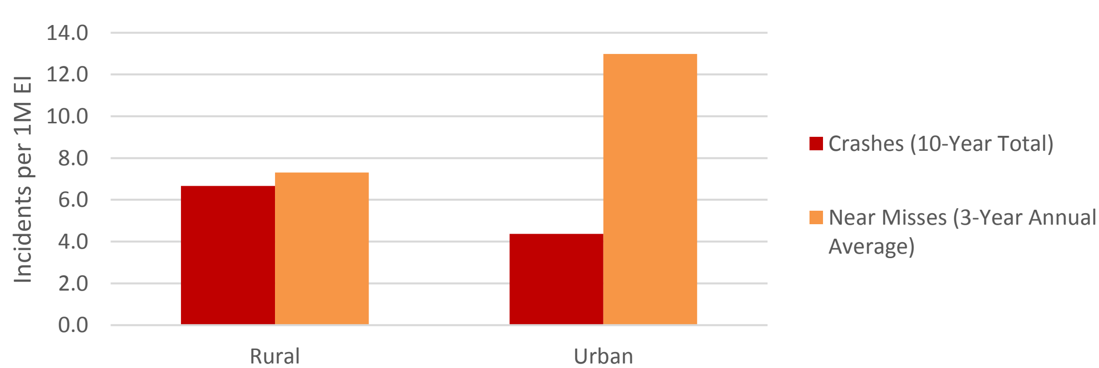
One of NDOT's concerns leading into this study is that the current hazard index prioritizes high-volume urban crossings at the expense of low-volume rural crossings. In order to evaluate differences between these crossing types, this evaluation designated crossings as urban if they are located within a Census-designated urbanized area, or UZA. All remaining crossings were designated as rural. The results show that while there is a nearly even split between urban and rural crossings, there is a higher proportion of crashes and near misses at urban crossings (Figure 16). This result is expected due to the typically higher highway volumes present at urban crossings.

Figure 16. Crossing, Crash, and Near Miss Proportions by Urban/Rural



Based on the earlier finding that low-volume crossings typically have higher crash rates than high-volume crossings, it is expected that similar results would be found for urban and rural crossings. This review shows that while crash rates are higher at rural crossings as expected, the rate of near misses is actually higher at urban crossings. **Because of this, NDOT should not consider the urban/rural designation as a factor in the proposed hazard index, but rather should rely on highway ADT or exposure index instead.**

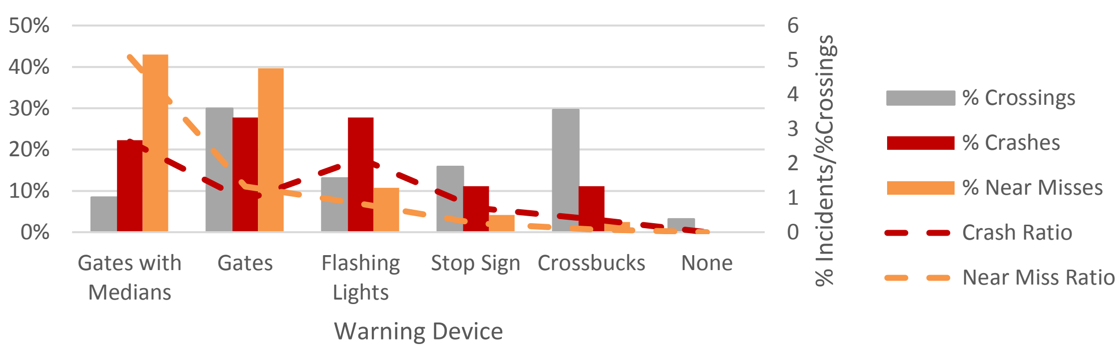
Figure 17. Crash and Near Miss Rates by Urban/Rural



Warning Devices

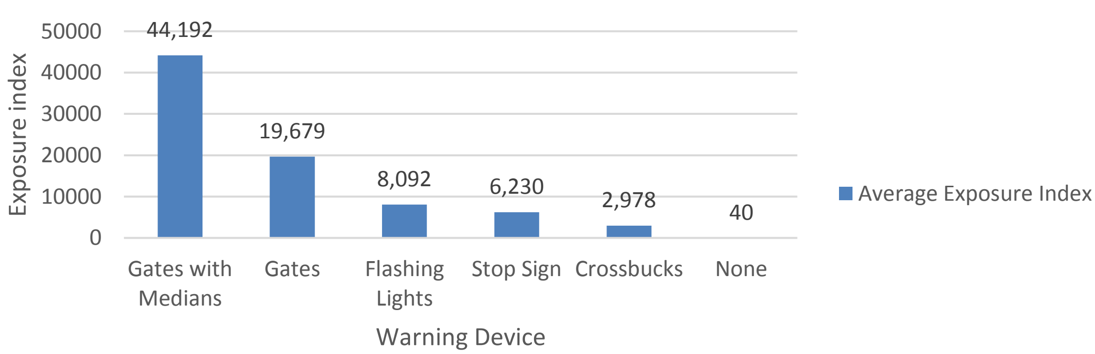
The existing warning device configurations at each crossing were grouped into the following categories, arranged in decreasing "intensity" of treatment: gates (with or without channelizing medians), flashing lights only, stop signs, crossbucks, and none. Approximately 30 percent of Nevada's crossings are equipped only with crossbucks. On the other end of the spectrum, nearly 40 percent of the crossings are equipped with gates. The review of the various proportional share of crashes, near misses, and crossings (Figure 18) shows that crossings with more intense treatments generally have a greater share of crashes and near misses compared to their overall proportion. However, these results do not necessarily indicate a causal relationship. It is more likely that intense treatments are placed at crossings with a higher need for warning devices due to roadway or train volumes, sight distance issues, and/or other known safety issues.

Figure 18. Crossing, Crash, and Near Miss Proportions by Warning Device



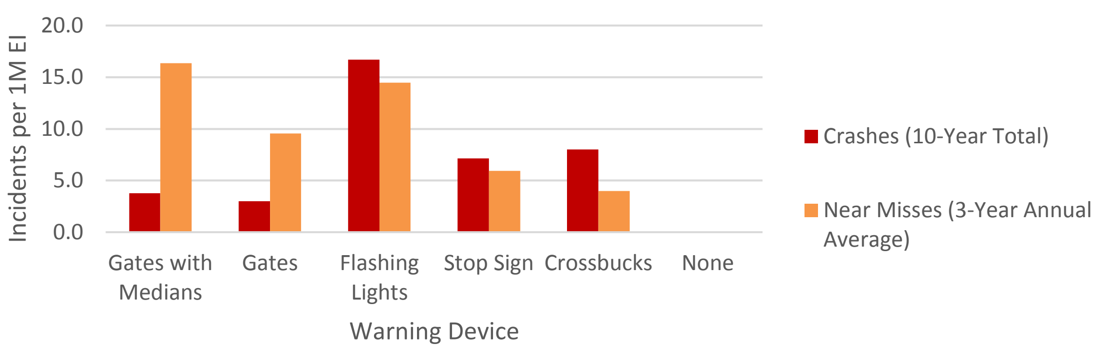
This interpretation is supported by Figure 19, which shows the average exposure index for each warning device category. On average, the exposure index for crossings with gates and medians is more than double the index for crossings with gates alone. The exposure indices for crossings with flashing lights or stop signs are relatively close, but are both more than double the exposure index for crossings with crossbucks only. Crossings with no warning devices have an average exposure index of only 40.

Figure 19. Average Exposure Index by Warning Device



In this instance, a more useful comparison is between the varying crash and near miss rates for each warning device (Figure 20). Interestingly, there is not a strong correlation between the crash and near miss rates. Excluding the flashing lights category, the near miss rates are highest for gates with and without medians while the crash rates are highest for stop signs and crossbucks. Of note are the exceptionally high crash and near miss rates for flashing lights. Despite the average exposure index for crossings with flashing lights being only 30 percent higher than crossings with stop signs, the crash and near miss rates are more than twice as high. **This indicates that flashing lights alone are not an effective treatment option. If it is determined that stop signs or crossbucks are insufficient, the warning devices should be upgraded to include gates.**

Figure 20. Crash and Near Miss Rates by Warning Device



Many of the current hazard index models use a "protection factor" that reduces the estimated crossing risk based on the existing warning device configuration. The crash rates calculated for each of the warning device categories may be used to approximate similar protection factors for NDOT's proposed hazard index. The results show that the crash rates for crossing with gates are less than half that of crossings with stop signs or crossbucks, indicating that gates are an effective treatment option. A protection factor of at least 0.5 should be considered for the proposed hazard index.

Interestingly, there does not appear to be an improvement to crash rates through the implementation of medians at gates, despite research from the FRA estimating that the implementation of medians at gated crossings should reduce the crash risk by approximately 80 percent. **It may not be appropriate to use a protection factor to distinguish between crossings with gates and medians compared to gates alone**.

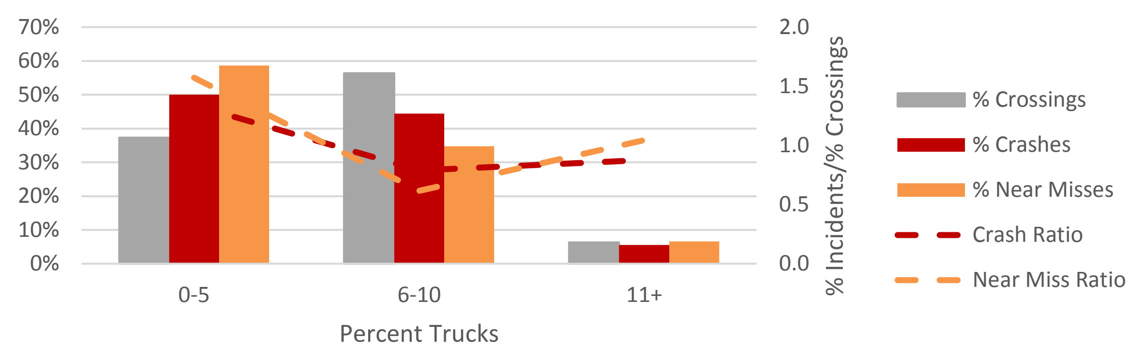
Due to the significantly higher crash rate seen for crossings with flashing lights, a non-modifying protection factor of 1.0 (similar to the factors typically applied for passive protection along) should be considered.

Percentage of Trucks

Out of the 284 crossings included in this review, 77 percent had an estimated truck percentage of 5 or 7 percent. The remaining crossings ranged from a low of 2 percent to a high of 37 percent. One potential weakness of this data is that it represents an estimate rather than a precise value. Still, the estimated values help shed light on general trends related to this factor.

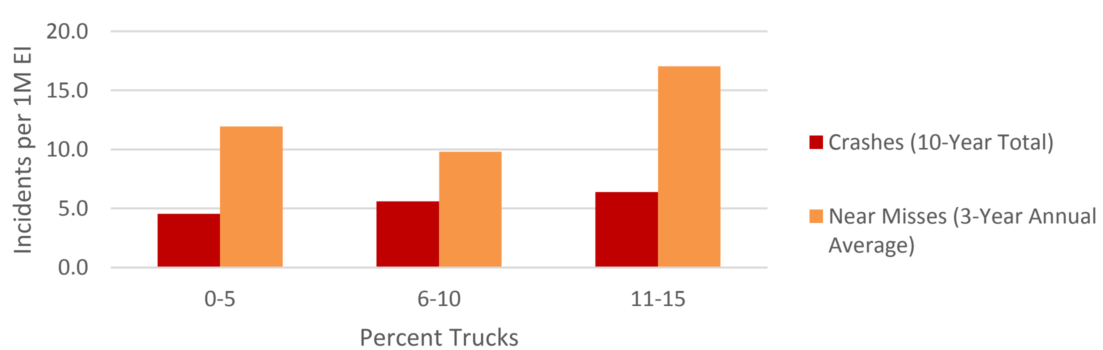
The results do not show a strong correlation between percent trucks and the proportion of crashes and near misses (Figure 21). Approximately half of all crashes and more than half of the near misses occurred at crossings with 5 percent trucks or less. These crossings account for just under 40 percent of all Nevada crossings.

Figure 21. Crossing, Crash, and Near Miss Proportions by Truck Percentage



A review of the crash and near miss rates shows a slightly positive correlation between the incident rates and the percent trucks. However, this trend is slight, and may be related more to the overall ADT volumes than the actual truck percentages. That is, crossings with high truck percentages are more likely to be at low-volume crossings, which—as shown previously—are more likely to have higher crash and near miss rates. **Despite the small correlation between truck percentage and crashes/near misses, NDOT may still wish to consider using this factor in the proposed hazard index.** While the percentage of trucks may not contribute to additional crashes, collisions involving heavy trucks are much more likely to lead to derailments as well as the potential for fatalities or severe injury.

Figure 22. Crash and Near Miss Rates by Truck Percentage



Proposed Hazard Index Factor Considerations

The following section summarizes the key takeaways from both the review of existing hazard index models and peer state reviews as well as the review of Nevada's existing crossing conditions and characteristics. Each of these will be influential in the selection of the factors to be considered for NDOT's proposed hazard index.

Existing Hazard Model and Peer Review Considerations

The various hazard index models and formulas discussed in the previous section use a wide variety of crossing characteristics as inputs. Figure 23 below summarizes the major inputs used in those approaches.

Certain characteristics are nearly universally found in every hazard index methodology. For example, train volumes and highway traffic volumes are key components of every index included in this review. The inclusion of these factors is intuitive as the chance of a collision will naturally be higher at crossings with more opportunities for those collisions (i.e., each additional train and highway vehicle represent one more potential conflict point).

The inclusion of highway and rail speeds is somewhat less frequent, however. Highway speeds are only included in two of the indices reviewed: Oregon's Jaqua model and the recommended factors from Minnesota's crossing study. Train speed is more commonly used and is included in five of the indices reviewed. Other common inputs include existing crossing warning devices, used in all but one index[1], and crash history, used in five of the indices. A distinction between urban and rural crossings is a fairly common approach, used in three of the models reviewed.

The remaining potential inputs are used must less frequently. Factors related to the geometry of the crossing (e.g., number of lanes/tracks, crossing angle, approach curves/grades) and those related to characteristics of the surrounding environment (e.g., population characteristics, sight distance restrictions) are generally used in only one or two of the indices reviewed. Based on our discussion with peer states, the review of close call/near miss records provided by railroads is an important factor in discussing potential crossing improvements. However, Minnesota's crude-by-rail study is the only hazard index that explicitly incorporated this input.

[1] Note that while the Minnesota recommended input factors did not explicitly include crossing warning devices, the final results were tallied separately for active and passive crossings.

Figure 23. Factors Used in Hazard Index Models/Formulas

Crossing Characteristic	Nevada (Modified New Hampshire Index)	USDOT Accident Prediction Formula	Peabody-Dimmick Crash Prediction Formula	NCHRP Report 50 Accident Prediction Formula	Texas Priority Index	Oregon (Jaqua Model)	Minnesota Crude-by-Rail Study	Minnesota Suggested Risk Factors
Highway Traffic Volumes	■	■	■	■	■	■	■	■
Highway Speed						■		■
Train Volumes	■	■	■	■	■	■	■	■
Train Speed		■			■	■	■	■
Existing Warning Devices	■	■	■	■	■	■	■	
Crash History	■	■			■	■	■	
Crash Severity	■	■					■	
Number of Tracks		■				■	■	■
Number of Highway Lanes		■					■	
Highway Pavement		■					■	
Urban/Rural Classification		■		■		■		
Sight Distance Restrictions						■	■	■
Crossing Angle						■		■
Highway Approach Geometry						■		
Rail Approach Geometry						■		
Proximity of Highway Accesses						■		
Proximity to Highway Intersections						■		■
Functional Classification		■					■	
Hazardous Materials								
Commercial/Heavy Vehicles							■	
School Buses							■	
Passenger Trains						■		
Nearest At-Grade Crossing								■
Population Characteristics							■	
Physical Condition of Crossing							■	
Railroad Close Call/Near Miss List							■	

Some lessons and guiding principles can be learned from a review of both the current hazard index models as well as the results of recent research on trends in grade crossing safety. Key takeaways from this review are summarized below:

- **Highway and rail volumes should be critical components of any hazard index model:** Recent research suggests that many hazard indices are over reliant on highway and rail volumes at the expense of other important factors. However, the correlation between crash rates and highway/rail volumes is clear and should not be ignored. NDOT should incorporate these inputs into its revised model, but should also ensure that they do not dominate the final results of the revised hazard index.
- **Crash history is no longer a good indicator of future crashes:** The dramatic decrease of crossing crash frequency in recent decades is something to be celebrated. However, the rarity of these events means that they are no longer good predictive indicators. In the past ten years, only 18 crashes have been recorded at public crossings in Nevada. Out of these, only two have occurred at the same crossing. The remaining crashes can be described as one-off events that have not been repeated. NDOT should carefully consider the weight given to crash history in the revised hazard index. If crash history is used, it should be incorporated in a way that only changes the result if multiple crashes have occurred in the past 5 years.
- **Highway and rail user type should be an important factor:** While the research shows the decreasing predictive value of crash history, there is also a growing body of research suggesting the importance of crash severity as a measure for hazard indices. The 2011 Miriam crash is a good example of this. All things equal, if the train involved had been a freight train rather than a passenger train, or if the highway user had been a passenger vehicle rather than a heavy commercial vehicle, it is likely that the resulting collision would have been much less severe. NDOT should consider incorporating measurements for heavy commercial vehicles, passenger/transit trains, and school/transit buses into the revised hazard index.
- **Characteristics of the surrounding area may be important, but should be balanced by the ease of data collection:** With a growing national focus on the potential impacts of train crashes involving hazardous materials, some states are considering the inclusion of factors such as population density and the proximity of schools and other vulnerable populations in their grade crossing reviews. One challenge to this approach is that data is not typically collected for these measures on a typical basis and additional effort is required to generate the input variables. NDOT should consider the potential inclusion of these inputs in the revised hazard index, but should also weight the benefits against the cost of collection.
- **A breakout of rural and urban crossings should be considered as an approach to separate the different type of crossings:** While this may not be an important factor in the final hazard index chosen by NDOT, the ability to consider the unique attributes and characteristics of these different crossing types will be important.

Existing Crossing Characteristic Considerations

The review of Nevada's existing crossing characteristics compared to crash and near miss data revealed correlations between some factors. A summary the factors reviewed and potential hazard index inputs are summarized below.

Characteristic	Description	Proposed Hazard Index Variable Options
Average Daily Traffic	This factor was found to have a clear correlation with crashes and near misses and should be the base input for the proposed hazard index.	- Raw ADT Count
Average Daily Train Counts	This factor alone was found to have a small correlation with crashes. If used, an adjusted input value based on thresholds may be appropriate.	- Raw Train Count - Multiplier based on threshold (0-10 trains, 11-20 trains, etc.)
Exposure Index (ADT x Train Counts)	This factor was found to have a stronger correlation to crashes and near misses than the use of each factor individually. In order to avoid overemphasis of high-volume crossings, this factor may also be modified such as through the use of squaring the index value.	- Raw Exposure Index - Modified Exposure Index (e.g., Squared Root of Index Value)
Highway Speed	The correlation between crash rates and highway speed tended to be grouped into similar rates for three distinct speed limit ranges. Highway speed could factored based on these ranges or raw speed limit alone could be applied as an unmodified factor.	- Raw posted speed - Speed Factors: ○ ≤ 30 mph = 1.0 ○ 35-65 mph = 1.25 ○ 70 mph = 1.50
Train Speed	Due to the lack of correlation between train speed and crashes or near misses, it is not recommended that the proposed hazard index include a variable for this characteristic.	- No recommended variable
Urban/Rural	The granular distinctions between varying levels of urban and rural designation are better handled using highway ADT or Exposure Index.	- No recommended variable
Current Warning Devices	The presence of existing warning devices will play a role in estimating levels of safety. The use of a protection factor will also aid in the determination of when the next level of improvement is warranted. While this review found no difference between gates with or without medians, the existing research suggests that a higher protection value is warranted for gates with medians.	Protection Factors: - Passive or Flashing Lights Only = 1.0 - Gates = 0.5 - Gates with Medians = 0.2
Truck Percentage	The review found very slight correlations between truck percentage and crashes. However, the existing research shows that crashes involving heavy vehicles are much more likely to result in fatal or injury crashes.	- Multiplier based on percentage (e.g., 1.07 for 7 percent trucks) - Multiplier based on thresholds (0-5%, 6-10%, etc.)

Expert Panel Discussion and Input

The project team held two meetings with an expert panel consisting of representatives from several different agencies and organizations to gain input regarding issues with the existing hazard index model and priorities for grade crossing safety improvements. Agencies and organizations represented at the meetings included various divisions of the NDOT, the Federal Railroad Administration (FRA), Federal Highway Association (FHWA), Operation Lifesaver, Union Pacific Railroad, and several cities and counties.

Expert Panel Meeting 1

The first expert panel meeting consisted of a presentation summarizing the existing NDOT hazard index model and alternative models and methodologies for evaluating grade crossing safety. The presentation reviewed both traditional models such as the USDOT Accident Prediction Model and the Texas Priority Index, as well as more recently developed models and approaches. Additionally, an overview was provided of grade crossing safety trends at the state and national level. This information is summarized in the Grade Crossing Safety Trends section of this report.

Lessons and guiding principles identified through this review are summarized below.

- **Highway and rail volumes should be critical components of any hazard index model:** Recent research suggests that many hazard indices are over-reliant on highway and rail volumes at the expense of other important factors. However, the correlation between crash rates and highway/rail volumes is clear and should not be ignored. NDOT should incorporate these inputs into its revised model, but should also ensure that they do not dominate the final results of the revised hazard index.
- **Crash history is no longer a good indicator of future crashes:** The dramatic decrease of crossing crash frequency in recent decades is something to be celebrated. However, the rarity of these events means that they are no longer good predictive indicators. In the past ten years, only 18 crashes have been recorded at public crossings in Nevada. Out of these, only two have occurred at the same crossing. The remaining crashes can be described as one-off events that have not been repeated. NDOT should carefully consider the weight given to crash history in the revised hazard index. If crash history is used, it should be incorporated in a way that only changes the result if multiple crashes have occurred in the past 5 years.
- **Highway and rail user type should be an important factor:** While research shows the decreasing predictive value of crash history, there is also a growing body of research suggesting the importance of crash severity as a measure for hazard indices. NDOT should consider incorporating measurements for users typically involved in more severe crashes into the revised hazard index, including heavy commercial vehicles, passenger/transit trains, and school/transit buses.

- **Characteristics of the surrounding area may be important, but should be balanced by the ease of data collection:** With a growing national focus on the potential impacts of train crashes involving hazardous materials, some states are considering the inclusion of factors such as population density and the proximity of schools and other vulnerable populations in their grade crossing reviews. One challenge to this approach is that data is not typically collected for these measures and additional effort is required to generate the input variables. NDOT should consider the potential inclusion of these inputs in the revised hazard index, but should also weight the benefits against the cost of collection.
- **A breakout of rural and urban crossings should be considered as an approach to separate the different type of crossings:** While this may not be an important factor in the final hazard index chosen by NDOT, the ability to consider the unique attributes and characteristics of these different crossing types will be important.

The meeting summary for the first expert panel meeting is included in Appendix A.

Expert Panel Meeting 2

At the second meeting with the expert panel, the project team provided additional information regarding the correlation between various crossing characteristics and existing crash and near miss incidents. The project team also reviewed a list of twelve Nevada crossings that were selected as a representative sample of various crossing characteristics throughout Nevada. The crossings range in terms of train volumes, highway volumes, urban/rural location, and the extent of the warning devices installed (gates, flashing lights, passive, etc.). The expert panel was divided into four groups and each group was asked to identify the top three and bottom three crossings in terms of prioritization for additional safety measures. Each vote from each group was then tallied to arrive at a score for each crossing. The results of the ranking exercise are shown in Table 1 below.

Table 1. Expert Panel Ranking

Crossing Number	Crossing Name	Top 3	Bottom 3
804209T	Wyoming Avenue	3	
913213H	Rainbow Blvd	2	
833601K	Fourth Street East - Reno	2	
762088D	Sutro Street	2	
740765S	US 95 - Lovelock Cutoff	2	
740918T	US 95 Alternate - Weeks	1	
833452L	Gold Acres Road - North		
833585D	Jodi Avenue		
804185G	Green Valley Parkway		1
913085C	US 93 - Ely		3
740886P	Icarus Road		4
804059M	Navajo Avenue		4

Wyoming Avenue was most highly ranked as the crossing that should be prioritized for improvements, with votes from three of the four groups. Rainbow Boulevard, Fourth Street East, Sutro Street, and US 95-Lovelock Cutoff each tied for the second highest ranked crossing with two votes each. All four groups voted for Icarus Road and Navajo Avenue as the lowest ranked crossings in the list. The purpose of the ranking exercise was to develop a measure of hazard index suitability for each existing and proposed hazard index model. If any of the models rank the twelve sample crossings in an order that closely matches the expert panel ranking, this is an indication that the model is accurate and reflects the professional judgement of expert panel members.

Next, the project team presented the ranking results of a number of existing and proposed hazard index models for the twelve sample crossings. This analysis highlights the similarities and differences between each of the individual models. The results of this analysis are discussed in later in the Comparison of Hazard Index Models section of this report.

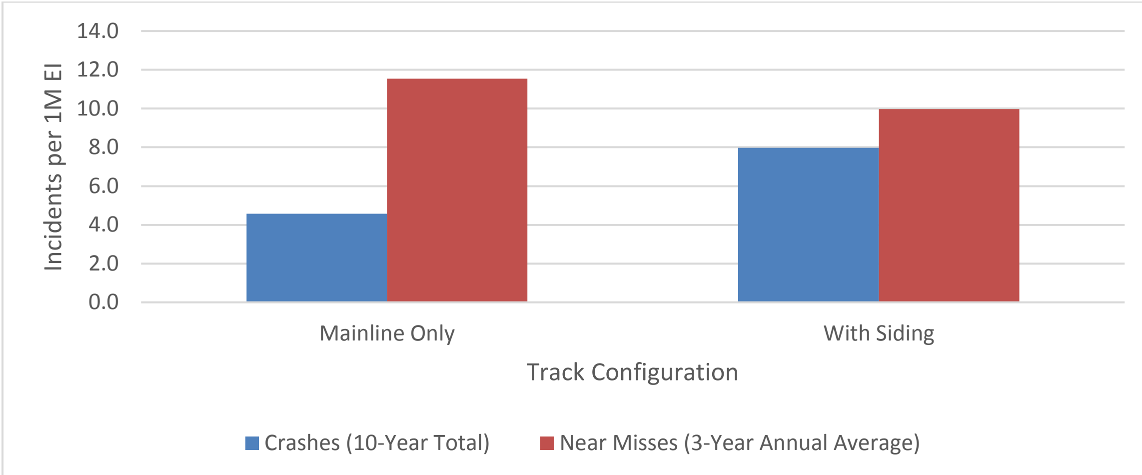
Additional Analysis

Many of the topics discussed at the expert panel meeting prompted additional analysis to further examine safety issues. The following is a summary of the discussion items and the results of any additional analysis completed to address them.

Number and Type of Tracks

The expert panel recommended further analysis on how the number and type of tracks at each crossing plays a role in overall safety. In total, 70 percent of Nevada's grade crossings consist of only one mainline track. Another 28 percent consist of only one siding or industrial track. The remaining 2 percent of crossings consist of either two siding tracks or one mainline and one siding track. The results of the additional analysis indicate that the crash rates for crossings with one or more siding tracks was nearly twice as high as the crash rate for crossings with only mainline tracks. The potential reason for this increase is that siding tracks are typically used on a more infrequent or seasonal basis. Motorists may become accustomed to not seeing any trains at the crossing and, therefore, be less alert to train traffic. While there was a distinct difference between the crash rates, crossings with siding tracks have only slightly lower rates of near miss incidents compared to crossings with mainline tracks only. Despite this, the difference in crash rates suggests that the proposed hazard index model for Nevada should include a factor that increases the index value of crossings with siding tracks.

Figure 24.Incident Rates by Track Configuration



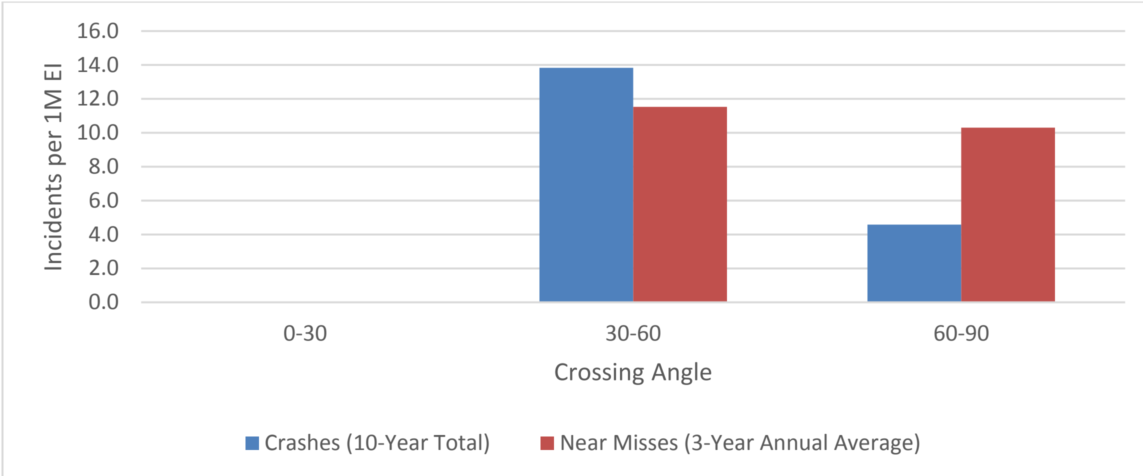
Double Counting Issues with Passenger Rail Counts and High-Speed Crossings

The expert panel expressed concern that including factors for both passenger train volumes and train speed could potentially lead to a double-counting issue since it is primarily passenger trains that travel at high speeds. In fact, two-thirds of Nevada crossings with passenger rail traffic have a maximum timetable speed of 70 mph or higher. Additionally, nearly all the high-speed crossings have passenger rail volumes of only two per day. Therefore, the project team recommends that only one of these factors (passenger rail volumes or speed) be included in the final hazard index formula to avoid a potential double-counting issue.

Vertical and Horizontal Geometry

The expert panel recommended reviewing additional factors related to vertical and horizontal geometry at the crossings. Horizontal geometry, particularly skew or angle of the highway with the railroad track was of particular concern to the expert panel. Crossings with sharp crossing angles can interfere with the ability of motorists to see oncoming trains. The NDOT grade crossing database includes an attribute noting crossing angle. However, NDOT is currently in the process of reviewing the accuracy of crossing angle data through site visits. Much of the current information on this attribute is inaccurate, which therefore limits the ability to properly assess the impact of crossing angle on crash or near miss rates. As an alternative approach, the project team conducted a GIS analysis to measure the angle between the road and rail at each track. Due to data limitations, this angle could only be measured for 95 crossings. However, the analysis of this limited dataset confirms input from NDOT and Union Pacific Railroad (UP) that sharp crossing angles should be given additional consideration in the hazard index model. As shown in Figure 25, the crash rate at crossings with a 30-60-degree angle is three times as high as the rate at crossings with a 60-90-degree angle. Only four crossings in the dataset have an angle between 0 and 30 degrees, and no crashes or near misses were recorded at these locations.

Figure 25.Incident Rates by Crossing Angle



The role of vertical geometry in crash and near miss rates was also evaluated by the project team. NDOT grade crossing database includes two attributes related to vertical geometry. The first attribute is "Vertical Curve at Crossing" and is used to identify crossings with substantial vertical curvature in the roadway on or adjacent to the crossing. A review of this factor shows only small differences between crossings with and without vertical curvature. The second attribute used to review vertical curvature is the presence of a "Low-Ground Clearance Sign". The presence of this sign indicates a significant roadway hump at the crossing with the potential to "bottom out" trailers with lower ground clearance. However, only six crossings in Nevada are equipped with this sign, and no crashes or near misses have been recorded at any of them. Therefore, while the hazard index model should include a factor for horizontal geometry, the project team recommends that no factor be included to address vertical geometry at this time.

Role of Train Speed at Low-Volume crossings

During the second expert panel meeting, concerns were discussed regarding crossings with high-speed, but infrequent train usage. Expert participants were concerned that motorists would not expect a train on an infrequently-used crossing and, as a result, would have limited reaction time in the event of a high-speed train approaching the crossing. The project team reviewed this concern by evaluating the impact of train speed on crash and near miss rates for crossings with 10 or fewer trains per day. The results of this analysis largely matched the analysis of all crossings by train speed. On further inspection, this is not surprising; nearly all low-volume (less than 10) crossings throughout the state have maximum timetable speeds of 20 mph or less. For the crossings with time table speeds of 50 mph or more, only one crossing has fewer than 10 trains per day. Based on this review, the project team does not recommend that any additional consideration be made in the hazard index formula to address crossings with high speeds and low volumes.

Distance to Adjacent Intersections

One final discussion topic was the importance of highway intersection proximity to the crossing. In some cases, close proximity of an intersection to a crossing may increase the likelihood of a crash due to motorists stopping on the tracks or turning vehicles not being aware of an approaching train. The NDOT crossing database contains data of the distance between the crossing and nearest highway intersection. Nearly all the data in this attribute field are grouped into one of three values: 75 feet, 200 feet, and 500 feet. Based on a review of this data, the rates of crashes and near misses do not vary substantially between these three values and, in fact, is slightly higher for crossings located 500 feet from the nearest intersection. Therefore, the project team does not recommend that any additional factors regarding intersection proximity are incorporated into the hazard index formula.

Preliminary Hazard Index Model Comparison

A series of existing and proposed hazard index models were evaluated for their suitability in meeting NDOT's needs and goals. Twelve sample crossing were used to compare the results of all existing and proposed hazard index models.

Existing Hazard Index Models

Six existing hazard index models were employed in the suitability evaluation. These included all the existing models discussed earlier in this report, including:

- Current NDOT model
- Basic New Hampshire Hazard Index
- USDOT Accident Prediction Model
- Peabody-Dimmick Crash Prediction Formula
- NCHRP Report 50 Accident Prediction Formula
- Texas Priority Index.

These models were selected based on input from interviews with other state transportation agencies and the expert panel and their inclusion in the Federal Highway Administration's (FHWA) Railroad-Highway Grade Crossing Handbook.

Proposed Hazard Index Models

Four original hazard index models were also developed specifically for NDOT based on guidance from NDOT staff and the expert panel. Each of the proposed models focuses on specific crossing attributes or distinct approaches to prioritizing Nevada's crossings.

New Model #1

New Model #1: Reduce Impact of Exposure Index

HI = SQRT(TADT x AADT) x (100+HwySpeed)/100 x PF

PF = Protection factor

Gates with Medians:	0.05
Gates:	0.10
Flashing Lights or Passive:	1.00

This study found a strong link between highway and train volumes and crash rates. However, it was also found that this relationship is not linear and the influence of these volumes decrease for very high-volume crossings. This proposed model addresses this relationship by taking the squared root of the exposure index. The proposed model also includes a factor for highway speed and uses updated protection factors. In comparison to the current NDOT Hazard Index protection factors, crossings with flashing lights only are assumed to have no increased safety benefit compared to crossings with passive protection. An additional protection factor level for crossings with gates and highway medians is also added. The protection factor for crossing with gate and medians is lower than for gates alone to reflect the added safety benefits of the medians.

New Model #2

New Model #2: Nevada-Specific Crash Rates

HI = (TADT x AADT) x (EI Rate + Hwy Speed Rate + Warning Device Rate)

EI Rate:
- 0-1000 = 60
- 1000-5000 = 30
- 5000 = 10000 = 10
- 10000+ = 3

Hwy Speed Rate
- 0-15 = 0
- 20 - 35 = 5
- 40 - 65 = 15
- 70 = 30

Warning Device Rate:
- Gates w/ Med = 2
- Gates = 4
- Flash Lights = 15
- Passive = 7

Crash rates (in terms of crashes per exposure index) were calculated for multiple factors during this study. This proposed model uses the exposures index of each crossing multiplied by the summation of crash and near miss rates for three factors: exposure index, highway speed, and warning device type. One benefit of this model is that it relies exclusively on the actual crash rates calculated during the study. Like Model #1, this proposed model also addresses the non-linear effects of exposures index; with each increase in exposure index range, the crash rate used in the formula decreases. Under this model, increases in highway speed are tied with increased likelihood of crashes. The high expected crash rate for crossings with flashing lights only reflects the incident rates found during the study.

New Model #3

New Model #3: Trucks and Passenger Trains

PI = [(AADT x TADT) + (HC x PT)] x (S x 0.1) x PF x A^1.15

HC = Number of heavy commercial vehicles per day
PT = Number of passenger trains per day
S = Train speed
PF = Protection factor

Gates with Medians:	0.05
Gates:	0.10
Flashing Lights or Passive:	1.00

A = Train crashes in 5 years (Default = 1)

This model includes factors that account for highway and rail vehicle types. Crossings with higher volumes of heavy commercial vehicles and passenger trains will rank more highly than similar crossing without those vehicle types. The purpose of this approach is to focus efforts on crossing where the combination of vehicle types has the potential to result in severe collisions. Like Model #1, this proposed model incorporates a factor for highway speed and uses modified protection factor values. This model also incorporates the crash factor used in the Texas Priority index which only affects the final value if one or more crashes has occurred in the previous five years.

New Model #4

New Model #4: Approach Speeds and Near Miss Data

PI = [(AADT x TADT) + (TS x HS)] x PF x A^1.5 x M/3

TS = Train speed
HS = Highway speed
PF = Protection factor

Gates with Medians:	0.05
Gates:	0.10
Flashing Lights or Passive:	1.00

A = Train crashes in 5 years (Default = 1)
M = Train near misses in 3 years (Default = 3)

The previous three proposed models incorporated factors for highway approach speed. This proposed model builds on that approach by including a factor that is a combination of both highway and rail approach speeds, increasing the priority of crossings with high-speed vehicle traffic. In addition to the Texas Priority Index Model's crash factor, this proposed model also incorporates a factor for the near miss data provided by UP. Like the Texas Priority Index crash factor, this model's near miss factor only affects the final value if the number of near misses exceeds three in the previous three years. The threshold for near misses to affect the model is higher due to the greater number of near misses overall compared to the number of crashes.

Comparison of Hazard Index Models

Twelve sample Nevada crossings were utilized to compare the safety ranking results of all six existing hazard models and the four proposed models. The selected crossings serve as a representative sample of crossings throughout the state and vary widely pertaining to highway and train volumes, urban/rural location and type of warning device installed. The twelve crossings were evaluated for each existing and proposed model. The results of the models were compared against the expert panel rankings as a measure of the model's consistency with NDOT's safety crossing improvement priorities. Table 2 presents the results of this analysis.

As discussed previously, members of the expert panel were asked to vote for the top three and bottom three crossings according to the groups determination of crossing improvement needs. Due to this approach, multiple crossings received tied ranking results. For the purposes of correlation calculations, these tied rankings were assigned a value corresponding to the average of their ranked positions. For example, Icarus Road and Navajo Avenue tied for the lowest priority ranking, sharing the position for rank 11 and 12. Both crossings were therefore assigned an average rank of 11.5.

While many of the rankings are similar, a few of the models produce more significant differences. These include the USDOT Accident Prediction Model, the NCHRP Report 50 Model and the Minnesota Department of Transportation (MnDOT) Crude by Rail Model. Proposed Model #4 most strongly correlated with the expert panel rankings, whereas the MnDOT Model generated the weakest correlation with the expert panel rankings.

Table 2. Sample Crossing Ranking by Hazard Index Model

Crossing Number	Crossing Name	Expert Panel Ranking	Current NDOT Model	Basic New Hampshire Index Rank	Peabody-Dimmick Rank	Texas Priority Index Rank	USDOT Accident Prediction Model Rank	NCHRP Report 50 Rank	MnDOT Rank	New Model #1 Rank	New Model #2 Rank	New Model #3 Rank	New Model #4 Rank
804209T	Wyoming Avenue	1	1	1	2	1	5	2	3	1	1	1	1
913213H	Rainbow Blvd	3.5	2	2	1	4	6	1	9	2	7	4	3
762088D	Sutro Street	3.5	3	3	3	2	1	3	1	3	2	2	2
740765S	US 95 - Lovelock Cutoff	3.5	6	7	7	5	3	7	5	7	5	5	7
833601K	Fourth Street East - Reno	3.5	7	6	6	7	4	6	2	6	6	7	5
740918T	US 95 Alternate - Weeks	6	8	8	9	8	9	10	11	8	8	8	8
833452L	Gold Acres Road - North	7.5	4	4	5	3	7	4	6	4	3	3	4
833585D	Jodi Avenue	7.5	10	10	10	10	10	11	6	10	9	10	10
804185G	Green Valley Parkway	9	5	5	4	6	2	5	4	5	4	6	6
913085C	US 93 - Ely	10	9	9	8	9	12	9	6	9	10	9	9
740886P	Icarus Road	11.5	11	11	11	11	8	8	9	11	11	11	11
804059M	Navajo Avenue	11.5	12	12	12	12	11	12	12	12	12	12	12

Correlation with Expert Panel Ranking	78.2%	78.2%	72.5%	79.3%	60.7%	65.7%	55.4%	78.2%	73.2%	79.3%	82.2%

Detailed Review of Hazard Index Model Factors

Based on the Expert Panel's feedback on the review of the existing and proposed models, an inventory of potential factors to include in the final hazard index model was generated. For each of these factors, four evaluation criteria were applied to identify the factors that are most appropriate for inclusion in the final hazard index model recommendation.

Evaluation Criteria

Four evaluation criteria were developed to assess the suitability of each individual factor. Each factor was rated with a high, medium, or low ranking. A description of the purpose and application of each criterion is summarized below:

- **Alignment with Expert Panel Ranking:** The purpose of the sample crossing ranking exercise was to develop a measure of hazard index suitability for each existing and proposed hazard index model. If the model ranks the twelve sample crossings in an order that closely matches the expert panel ranking, this is an indication that the model is accurate and reflects the professional judgement of expert panel members. The relationship between the model ranking and the expert panel ranking was assessed by calculating the Pearson Correlation Coefficient between each set of rankings. If the inclusion of each individual factor increased this correlation value, it was ranked "high". If the inclusion decreased the correlation value, it was ranked "low". If he inclusion had no effect, it was ranked "medium".

- **Correlation with Crash/Near Miss Data:** A correlation analysis was conducted to measure the strength of the relationship between hazard index model factors and crash and near miss occurrences. Factors that strongly correlated to crash and near miss occurrences were considered significant indicators of crossing safety. Factors with clear correlations with the crash data were ranked "high". Factors with small correlations were ranked "medium". Factors with no correlation were ranked "low".

- **Data Availability/Ease of Collection:** It is essential that NDOT can obtain the necessary data to implement the recommended hazard index model. Therefore, data availability/ease of collection was identified as a key measure of the suitability of each existing and proposed hazard index model. Factors currently available in the existing NDOT crossing databases were ranked "high". Factors available through some additional analysis or data combination were ranked "medium". Factors not readily available or available only through significant analysis were ranked "low".

- **Complexity:** The data inputs and calculations employed by the recommended hazard index model should be relatively straightforward to ensure the City and County stakeholders have a firm understanding of the application of the model and which of the crossings under their jurisdiction are most at risk in terms of grade crossing safety. Less complex factors also allow for easier duplication of results and can be more easily refined as new crossing and crash data become available. For this criterion, models relying on less complicated calculations were ranked more highly than those utilizing complex formulas. Factors with easily understood formulas that are readily were ranked "high". Factors with more complicated formulas were ranked "medium". Factors where the formula is complex and the relationship to the estimated crash rates is not immediately apparent were ranked "low".

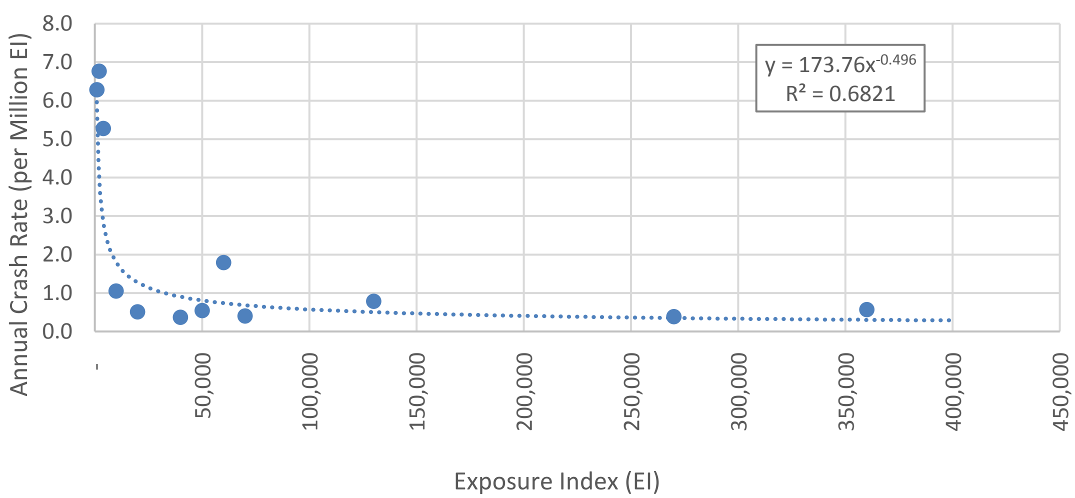
Hazard Index Model Factors

The project team evaluated factors utilized in existing hazard index models and solicited feedback from NDOT staff and the expert panel to select the most appropriate factors to include in the recommended hazard index model. The following provides a description of the hazard index model factors considered and the rankings assigned to each factor based on the four evaluation criteria. For many of the factors, multiple approaches are considered for how they should be included in the hazard index model. The results of the factor evaluation are shown in Table 3.

Exposure Index

Of all factors reviewed, highway and rail volumes were found to have the highest correlations with crash and near miss incidents. The product of the two values (exposure index) was found to be an even stronger indicator. However, while the total number of incidents is higher at crossings with high exposure index rankings, the results of the analysis indicate that the rate of incidents decreases as the exposure index increases. As shown in Figure 26, the data show high crash rates for crossings with low exposure index values, but the rates drop sharply between exposure index values of 0 and 50,000 and steadily decrease further as the exposure index increases. The trend line that best fits the data is a power function with the formula $y = 173.76x^{-0.496}$, where x equals the exposure index.

Figure 26.Annual Crash Rates by Exposure Index (10-year Crash History)



Multiplying the crash rate formula above by the exposure index will result in a predictive value of the number of crashes at a crossing based solely on the exposure index. This formula—and its simplified form—is shown below.

$$Predicted\ Crashs = EI \times 173.76(EI)^{-0.486} = 173.76(EI)^{0.504} \cong 173.76\sqrt{EI}$$

Since the hazard index model values are intended to be unitless indicators for comparing the relative needs of crossings, the constant value of 173.76 can be dropped from the equation without affecting the relative rankings of each crossing.

For this evaluation, both the linear and squared root forms of the exposure index were reviewed in combination with multiple other factors. These two approaches are shown in Table 3 below. Each of these approaches was used as the base value for the assessment of other factors. That is, both the linear and squared values of the exposure index were the starting point to be modified by other factors. In each case, a minimum value of one was used for highway and train traffic to ensure no values of zero at crossing with minimal train or highway traffic.

Table 3. Factor Evaluation for Exposure Index

Proposed Exposure Index Factors	Linear: ADT x TADT	Squared Root: $\sqrt{EI}$
	ADT = Highway Average Daily Traffic (minimum. = 1) TADT = Total Average Daily Trains (minimum = 1) EI = ADT x TADT	
Alignment with Expert Panel	Medium: Using the Exposure Index alone achieves a correlation of 71.4% with the expert panel's ranking. All other factors were evaluated to see if their inclusion increased or decreased this correlation.	Medium: When used alone, the squared exposure index correlation does not differ from the linear approach. Distinctions will be seen when other factors are applied to each approach.
Correlation with Crash/Near Miss Data	Medium: The linear approach correlates with the crash data, but does not account for the non-linear increase in crash rates.	High: The squared approach provides a much better fit to the crash data by scaling back the differences between crossings with high exposure index values.
Data Availability/ Ease of Collection	High: Data for highway and train volumes is readily available and updated regularly.	High: Data for highway and train volumes is readily available and updated regularly.
Complexity	High: This approach is straightforward and easy to understand. More train and highway traffic provides more opportunities for crashes.	Medium: While still relatively easy to understand, using the squared root to scale back the impact of exposure index is a slightly more complicated approach.

Crash History

Due to steadily increasing rail safety in Nevada and across the country, crash history is no longer a good predictor of future crashes. In the past five years, only nine crashes have occurred in the state and no crossings have had more than one crash in that time period. This study concluded that the current Nevada Hazard Index Model as well as many of the existing traditional models provide too much weight to crash history. Three methodologies were considered to evaluate crash history and are evaluated below in Table 4. These include the factor currently used in the Nevada model, the factor from the Texas Priority Index, and an alternative approach to further reduce the impact of crashes on the final hazard index model result.

Table 4. Factor Evaluation for Crash History

Proposed Crash History Factors	Current: $1 + \sum \begin{matrix}(\#Fat \times 1.00)\\(\#Inj \times 0.10)\\(\#PDO \times 0.05)\end{matrix}$	Texas Priority Index Approach: $A^{1.15}$ (Default= 1)	Reducing Weight of Crash History: 1.3^{A}
	A = Total Crashes (5-year history) Fat = Crash resulting in fatality (5-year history) Inj = Crash resulting in injuries (5-year history) PDO = Crash resulting in property damage only (5-year history)		
Alignment with Expert Panel	High: Inclusion of this factor increases the correlation with the expert panel ranking by 4.0% (squared root of EI).	Medium: Inclusion of the Texas Priority Index crash factor has no impact to the correlation.	Low: Inclusion of this crash factor reduces the correlation with the expert panel ranking by 1.0% (square root of EI).
Correlation with Crash/Near Miss Data	Medium: Crossings with a crash history do not correlate strongly with the potential for future crashes, but should be investigated by NDOT staff to identify safety issue or concerns.	Medium: Crossings with a crash history do not correlate strongly with the potential for future crashes, but should be investigated by NDOT staff to identify safety issue or concerns.	Medium: Crossings with a crash history do not correlate strongly with the potential for future crashes, but should be investigated by NDOT staff to identify safety issue or concerns.
Data Availability/ Ease of Collection	High: Crash data is a key component of the FRA and NDOT databases and is updated regularly.	High: Crash data is a key component of the FRA and NDOT databases and is updated regularly.	High: Crash data is a key component of the FRA and NDOT databases and is updated regularly.
Complexity	Low: This approach's inclusion of crash severity provides an additional level of complexity compared to using only the total number of crashes.	Medium: This approach is simpler than the current formula, but the need for a default value so that the factor does not equal zero adds complexity.	High: This simple factor increases the hazard index by 30% with each occurrence of a crash and does not require the use of a default value.

Near Miss History

Near miss data provided by UP serves as an alternative to the limited crash history data. However, a review of the data shows that a high number of near misses does not strongly correlate with future crash occurrences. Of the nine crashes in the past five years, four occurred at crossings with zero near misses and four occurred at crossings with only one near miss (3-year near miss data). Two approaches were proposed for the evaluation of near miss data and are summarized in Table 5. The first was based on the Texas Priority Index Approach and assumes a floor of one near miss per year before inclusion in the model. The second approach provides a combined assessment of crash and near miss history using the reduced impact approach proposed in the previous section.

Table 5. Factor Evaluation for Near Miss History

Proposed Near Miss Factors	Texas Priority Index Approach: $(N/3)^{1.15}$ (Default = 1)	Combination of Crash and Near Miss Factors: $1.3^{(A + N/3)}$
	A = 5-year crash count N = 3-year near miss count	
Alignment with Expert Panel	Low: Inclusion of this near miss factor reduces the correlation with the expert panel ranking by 1.8% (squared root of EI).	Low: Inclusion of this near miss factor reduces the correlation with the expert panel ranking by 1.1 % (linear EI) and 2.9% (squared root of EI).
Correlation with Crash/Near Miss Data	Medium: Crossings with a near miss history do not correlate strongly with the potential for future crashes, but should be investigated by NDOT staff to identify safety issue or concerns.	Medium: Crossings with a near miss history do not correlate strongly with the potential for future crashes, but should be investigated by NDOT staff to identify safety issue or concerns.
Data Availability/ Ease of Collection	Medium: Near miss data is routinely provided to NDOT staff by UP, but similar data is not available for non-UP crossings.	Medium: Near miss data is routinely provided to NDOT staff by UP, but similar data is not available for non-UP crossings.
Complexity	Medium: This approach builds on crash factor used in the Texas Priority index, but the need for a default value so that the factor does not equal zero adds complexity.	Medium: This factor increases the hazard index by 30% with each occurrence of a crash and every three near misses. It is somewhat complicated by the combination of both crash and near miss data in the same factor.

Warning Device Protection Factors

Warning device protection factors reduce the hazard index value based on the current safety improvements installed at each crossing. Two approaches were proposed for inclusion in the revised hazard index model. The first is the current model, which includes protection factors for crossings with gates, flashing lights, or passive protection only. The second approach is an alternative that includes protection factors for three levels of protection: 1) 4-quadrant gates or gates with medians on the highway approach, 2) 2-quadrant gates only, and 3) crossings with passive protection or flashing lights. The proposed protection factors are based on the crash rates calculated with the most recently available Nevada crossing data. For example, the crash rate at crossings with gates was found to be approximately 30 percent of the rate at crossings with passive protection. Likewise, the crash rates for crossing with flashing lights only were found to be equal to or greater than crossings with passive protection only.

Table 6. Factor Evaluation for Protection Factors

Proposed Protection Factors	**Current:** Gates → 0.10 Flashing Lights → 0.60 Passive → 1.00	**Crash Rate-Based:** 4-Quad or Gates/Median → 0.15 Gates Only → 0.30 Passive/Flashing Lights → 1.00
Alignment with Expert Panel	Medium: Inclusion of this factor increases the correlation with the expert panel ranking by 9.3% (linear EI) and decreases the correlation by 2.9% (squared root of EI).	High: Inclusion of this factor increases the correlation with the expert panel ranking by 11.4% (linear EI) and 9.6% (squared root of EI).
Correlation with Crash/Near Miss Data	Medium: The current protection factors are consistent with many existing hazard index models and roughly correlate with the current crash rates.	High: These protection factors are based on the most recently available crossing crash data. The categories and protection factor values are more in line with the available data.
Data Availability/ Ease of Collection	High: Warning device data is a key component of the FRA and NDOT databases and is updated regularly.	High: Warning device data is a key component of the FRA and NDOT databases and is updated regularly.
Complexity	High: Application of the protection factors based on the current warning devices is a relatively simple process.	High: Application of the protection factors based on the current warning devices is a relatively simple process.

Highway Speed

Highway speed was found to correlate strongly with near miss incident rates; The rate of near misses rises steadily as highway speeds increase. However, the correlation with crash rates is not quite as strong due to a lack of crashes in many of the speed categories. Of the 18 crashes in the past 10 years, all but two have occurred at crossings with highway speed limits of 25 or 35 mph. It is assumed that a stronger trend would appear if more crashes had occurred. Three alternative approaches were considered which modify the hazard index based on the highway speed limit. The first approach uses a simple formula to steadily increase the hazard index as the highway speed increases. The second approach relies on the application of simple factors based on ranges of highway speeds. The majority of crossings (68 percent) in the 20-35 mph range remain unchanged by this factor. The third approach considers a combination of both highway and rail speed.

Table 7. Factor Evaluation for Highway Speed

Proposed Highway Speed Factors	Formula Approach: 1 + HS/100	Simple Factors: 0-15 mph → 0.50 20-35 mph → 1.00 40-65 mph → 1.50 70 mph → 2.00	Combination with Train Speed: $1+\frac{(HS \times TS)}{1000}$
	S = Highway Speed Limit (mph) TS = Train Maximum Timetable Speed		
Alignment with Expert Panel	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.	High: Inclusion of this factor increases the correlation with the expert panel ranking by 3.9% (linear EI).	High: Inclusion of this factor increases the correlation with the expert panel ranking by 4.0% (linear EI) and 5.0% (squared root of EI).
Correlation with Crash/Near Miss Data	Medium: This approach matches the finding that increased highway speed is correlated with increased incident rates.	Medium: This approach matches the finding that increased highway speed is correlated with increased incident rates.	Low: The inclusion of the rail speed factor results in very little correlation with the crash and near miss data.
Data Availability/ Ease of Collection	High: Highway speed data is a key component of the FRA and NDOT databases and is updated regularly.	High: Highway speed data is a key component of the FRA and NDOT databases and is updated regularly.	Medium: The maximum timetable speed included in the FRA/NDOT databases may not reflect the actual speeds of trains at the crossings.
Complexity	High: Application of this highway speed factor is a relatively simple process.	High: Application of this highway speed factor is a relatively simple process.	Medium: Application of this factor is slightly more complex with the inclusion of the rail speed component.

Rail Speed

Rail speed is a common attribute used in many hazard index formulas. However, this evaluation indicated a weak correlation with crash and incident rates. One potential explanation of the lack of a correlation with rail speed is that it is often difficult to identify the actual speed of trains over crossings. Many trains do not travel at the maximum timetable speeds noted in the FRA and NDOT crossing databases and in many cases there may be variation in typical rail speeds from day to day and from year to year. The results also suggest that there is a significant overlap between rail speed and passenger train volumes factors. As discussed previously in this report, the expert panel noted concerns that double counting would occur if both factors are included. Therefore, only one of these factors should be incorporated into the model.

Two formula-based approaches were considered for inclusion in the model. The first is pulled directly from the Texas Priority Index Model. The second approach uses a formula similar to the formula proposed for a highway speed factor in the previous section. This formula would have a smaller overall impact on the final hazard index model results. For example, a crossing with a speed limit of 30 mph would result in a rail speed factor of 3 under the Texas Priority Index Approach and 1.3 under the alternative formula approach.

Table 8. Factor Evaluation for Rail Speed Factors

Proposed Rail Speed Factors	Texas Priority Index Approach: TS x 0.1	Formula Approach: 1 + TS/100
	TS = Train Maximum Timetable Speed (mph)	
Alignment with Expert Panel	Medium: Inclusion of this factor increases the correlation with the expert panel ranking by 3.9% (linear EI) and decreases the correlation by 6.4% (squared root of EI).	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.
Correlation with Crash/Near Miss Data	Low: Rail speed was not found to have a strong correlation to incident rates.	Low: Rail speed was not found to have a strong correlation to incident rates.
Data Availability/ Ease of Collection	Medium: Rail speed data is available in the FRA/NDOT databases (as maximum timetable speed and typical train speed), but may not reflect actual train speeds over the crossing.	Medium: Rail speed data is available in the FRA/NDOT databases (as maximum timetable speed and typical train speed), but may not reflect actual train speeds over the crossing.
Complexity	High: Application of this highway speed factor is a relatively simple process.	High: Application of this highway speed factor is a relatively simple process.

Heavy Commercial Vehicles

Highway rail crashes involving heavy commercial vehicles are likely to be more severe and potentially result in derailments than crashes involving passenger vehicles. However, the analysis indicates that there is only a weak correlation between incident rates and the volume of heavy commercial vehicle traffic. This result may be in part due to limited data on the actual volumes of heavy commercial vehicles at Nevada crossings. Many of the current volumes used in the NDOT database are based on estimates.

Two approaches were considered for incorporating measure heavy commercial volumes. The first increases the hazard index value based on the proportion of heavy commercial vehicles. This would have the effect of increasing the index for rural crossings with higher volumes of mining vehicles and other heavy commercial traffic. The second approach incorporates a combination of heavy commercial vehicle traffic and passenger train traffic. Collisions between these two vehicle types have more potential for fatal or sever injury crashes due to the size and speed of the vehicles involved. The second factor calculates the proportion of the exposure index that is based on heavy commercial vehicles and passenger trains. The formula was raised to the power of 1.5 to result in factor values closer to the other potential hazard index model factors.

Table 9. Factor Evaluation for Heavy Commercial Vehicle Factors

Proposed Heavy Commercial Vehicle Factors	Proportion: 1 + HCADT%	Combination of Heavy Commercial and Passenger Train Volumes: $1+\frac{(\text{HC x PT})^{1.5}}{\text{EI}}$
	HCADT% = Percentage of highway traffic that is Heavy Commercial HC = Heavy Commercial Vehicle Daily Traffic Counts PT = Passenger Train daily counts EI = Exposure Index = Highway Traffic x Train Traffic	
Alignment with Expert Panel	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.
Correlation with Crash/Near Miss Data	Low: Heavy commercial vehicle traffic proportions were not found to have a strong correlation with incident rates.	Low: Neither heavy commercial vehicle traffic counts nor passenger train counts were found to have a strong correlation with incident rates.
Data Availability/ Ease of Collection	Medium: Highway speed data is a key component of the FRA and NDOT databases, but is often based on estimates rather than actual data.	Medium: Highway speed data is a key component of the FRA and NDOT databases, but is often based on estimates rather than actual data
Complexity	High: Application of this factor is a relatively simple process.	Medium: Application of this factor is somewhat more complicated due to the inclusion of passenger train counts and exposure index values.

Passenger Train Volumes

While the data does not show the presence of passenger trains to be a strong indicator of crash risk, crashes involving passenger trains are more likely to result in severe injuries and fatalities. Recent passenger train crashes in Nevada have also drawn more concern for ensuring that similar crashes are not repeated in the future. Nearly all of crossings that carry passenger traffic throughout the state have only two passenger trains per day. Because of this, an approach based on passenger train volumes will result in very little differentiation between crossings. Therefore, only one simple approach was proposed, which increases the hazard index by 50 percent if any passenger trains are present and has no effect if there are no passenger trains present.

Table 10. Factor Evaluation for Passenger Train Volumes

Proposed Passenger Train Volume Factors	Simple Factors: Passenger Trains = 0 → 1.0 Passenger Trains > 0 → 1.5
Alignment with Expert Panel	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.
Correlation with Crash/Near Miss Data	Low: Passenger train volumes were found have little to no correlation with incident rates.
Data Availability/Ease of Collection	High: Passenger train volume data is a key component of the FRA and NDOT databases and is updated regularly.
Complexity	High: Application of this factor is a relatively simple process.

Track Configuration

The number and type of tracks present at a crossing can play an important role in crossing safety. The presence of one or more siding tracks at a crossing was found to be strongly correlated with crash and near miss rates in Nevada. Based on this result, one approach was evaluated for inclusion of a track configuration factor in the revised model.

Table 11. Factor Evaluation for Track Configuration Factors

Proposed Track Configuration Factors	**Simple Factors:** One Siding/Industry Track → 1.25 Two Siding/Industry Tracks → 1.50 >Two Siding/Industry Tracks → 2.00
Alignment with Expert Panel	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.
Correlation with Crash/Near Miss Data	High: The number of siding/industry tracks at each crossing was found to be well correlated with crash and near miss rates.
Data Availability/Ease of Collection	High: Data on the type and number of tracks at each crossing is a key component of the FRA and NDOT databases and is updated regularly.
Complexity	High: Application of this factor is a relatively simple process.

Population Density

The project team theorized that crossings located in areas with greater population density were more likely to experience high pedestrian traffic and a greater potential for crashes or near misses involving pedestrians. However, the results of the analysis found an inverse relationship with crash and near rates, indicating that incident rates decrease as population density increases. One approach presented below was evaluated for inclusion in the model. The approach provides a slight increase in hazard index for high-density areas (greater than 2.5 persons per acre).

Table 12. Factor Evaluation for Population Density

Proposed Population Density Factors	Simple Factors: Population Density < 2.5 persons/acre → 1.0 Population Density > 2.5 persons/acre → 1.25
Alignment with Expert Panel	Low: Inclusion of this factor decreases the correlation with the expert panel ranking by 1.1% (squared root of EI).
Correlation with Crash/Near Miss Data	Low: Population density was not found to have a positive correlation with incident rates.
Data Availability/ Ease of Collection	Low: Inclusion of this factor requires additional GIS analysis of census data to calculate population density. This effort is not part of NDOT's typical data collection process.
Complexity	High: Application of this factor is a relatively simple process.

Crossing Angle

As discussed previously in the Additional Analysis Section of this report, crossings with sharp crossing angles can disrupt motorists' ability to see oncoming trains. After conducting additional analysis, the results of this study indicate there is strong correlation between crossing angle and crash and near miss incident rates. One approach was evaluated for inclusion in the hazard index model. Since information on crossing angle is grouped into three angle ranges in the NDOT crossing database, the proposed approach applies factors based on those three categories. Crossings with the most perpendicular angles have no effect on the final hazard index. Crossings with very sharp angles increase the hazard index by a factor of 2. Crossings with somewhat sharp angles between 30 and 60 degrees increase the hazard index by a factor of 1.5.

Table 13. Factor Evaluation for Crossing Angle Factors

Proposed Crossing Angle Factors	Simple Factors: 0° - 30° → 2.00 30° - 60° → 1.50 60° - 90° → 1.00
Alignment with Expert Panel	Medium: Inclusion of this factor has no effect on the correlation with the expert panel ranking.
Correlation with Crash/Near Miss Data	High: Crossing angles were found to have a strong correlation with crash and near miss rates.
Data Availability/ Ease of Collection	High: Crossing angle is a key component of the NDOT crossing database and is updated regularly (note that at the time of this report the crossing angel attribute is currently being reviewed and updated to ensure accuracy).
Complexity	High: Application of this factor is a relatively simple process.

Discussion of Factor Suitability

The determination of the final recommended hazard index model was based on a comprehensive view of both the individual assessments of each potential factor as well as a review of the effects of various factors in combination. A summary of the individual factor evaluation based on the four evaluation criteria of 1) Alignment with Expert Panel Ranking, 2) Correlation with Crash/Near Miss Data, 3) Data Availability/Ease of Collection, and 4) Complexity is shown in Table 14. There is a wide range of rankings between the factors with some factors scoring more highly on specific criteria than on others.

The first step in recommending the new model is to identify whether the linear or squared root approach to the inclusion of exposure index should be selected. Each of these approaches scored roughly equivalently with two "highs" and two "mediums" each. However, while each of the four criteria are treated ostensibly as equal in importance to this evaluation, in practice, the measures of correlation with the expert panel ranking and correlation with the crash and near miss data are likely more important than the other two criteria. For the sake of robustness and public trust in the hazard index model, it is important that it reflect both real crash data and the professional judgement of rail safety experts. For this reason, **it is recommended that the squared root form of the exposure index be used as the base value for the proposed hazard index model.**

The next step is to identify additional factors that score highly under multiple criteria. The only factor to score "high" in all four criteria is the protection factor using the crash rate-based approach. While equal in complexity to the current protection factor approach, the revised categories and values are based on existing crash data and provide a substantial improvement to the correlation with the expert panel ranking. Therefore, **it is recommended that the crash rate-based protection factor be included as a modifying factor in the proposed hazard index model.**

The next highest scoring factors each were ranked with three "highs" and one "medium". These include the Simple Factor Approaches for Highway Speed, Track Configuration, and Crossing Angle. **Due to the high scores over multiple criteria, each of these factors was recommended for inclusion in the proposed hazard index model.**

All the remaining factors either received a "low" score on one or more categories, or are in a factor category where one approach has been selected in favor of the others (Protection Factor, Highway Speed). Despite this, each of the factors was reviewed to see if their inclusion would increase or decrease the correlation with the expert panel ranking. This review found that while the inclusion of most of the factors resulted in a decrease in that correlation, the factor using a combination of crash and near miss rates resulted in a 7.5 percent increase in correlation, increasing the total correlation value to 94.7 percent. Based on this result, and the desire of NDOT staff to utilize both the crash data and the near miss data provided by UP, the factor for **the Combination of Crash and Near Miss data was recommended for inclusion in the proposed hazard index model.**

Table 14. Factor Evaluation Summary

Factor	Approach	Correlation with Expert Panel Ranking	Correlation with Crash/Near Miss Data	Data Availability	Complexity	Recommended
Exposure Index	Linear	Medium	Medium	High	High	No
	Squared Root	Medium	High	High	Medium	Yes
Crash History	Current	High	Medium	High	Low	No
	Texas Priority Index Approach	Medium	Medium	High	Medium	No
	Reducing Weight of Crash History	Low	Medium	High	High	No
Near Miss History	Texas Priority Index Approach	Low	Medium	Medium	Medium	No
	Combination of Crash and Near Miss Data	Low	Medium	Medium	Medium	Yes
Protection Factor	Current	Medium	Medium	High	High	No
	Crash Rate-Based	High	High	High	High	Yes
Highway Speed	Formula Approach	Medium	Medium	High	High	No
	Simple Factors	High	Medium	High	High	Yes
	Combination with Train Speed	High	Low	Medium	Medium	No
Rail Speed	Texas Priority Index Approach	Medium	Low	Medium	High	No
	Formula Approach	Medium	Low	Medium	High	No
Heavy Commercial Vehicles	Proportion	Medium	Low	Medium	High	No
	Heavy Commercial/Pass. Train Volumes	Medium	Low	Medium	Medium	No
Passenger Trains	Simple Factors	Medium	Low	High	High	No
Track Configuration	Simple Factors	Medium	High	High	High	Yes
Population Density	Simple Factors	Low	Low	Low	High	No
Crossing Angle	Simple Factors	Medium	High	High	High	Yes

Recommended Hazard Index Model

The recommended replacement for the Nevada Hazard Index Model is shown below and is based on the evaluation of potential model factors using the four evaluation criteria. The based value of the consists of the squared root of the exposures index. This base value is then modified by five additional factors based on crash/near miss data, existing warning devices, highway speed, number and type of tracks, and the crossing angle.

Hazard Index =

$\sqrt{\mathrm{EI}}$ (Base Value)

$\times \left(1.3^{\left(A+\frac{N}{3}\right)}\right)$ (Crash and Near Miss Factor)

$$\times \begin{bmatrix} \text{4 Quad Gate or Gates with Medians} \rightarrow 0.15 \\ \text{Gates Only} \rightarrow 0.30 \\ \text{Flashing Lights or Passive} \rightarrow 1.00 \end{bmatrix}$$ (Protection Factor)

$$\times \begin{bmatrix} \text{0 to 15 mph} \rightarrow 0.50 \\ \text{20 to 35 mph} \rightarrow 1.00 \\ \text{40 to 65 mph} \rightarrow 1.50 \\ \text{70 mph and Above} \rightarrow 2.00 \end{bmatrix}$$ (Highway Speed Factor)

$$\times \begin{bmatrix} \text{1 siding/other track} \rightarrow 1.25 \\ \text{2 siding/other tracks} \rightarrow 1.50 \\ \text{3 or more siding/other tracks} \rightarrow 2.00 \end{bmatrix}$$ (Track Configuration Factor)

$$\times \begin{bmatrix} \text{0 to 30 degrees} = 2.0 \\ \text{30 to 60 degrees} = 1.5 \\ \text{60 to 90 degrees} = 1.0 \end{bmatrix}$$ (Crossing Angle Factor)

EI (Exposure Index) = Average Daily Highway Traffic x Daily Train Volumes

A = Crashes within the past 5 years

N = Near Misses within the past 3 years

Evaluation of Recommended Hazard Index Model

The factors included in the proposed hazard index model were selected based on their individual performance as measured against the four evaluation criteria of 1) alignment with the expert panel, 2) correlation to crash/near miss data, 3) data availability, and 4) complexity. Further evaluation of the complete model's performance against these measures is discussed below.

Alignment with Expert Panel Ranking

The proposed hazard index model performs well in relation to generating rankings in alignment with the recommendations of the expert panel. Table 12 summarizes the expert panel ranking for each of the 12 sample crossings and compares this against the rankings of the current NDOT model and the proposed model. Both models are consistent with the expert panel in ranking the Wyoming Avenue crossing as the number one priority in the sample list. The next three ranking positions are also fairly consistent with only minor variation between the two models. The biggest differences changes are the lower rank assigned to US-95 (a change from rank 7 to rank 5) and the higher rank assigned to Green Valley Pkwy (a change from rank 5 to rank 8). In each of these cases the ranking is set closer to the preferred ranking of the expert panel. Overall the correlation of the proposed model to the expert panel is 94.7 percent compared to only 82.7 percent for the current hazard model.

Table 15. Sample Crossing Ranking Comparison

Crossing ID	Highway Name	Expert Panel Rank	NDOT Model Rank	Proposed Model Rank	Change in Rank
804209T	WYOMING AVENUE	1	1	1	0
833601K	4TH STREET	3.5	3	2	1
913213H	RAINBOW BLVD	3.5	2	3	-1
762088D	SUTRO STREET	3.5	4	4	0
740765S	US-95	3.5	7	5	2
740918T	US-95-A	6	8	7	1
833452L	M2-SR 306	7.5	6	6	0
833585D	JODI AVENUE	7.5	10	9	1
804185G	GREEN VALLEY PKWY	9	5	8	-3
913085C	Ely	10	9	11	-2
740886P	ICARUS ROAD	11.5	10	10	0
804059M	NAVAJO AVENUE	11.5	12	12	0
Correlation with Expert Panel			82.7%	94.7%	

Correlation with Crash/Near Miss Data

Each of the factors selected for inclusion in the proposed hazard index model are well correlated with the crash and near miss data reviewed during this study. Of the six factors comprising the model, four were rated as "high" and two were rated as "medium" in relation to how closely each factor correlated with the existing crash and near miss data. Many factors common in other existing hazard index models (such as rail speed) were excluded from the proposed model due to a lack of any significant correlation with the data.

Data Availability/Ease of Collection

The proposed hazard index model uses only factors that are readily available to NDOT staff through routine collection of FRA crossing inventory information supplemented by grade crossing field reviews. The exposures index, protection factor, highway speed, and crossing angle factors were all rated "high" for data availability. The crash and near miss factor was the only one rated "medium". This is because the near miss data provided by UP—while valuable—is limited only to UP crossings throughout the state. The data is also slightly less objective than crash data since the determination of what constitutes a near miss may change from engineer to engineer or from region to region. Despite this, the near miss data provides excellent supplementary data, especially given the low number of crashes experienced in recent years.

Complexity

The proposed model is more complex than the existing NDOT model, but this additional complexity (in terms of the formulas and the number of factors used) achieves a result that better correlates with existing data and expert panel input. Additionally, the proposed model is far less complex than many of the existing hazard index models. The function and impact of each variable should be easy to follow for most people with only limited knowledge of highway-rail grade crossing safety issues.

Application of Proposed Model to Nevada Crossings

The proposed hazard index model was applied to all of Nevada's grade crossing, resulting in the top 20 ranked crossings shown in Table 16. California Road, the highest ranked crossing under the proposed model, has an index value more than three times as high as the next highest index value at State Route 789. This is due to the crossing having one of the highest exposure index values in the state while being equipped only with passive warning devices.

Table 16. Top 20 Ranked Nevada Crossings

Crossing No.	City	Street or Road Name	Proposed Index Score	Crossing Rank
740763D	HAZEN	CALIFORNIA ROAD	1,330.33	1
740805M	GOLCONDA	M1-SR-789	402.49	2
740890E	MONTELLO	BALD EAGLE CANYON	394.97	3
833434N	GOLCONDA	M2-GETCHELL MINE	392.30	4
804239K	LAS VEGAS	EASTERN AVENUE	373.76	5
834559S	RENO	LEAR BLVD	304.65	6
740740W	SPARKS	GALLETTI WAY	285.82	7
740799L	WINNEMUCCA	BRIDGE STREET	284.53	8
804209T	LAS VEGAS	WYOMING AVENUE	259.48	9
912602K	HENDERSON	PARADISE HILLS DR	255.72	10
833601K	RENO	4TH STREET	244.66	11
913213H	ARDEN	RAINBOW BLVD	244.47	12
740719R	RENO	WOODLAND AVENUE	231.65	13
740797X	WINNEMUCCA	AIRPORT ROAD	215.20	14
834498D	RENO	SILVER LAKE DRI	205.40	15
804245N	LAS VEGAS	DEAN MARTIN DR	194.78	16
804022X	LAS VEGAS	APEX-ARROWLIME SP	186.43	17
740816A	BATTLE MOUNTAIN	M1-REESE RD SR806	185.90	18
833523F	WELLS	US 93 ELY	185.27	19
855906U	MCGILL	POLELINE RD	174.93	20

Final Hazard Index Model Recommendation

Final Expert Panel Input

The recommended hazard index model was presented to the expert panel for a final round of input and feedback. Overall the panel was supportive of the final recommended model and agreed that the resulting ranking of Nevada's rail crossings was reflective of the actual safety risks and need for crossing improvements. However, three recommendations were made for potential improvements to the model.

Adjusted Crash/Near Miss Factors

While the proposed model incorporates both crash and near miss counts, some members of the panel recommended that the model should adjust the counts based on the highway and train volumes experienced at the crossing. It could be argued that if two crossings experience an equal number of near misses, the crossing with smaller traffic and train volumes should be weighted more highly than the crossing with higher volumes. The near misses at the low-volume crossing occur at a higher rate, indicating a potentially greater safety issue.

To assess the impact of this change, the recommended crash/near miss factor was adjusted to account for crash/near miss rates rather than total counts. This had the effect of reducing the correlation of the model ranking with the expert panel ranking from 94.7 percent to 85.4 percent. Another aspect considered by the project team was that none of the existing hazard index models reviewed during this study included a rate-based crash or near miss factor. After discussion and further evaluation of this comment, NDOT staff determined that the crash/near miss factor should not be modified from its recommended version.

Traffic Volumes of Close-Proximity Intersections

Some members of the expert panel also recommended the inclusion of a factor to account for the proximity of adjacent highway intersections. The proximity of crossings to highway intersections is a known safety issue at rail crossings in Nevada and across the country. Highway traffic stopped at the intersection has the potential to queue onto the tracks. Sight distances are also limited for vehicles turning onto the roadway with the crossing. For these reasons, the project team reviewed potential crossing characteristics, such as adjacent intersection distance to determine if they should be incorporated as factors in the proposed hazard index model. However, no correlations were found during this study between crash/near miss rates and these factors. After further discussion, NDOT staff determined that the assessment of safety issues resulting from intersection proximity will be better assessed during the periodic field reviews of each crossing.

Train Speed

While train speed is a common component of many existing hazard index models, this study found very little correlation between crash and near miss rates and the maximum timetable speed of trains over the crossings. Train speed was therefore not included as a factor in the recommended model. Some members of the expert panel suggested that a train speed factor should be included regardless of this finding due to the potential safety concerns of high speed trains.

To assess the potential impact of a simple train speed factor, the project team considered a factor increase of 1.5 for crossings with a train speed of 60 mph or greater. Crossings with a train speed less than 60 mph received a factor of 1.0. The use of this approach had a relatively minor effect on the rankings of the top-ranked crossings under the recommended model. The top four ranked crossings remained unchanged while the average change in rank for the top 20 crossings was 2.5. However, this approach also had the effect of reducing the correlation with the expert panel ranking from 94.7 percent to 88.9 percent.

After further discussion, NDOT staff concluded that the rail speed factor should be included in the final model recommendation. Despite the limited findings of this study when reviewing Nevada crash data, it is likely that high train speeds will increase the potential for highway-rail crashes and increase the severity of crashes. The inclusion of a train speed factor is also consistent with many of the existing hazard index models.

Final Model Recommendation

Based on a review of this additional expert panel input, NDOT staff recommended that the Nevada Hazard Index Model as shown in the previous section should include an additional factor for rail speed. The revised model, as shown below, is recommended for official adoption by the Nevada Department of Transportation for the purpose of prioritizing the funding of highway-rail grade crossing improvements throughout the state. The full results of the proposed hazard model index are provided in Appendix C.

Hazard Index =

$\sqrt{\text{EI}}$ (Base Value)

$\text{x}\left(1.3^{\left(\text{A}+\frac{\text{N}}{3}\right)}\right)$ (Crash and Near Miss Factor)

$$\text{x}\begin{bmatrix} \text{4 Quad Gate or Gates with Medians} \rightarrow 0.15 \\ \text{Gates Only} \rightarrow 0.30 \\ \text{Flashing Lights or Passive} \rightarrow 1.00 \end{bmatrix}$$ (Protection Factor)

$$\text{x}\begin{bmatrix} \text{0 to 15 mph} \rightarrow 0.50 \\ \text{20 to 35 mph} \rightarrow 1.00 \\ \text{40 to 65 mph} \rightarrow 1.50 \\ \text{70 mph and Above} \rightarrow 2.00 \end{bmatrix}$$ (Highway Speed Factor)

$$\text{x}\begin{bmatrix} \text{0 to 59 mph} \rightarrow 1.00 \\ \text{60 mph and Above} \rightarrow 1.50 \end{bmatrix}$$ (Rail Speed Factor)

$$\text{x}\begin{bmatrix} \text{1 siding/other track} \rightarrow 1.25 \\ \text{2 siding/other tracks} \rightarrow 1.50 \\ \text{3 or more siding/other tracks} \rightarrow 2.00 \end{bmatrix}$$ (Track Configuration Factor)

$$\text{x}\begin{bmatrix} \text{0 to 30 degrees} = 2.0 \\ \text{30 to 60 degrees} = 1.5 \\ \text{60 to 90 degrees} = 1.0 \end{bmatrix}$$ (Crossing Angle Factor)

EI (Exposure Index) = Average Daily Highway Traffic x Daily Train Volumes

A = Crashes within the past 5 years

N = Near Misses within the past 3 years

Appendix A: Expert Panel Meeting 1 Notes

Development of Revised Grade Crossing Hazard Index Model

Expert Panel Meeting 1 - Summary

310 Galletti Way, Sparks, NV (Main Conference Room), 3:00pm – 5:00pm

Introductions

- The meeting began with introductions from all participants. The group included the following representatives:
    - UPRR: Alex Popovici & Terrel Anderson
    - NDOT Railroad Safety: Brandon Henning, Jon Allen, & Wes Osmer
    - NDOT Freight: Bill Thompson
    - City of Sparks: Amber Sosa
    - Nevada State Railroad Museum: Peter Barton
    - RTC Southern Nevada: John Penuelas
    - FHWA: Greg Novak & Juan Balbuena
    - FRA: Leeann Dickson
    - Nevada Operation Lifesaver: Richard Dent
    - NNRY: Mark Bassett
    - NDOT District III, Elko: Boyd Ratliff
    - NDOT District III, Winnemucca: David Lindeman
    - Humboldt County: Ben Garrett

Project Purpose, Scope and Timeline

- SRF began with an introduction to the purpose of the project and the role of the expert panel.
    - Purpose of project is to develop hazard index model for Nevada that better suits the needs and goals of the state.
        - NDOT feels that the current risk model overemphasizes highway and train volumes leading to prioritization of higher volume urban crossings at the expense of low-volume rural crossings.
        - The recent crash between a tractor trailer and a passenger train in 2011 on US Highway 95 near Miriam, Nevada highlights some of the potential factors that NDOT should consider giving higher weight in the revised model: Number of passenger trains, number of heavy vehicles, highway speeds, etc.
    - Existing models and data will be reviewed to identify factors for inclusion in model.
    - Role of the Expert Panel will be to provide feedback regarding rail safety issues and overall development of the new Nevada hazard index model.

Current NDOT Hazard Index Model

- The current NDOT model is a modified New Hampshire Index model. The calculated hazard index is the product of four variables: Train ADT, Highway ADT, a factor for

presence of gates, flashing lights, or passive protection, and a factor for the number and severity of crashes in the past 5 years. Two potential concerns about this model are:
    - Overemphasis of train and highway volumes at the expense of other potentially more important factors
    - Reliance on crash history. The number of crashes nationally has fallen to a point where previous crash history is no longer a good indicator of grade crossing safety issues in most cases.

Review Common Alternative Models

- The project team reviewed a number of existing alternative hazard index models. These included:
    - USDOT Accident Prediction Model
    - Peabody-Dimmick Crash Prediction Formula
    - NCHRP Report 50 Accident Prediction Formula
    - Texas Priority Index
- Previous studies have shown that many State DOTs are shifting toward the use of a custom formula or index to prioritize grade crossing safety. In 200, nearly half of all DOTs surveyed used a custom formula or index, up from only 32 percent in 1986.
- Two examples from Minnesota were also reviewed:
    - The Minnesota Crude-by-Rail Study recommended improvements along crude-by-rail routes through Minnesota. The study focused on both the likelihood of a collision or derailment as well as the potential impact of a derailment on adjacent areas. It included inputs such as population density, proximity of sensitive populations (schools, etc.) and physical crossing conditions.
    - The Minnesota Rail Grade Crossing Safety Project Selection identified risk factors with the highest correlation to previous collisions and developed a prioritization process using a set number of thresholds rather than formulas. If a certain number of thresholds were exceeded, the crossing would be identified as high-risk.
- Nearly all of the hazard indices reviewed included the use of highway and rail volumes as well as a factor for the type of warning device present. Less common, but still frequent was the inclusion of highway and rail speeds and crash history. The least common factors incorporated into the models included crossing geometry/condition, close call or near miss records from operating railroads, and characteristics of the surrounding area.

Peer State Interviews

- The project team conducted peer interviews with Arizona DOT, Oregon DOT, and Utah DOT. A brief summary of the takeaways from each interview are as follows:
    - Arizona DOT currently uses the Texas Priority Index for their grade crossing improvement prioritization, but like Nevada, they are unhappy with the current results of this model and are seeking alternatives.
    - Oregon DOT uses a custom hazard index model (the Jaqua model) that incorporates a wide variety of factors and characteristics. The three general factors used in the model are an exposure factor that estimates the maximum number of collisions possible based on crossing occupancy time estimates, a hazard ratting that accounts for characteristics that could adversely affect

crossing safety (number of tracks, sight line obstructions, etc.), and finally a protection factor value based on existing warning devices.
  - Utah DOT uses the FRA's Web Based Accident Prediction System to generate a list of the top 50 crossings in the state. However, this is used only as a starting point for discussion and much emphasis is placed on individual crossings reviews.

National and Statewide Crossing Safety Trends

- A review of grade crossing safety trends nationally shows that the number of crashes has reduced steadily and significantly over the past 25 years. Annual crashes nationwide have reduced from over 9,000 in 1981 to approximately 2,000 in 2015.
- Grade crossing safety trends in Nevada mirror the national trends. In the past 10 years, only 18 crashes have occurred in the state of Nevada. Only one crossing has more than one crash in this time period. This highlights the fact that previous crash history is not necessarily a good indicator of future crashes at individual crossings.

Comparison of Crossing Characteristics and Crash Frequency

- To evaluate the impact of various grade crossings factors and characteristics on safety, the project team reviewed the proportion of crashes in the past 10 years to the proportion of crossings for each factor. For example, 31 percent of crossings in Nevada have an ADT of 100 or less, yet only 6 percent of the crashes in the past 10 years have occurred here. Meanwhile, crossings with ADT between 5,000 and 10,000 comprise 8 percent of Nevada's crossings, yet 17 percent of all crashes in the past 10 years have occurred at this locations. The evaluation shows that in general, as ADT increases, the ratio of the share of crashes to the share of crossings in the state increases. As expected, this indicates that higher the potential for crashes is positively correlated with ADT.
- Similar evaluations were completed for highway speed, train volume train speed, warning devices, crossing angle, sight distance, and urban/rural location.

Sample Crossing Ranking Exercise

- The project team identified 12 crossings throughout the state with a variety of conditions and characteristics. The Expert Panel broke into small groups to assess each crossing individually and assign a rough prioritization score (high, medium, or low). These rankings will be used to assess the suitability of the various hazard index models in the future. Models that rank the 12 crossings similarly to the Expert Panel's assessment will be deemed more suitability to Nevada DOT's needs and goals.

- The ranking and general comments for each of the crossings is summarized below:

Loc. ID	Street and Crossing ID	Risk Level
1	Sutro St, 762088D	Medium
2	4th St, 833601K	Medium
3	Jodi Ave, 833585D	Medium-High
4	US 95 A, 740918T	Low
5	US 95, 740765S	Medium
6	Gold Acres Rd, 833452L	Highest Risk
7	Icarus Rd, 740886P	Low

8	Wyoming Ave, 804209T	High
9	Rainbow Blvd, 913213H	Medium-High
10	Green Valley Pkwy, 804185G	Low
11	Navajo Ave, 804059M	Low
12	US 93 ELY, 913085C	Low

- The following characteristics were discussed when determining the appropriate risk level:
    - Train and traffic volumes
    - Train and traffic speeds
    - Proximity to adjacent intersections
    - Type of track (mainline vs. spur/industry)
    - Sight lines and visibility issues
    - Presence of pedestrian traffic
    - Level or hump crossing
    - Proximity of roadway accesses
    - Existing safety improvements (gates, lights, medians)

Next Steps

- Some of the key takeaways from the initial research are:
    - Highway and rail volumes should be critical components for the revised model. Emphasis on them may be reduced, but they should not be excluded.
    - Crash rates are no longer good predictive indicators. The use of railroad near miss data should be considered as an alternative.
    - Highway/rail user type should be considered. Factors such as the presence of passenger trains and heavy vehicles may not have an effect on the overall collision rate, but the severity of a collision is more likely to be severe given the presence of these vehicle types.
    - Characteristics of surrounding area should be considered, but balanced against ease of collection

Summary of Additional Comments from Expert Panel

- What are the results of Operation Lifesaver's educational efforts on rail safety? It is difficult to quantify these efforts, but the research reviewed in three sources noted between 0 and 2 percent positive improvement in crash rates
- What is the threshold for determining when grade separation is called for? There are no standard defined thresholds, but many of the factors reviewed in this study are incorporated into grade separation studies. These typically also include benefit-cost analyses to weight the cost of separation against the benefits in crash reduction and travel time savings.

Appendix B: Expert Panel Meeting 2 Notes

Development of Revised Grade Crossing Hazard Index Model

Expert Panel Meeting 2 - Summary

1263S. Stewart St., Carson City, NV, 2:00pm – 4:00pm

1. Introductions

   - The meeting began with introductions from all participants. The group included the following representatives:
     - NDOT Railroad Safety: Brandon Henning, Jon Allen, & Wes Osmer
     - NDOT: PD Kiser
     - NDOT Freight: Bill Thompson
     - NDOT District III, Elko: Boyd Ratliff
     - NDOT District III, Winnemucca: David Lindeman
     - NDOT District III, Ely: Randy Hesterlee
     - UPRR: Terrel Anderson
     - Nevada State Railroad Museum: Peter Barton
     - PUCN: Tom Miller
     - Nevada Operation Lifesaver: Richard Gent
     - Utah DOT: Eric Cheng, Travis Bailey
     - FRA: Kevin Fitzgerald
     - FHWA: Juan Balbuena
     - Humboldt County: Huston Littlefair

2. Review of Project Purpose, Scope and Timeline

   - SRF began the meeting with an overview of the project purpose, scope, and timeline. The initial research, including a review of peer State DOTs, a review of the crash rates associated with various crossing characteristics, and a first meeting with the Rail Safety Expert Plan has been completed. The current task is an evaluation of existing and proposed alternative hazard indices to determine the most suitable formula for use by NDOT. Expert Panel feedback will be used as one of the primary means of assessing suitability of each model.

3. Summary of Previous Meeting and Brief Review of Tech Memo 1

   a. Correlation of factors to crashes and near misses: Multiple crossing characteristics were reviewed to find a correlation with crash rates. Characteristics reviewed included crossing volumes and speeds, crossing geometry, and existing warning devices.

   b. General Findings

      i. Very few variables correlate strongly with crashes and near misses: Factors with the highest correlation included exposure index (Highway ADT x Train ADT), highway speed, and the type of warning device installed. Many other characteristics were found to have limited, or no correlation.

ii. Small number of crashes limit predictive abilities of models: The small number of crashes (only 18 in the past 10 years) limits the ability to use crash history as a predictive measure. Near miss data collected by UPRR was also reviewed to provide additional supplementary information.

iii. Potential for severe crashes may be more important: It may be equally or more important to focus on the potential for severe crashes rather than just the overall predicted crash rate.

4. Review 12 sample crossings

- Twelve Nevada crossing were selected as a representative sample of crossings throughout Nevada. The various crossings included a wide range of highway and train volumes, urban/rural location, and type of warning device installed.
- These crossings will be used to assess the suitability of each model by comparing each model's ranking of the twelve crossings to the ranking recommended by the expert panel.
- The panel split into four groups. Each group was asked to review the twelve crossings and identify the three crossings that should be given the highest priority and the three crossings that should be given the lowest priority. The result of this exercise is shown in the table below:

Crossing	Crossing Name	Top	Bottom
804209T	Wyoming Avenue	3	
913213H	Rainbow Blvd	2	
833601K	Fourth Street East -	2	
762088D	Sutro Street	2	
740765S	US 95 - Lovelock	2	
740918T	US 95 Alternate -	1	
833452L	Gold Acres Road -		
833585D	Jodi Avenue		
804185G	Green Valley		1
913085C	US 93 - Ely		3
740886P	Icarus Road		4
804059M	Navajo Avenue		4

5. Review existing and proposed models

- The expert panel then reviewed the existing and proposed hazard index models considered for implementation. This included six existing models and four new proposed models developed specifically for NDOT.

- The ranking of the 12 sample crossings was compared to the ranking under the existing NDOT model. Many of the models are very similar in the rankings, but some (such as the USDOT Accident Prediction Model, the NCHRP Report 50 model and the MnDOT Crude-by-Oil) rankings differ quite significantly.

Crossing Number	Crossing Name	Current NDOT Model	Basic New Hampshire Index Rank	Peabody-Dimmick Rank	Texas Priority Index Rank	USDOT Accident Prediction Model Rank	NCHRP Report 50 Rank	MnDOT Rank	New Model #1 Rank	New Model #2 Rank	New Model #3 Rank	New Model #4 Rank
804209T	Wyoming Avenue	1	1	2	1	5	3	3	3	1	1	1
913213H	Rainbow Blvd	2	2	1	4	6	1	9	2	7	5	4
833601K	Fourth Street East - Reno	3	3	4	7	4	6	2	1	4	3	3
762088D	Sutro Street	4	4	3	2	1	4	1	5	2	4	2
833452L	Gold Acres Road - North	5	5	6	3	7	5	6	4	3	2	5
804185G	Green Valley Parkway	6	6	5	6	2	7	4	8	6	7	6
740765S	US 95 - Lovelock Cutoff	7	7	7	5	3	9	5	7	5	6	7
740918T	US 95 Alternate - Weeks	8	8	8	9	9	10	11	9	8	9	9
740886P	Icarus Road	9	9	9	8	8	2	9	6	10	8	8
833585D	Jodi Avenue	9	9	10	10	10	11	6	10	9	10	10
804059M	Navajo Avenue	11	11	11	11	11	8	12	11	11	11	11
913085C	US 93 - Ely	12	12	12	12	12	12	6	12	12	12	12

6. Group Discussion

- Topics and Comments discussed during the meeting area summarized below:
    - Some additional factors, including vertical crossing geometry (hump crossing), skew, adjacent signal interconnect, and distance to the nearest highway intersection should be further review for potential inclusion in the model. The type of track (industrial vs. mainline) should also be reviewed.
    - The combination of fast trains with low train volumes may be something that should be incorporated. At low train volume crossings, motorists may not expect to see a train, which can be especially problematic if the train is moving fast.
    - Since the majority of crossings with higher speeds are used by passenger trains travelling at high speeds, it may result in double-counting to factor in both the number of passenger trains and train speed.
    - Potential for pedestrian collisions is a major issue at some crossings. The use of population density for areas adjacent to crossings may be a useful proxy measure of pedestrian activity.
    - There was general agreement that the use of a crash factor similar to the Texas Priority Index may be a sound approach. Under this model, crashes only influence the model if there have been two or more in the past five years. The use of the near-miss data may also be importance considering the low

7. Next Steps

- The next steps will be to conduct additional analysis based on the feedback from the expert panel and additional coordination with NDOT staff. Additional hazard index models will be developed to incorporate other characteristics and crossing features.

- The models will then be reviewed to assess the suitability for use by NDOT using evaluation criteria such as: how well each model aligns with the expert panel ranking of the twelve sample crossings, availability of data and ease of collection, and how well the model aligns with NDOT goals and strategies.

- A final hazard index model will be recommended and the supporting documentation and analysis will be summarized in a Final Report.

Appendix C: Complete Ranking of Nevada Crossings

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
740763D	HAZEN	CALIFORNIA ROAD	1	0	Passive	34	7,700	511.66	1.30	1.00	1.00	1.50	1.00	2.00	1,995.49	1
740805M	GOLCONDA	M1-SR-789	0	0	Flashing Lights	40	800	178.89	1.00	1.00	1.50	1.50	1.00	1.50	603.74	2
740890E	MONTELLO	BALD EAGLE CANYON	0	0	Passive	30	5,200	394.97	1.00	1.00	0.50	1.50	1.00	2.00	592.45	3
833434N	GOLCONDA	M2-GETCHELL MINE	0	0	Flashing Lights	38	800	174.36	1.00	1.00	1.50	1.50	1.00	1.50	588.45	4
740799L	WINNEMUCCA	BRIDGE STREET	0	1	Gates	32	5,900	434.51	1.09	0.30	1.00	1.50	1.00	2.00	426.80	5
804209T	LAS VEGAS	WYOMING AVENUE	0	5	Gates	26	12,000	558.57	1.55	0.30	1.00	1.50	1.00	1.00	389.22	6
804239K	LAS VEGAS	EASTERN AVENUE	0	13	Gates with Medians	2	35,500	266.46	3.12	0.15	1.50	1.00	1.00	2.00	373.76	7
740797X	WINNEMUCCA	AIRPORT ROAD	0	1	Gates	32	1,500	219.09	1.09	0.30	1.50	1.50	1.00	2.00	322.80	8
834559S	RENO	LEAR BLVD	0	0	Flashing Lights	2	3,300	81.24	1.00	1.00	1.50	1.00	1.25	2.00	304.65	9
740740W	SPARKS	GALLETTI WAY	1	5	Gates	16	3,500	236.64	2.01	0.30	1.00	1.00	1.00	2.00	285.82	10
833523F	WELLS	US 93 ELY	0	2	Gates	14	1,200	129.61	1.19	0.30	2.00	1.50	1.00	2.00	277.90	11
912602K	HENDERSON	PARADISE HILLS DR	0	0	Passive	2	9,300	136.38	1.00	1.00	1.00	1.00	1.25	1.50	255.72	12
833601K	RENO	4TH STREET	0	2	Flashing Lights	2	13,500	164.32	1.19	1.00	1.00	1.00	1.25	1.00	244.66	13
913213H	ARDEN	RAINBOW BLVD	0	0	Passive	2	8,500	130.38	1.00	1.00	1.00	1.00	1.25	1.50	244.47	14
740775X	LOVELOCK	MAIN STREET	0	0	Gates	32	2,100	259.23	1.00	0.30	1.00	1.50	1.00	2.00	233.31	15
740719R	RENO	WOODLAND AVENUE	0	3	Gates	18	4,900	296.98	1.30	0.30	1.00	1.00	1.00	2.00	231.65	16
834498D	RENO	SILVER LAKE DRI	0	0	Flashing Lights	2	6,000	109.54	1.00	1.00	1.00	1.00	1.25	1.50	205.40	17
762094G	BATTLE MOUNTAIN	M1 - W2ND ST	0	3	Gates	40	700	167.33	1.30	0.30	1.00	1.50	1.00	2.00	195.78	18
804245N	LAS VEGAS	DEAN MARTIN DR	0	6	Gates	2	8,200	128.06	1.69	0.30	1.50	1.00	1.00	2.00	194.78	19
804022X	LAS VEGAS	APEX-ARROWLIME SP	0	3	Flashing Lights	2	1,300	50.99	1.30	1.00	1.50	1.00	1.25	1.50	186.43	20
740816A	BATTLE MOUNTAIN	M1-REESE RD SR806	0	0	Gates	40	2,400	309.84	1.00	0.30	1.00	1.00	1.00	2.00	185.90	21
833459J	CARLIN	M2-SR 278	0	2	Gates	24	900	146.97	1.19	0.30	1.50	1.50	1.00	1.50	177.25	22
740765S	LOVELOCK	US-95	0	1	Gates	16	900	120.00	1.09	0.30	2.00	1.50	1.00	1.50	176.81	23
855906U	MCGILL	POLELINE RD	0	0	Passive	0	3,400	58.31	1.00	1.00	1.50	1.00	1.00	2.00	174.93	24
762088D	RENO	SUTRO STREET	1	10	Gates with Medians	16	8,000	357.77	3.12	0.15	1.00	1.00	1.00	1.00	167.28	25
833452L	BEOWAWE	M2-SR 306	0	0	Gates	40	1,500	244.95	1.00	0.30	1.00	1.50	1.00	1.50	165.34	26
833584W	RENO	VALLEY ROAD	0	0	Flashing Lights	2	3,500	83.67	1.00	1.00	1.00	1.00	1.25	1.50	156.87	27
740786K	LOVELOCK	OREANA ROAD	1	0	Passive	16	100	40.00	1.30	1.00	1.00	1.50	1.00	2.00	156.00	28
804005G	NORTH LAS VEGAS	MITCHELL STREET	0	0	Passive	1	3,800	61.64	1.00	1.00	1.00	1.00	1.25	2.00	154.11	29
740902W	SPARKS	IND-GREG ST2	0	1	Gates	2	16,500	181.66	1.09	0.30	1.00	1.00	1.25	2.00	148.70	30
911093M	BABBIT	THIRD AVE	0	0	Passive	12	450	73.48	1.00	1.00	1.00	1.00	1.00	2.00	146.97	31
913207E	SPARKS	WALTHAM WAY	0	1	Gates	20	1,100	148.32	1.09	0.30	1.00	1.50	1.00	2.00	145.69	32

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
804232M	LAS VEGAS	SUNSET ROAD	0	4	Gates with Medians	2	24,500	221.36	1.42	0.15	1.50	1.00	1.00	2.00	141.33	33
740979J	FALLON	TRENTO LANE	0	0	Passive	2	700	37.42	1.00	1.00	1.50	1.00	1.25	2.00	140.31	34
740792N	IMLAY	COUNTY RD 115	0	0	Flashing Lights	16	60	30.98	1.00	1.00	1.50	1.50	1.00	2.00	139.43	35
740828U	BEOWAWE	M1-SR 306	0	0	Gates	40	1,500	244.95	1.00	0.30	1.00	1.00	1.25	1.50	137.78	36
906541H	NORTH LAS VEGAS	DONOVAN WAY	0	0	Passive	2	1,500	54.77	1.00	1.00	1.00	1.00	1.25	2.00	136.93	37
913198H	NORTH LAS VEGAS	INDDONOVAN WAY	0	0	Passive	2	1,500	54.77	1.00	1.00	1.00	1.00	1.25	2.00	136.93	37
833432A	GOLCONDA	M2 EDEN VALLY RD	0	1	Gates	24	350	91.65	1.09	0.30	1.50	1.50	1.00	2.00	135.04	39
804196U	LAS VEGAS	CITY PARKWAY	0	1	Flashing Lights	2	3,400	82.46	1.09	1.00	1.00	1.00	1.50	1.00	135.00	40
740787S	LOVELOCK	RYE PATCH DAM RD	0	0	Gates	32	300	97.98	1.00	0.30	1.50	1.50	1.00	2.00	132.27	41
804112W	CALIENTE	SPRING STREET	0	2	Gates	26	1,300	183.85	1.19	0.30	1.00	1.00	1.00	2.00	131.39	42
740843W	CARLIN	M1- 10TH STREET	0	1	Gates	42	950	199.75	1.09	0.30	1.00	1.00	1.00	2.00	130.80	43
740838A	CARLIN	M1- SR 51	0	0	Gates	40	500	141.42	1.00	0.30	1.50	1.00	1.00	2.00	127.28	44
740903D	RENO	INDWHITE FIR	0	0	Passive	2	4,900	98.99	1.00	1.00	1.00	1.00	1.25	1.00	123.74	45
753815F	RENO	SAGE STREET	0	4	Gates	16	1,300	144.22	1.42	0.30	1.00	1.00	1.00	2.00	122.77	46
740769U	LOVELOCK	WEST FALL	0	0	Gates	32	250	89.44	1.00	0.30	1.50	1.50	1.00	2.00	120.75	47
740803Y	GOLCONDA	M1- MORRISON AVE	0	0	Gates	40	450	134.16	1.00	0.30	1.00	1.50	1.00	2.00	120.75	48
762096V	SPARKS	IND-FRANKLIN WAY	0	0	Passive	2	1,100	46.90	1.00	1.00	1.00	1.00	1.25	2.00	117.26	49
833408Y	GERLACH	NEAR PHIL	0	0	Passive	10	150	38.73	1.00	1.00	1.00	1.50	1.00	2.00	116.19	50
833442F	BATTLE MOUNTAIN	M2 REESE ST	0	0	Gates	24	300	84.85	1.00	0.30	1.50	1.50	1.00	2.00	114.55	51
804244G	LAS VEGAS	LAS VEGAS BLVD	0	6	Gates with Medians	2	44,000	296.65	1.69	0.15	1.50	1.00	1.00	1.00	112.80	52
762068S	SPARKS	IND-PURINA WAY	0	0	Passive	2	1,000	44.72	1.00	1.00	1.00	1.00	1.25	2.00	111.80	53
740898J	SPARKS	IND FREEPORT BLVD	0	2	Passive	2	700	37.42	1.19	1.00	1.00	1.00	1.25	2.00	111.42	54
740897C	SPARKS	IND-GLENDALE AVE	0	0	Gates	2	11,000	148.32	1.00	0.30	1.00	1.00	1.25	2.00	111.24	55
833425P	WINNEMUCCA	M2-RHINEHART DAM	0	0	Gates	10	1,500	122.47	1.00	0.30	1.00	1.50	1.00	2.00	110.23	56
833573J	RENO	OLD US395 N VIR	0	0	Gates	2	4,700	96.95	1.00	0.30	1.50	1.00	1.25	2.00	109.07	57
833539C	RENO	PARR BLVD	0	0	Gates	2	10,500	144.91	1.00	0.30	1.00	1.00	1.25	2.00	108.69	58
740788Y	LOVELOCK	PITT DAM ROAD	0	0	Passive	32	40	35.78	1.00	1.00	1.00	1.50	1.00	2.00	107.33	59
833418E	WINNEMUCCA	JUNGO RD / NV-49	0	0	Gates	10	1,400	118.32	1.00	0.30	1.00	1.50	1.00	2.00	106.49	60
740889K	MONTELLO	STATE HIGHWAY 233	0	0	Gates	30	350	102.47	1.00	0.30	1.50	1.50	1.00	1.50	103.75	61
740772C	LOVELOCK	LOVELOCK YARD RD	0	0	Gates	17	750	112.92	1.00	0.30	1.00	1.50	1.00	2.00	101.62	62
740882M	WELLS	LAKE AVENUE	0	0	Gates	33	550	134.72	1.00	0.30	1.00	1.00	1.25	2.00	101.04	63
740899R	SPARKS	IND-GREG ST1	0	0	Gates	2	8,900	133.42	1.00	0.30	1.00	1.00	1.25	2.00	100.06	64

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
762081F	SPARKS	IND -GREG ST3	0	0	Gates	2	8,900	133.42	1.00	0.30	1.00	1.00	1.25	2.00	100.06	64
753644G	FALLON	ROBERSON LANE	0	0	Passive	2	800	40.00	1.00	1.00	1.00	1.00	1.25	2.00	100.00	66
906533R	LAS VEGAS	DESERT INN ROAD	0	1	Gates with Medians	26	13,500	592.45	1.09	0.15	1.00	1.00	1.00	1.00	96.99	67
740783P	LOVELOCK	COAL CANYON RD	0	1	Gates	32	300	97.98	1.09	0.30	1.00	1.50	1.00	2.00	96.24	68
912007S	BATTLE MOUNTAIN	MULESHOE RD	1	0	Gates	40	650	161.25	1.30	0.30	1.00	1.50	1.00	1.00	94.33	69
740984F	FALLON	YORK LANE	0	0	Passive	2	700	37.42	1.00	1.00	1.00	1.00	1.25	2.00	93.54	70
740901P	SPARKS	IND-E GLENDALE AV	0	2	Gates	2	5,400	103.92	1.19	0.30	1.00	1.00	1.25	2.00	92.84	71
740789F	IMLAY	HUMBOLDT	0	1	Passive	16	50	28.28	1.09	1.00	1.00	1.50	1.00	2.00	92.61	72
740872G	HALLECK	M1-SR 229	0	1	Gates	15	250	61.24	1.09	0.30	1.50	1.50	1.00	2.00	90.23	73
912597R	HENDERSON	PECOS ROAD	0	0	Gates with Medians	2	18,500	192.35	1.00	0.15	1.50	1.00	1.00	2.00	86.56	74
753639K	SPARKS	GLENDALE AVE 3	0	1	Gates	2	5,400	103.92	1.09	0.30	1.00	1.00	1.25	2.00	85.07	75
740812X	VALMY	M1 -VALMY RD	0	0	Passive	40	20	28.28	1.00	1.00	1.00	1.50	1.00	2.00	84.85	76
833592N	RENO	SIXTH STREET	0	0	Gates	2	6,300	112.25	1.00	0.30	1.00	1.00	1.25	2.00	84.19	77
913071U	VIRGINIA CITY	F St	0	0	Flashing Lights	20	350	83.67	1.00	1.00	1.00	1.00	1.00	1.00	83.67	78
913205R	NORTH LAS VEGAS	LA MADRE WAY	0	0	Passive	2	550	33.17	1.00	1.00	1.00	1.00	1.25	2.00	82.92	79
913201N	NORTH LAS VEGAS	ENGINEERS WAy	0	0	Passive	2	550	33.17	1.00	1.00	1.00	1.00	1.25	2.00	82.92	79
740780U	LOVELOCK	ROGERS ROAD	0	0	Gates	32	250	89.44	1.00	0.30	1.00	1.50	1.00	2.00	80.50	81
740796R	WINNEMUCCA	HERSCHELL ROAD	0	0	Gates	32	250	89.44	1.00	0.30	1.00	1.50	1.00	2.00	80.50	81
833403P	GERLACH	SUTCLIFF ROAD	0	0	Passive	10	150	38.73	1.00	1.00	1.00	1.00	1.00	2.00	77.46	83
833491C	ELKO	HOT SPRINGS	0	1	Passive	2	400	28.28	1.09	1.00	1.00	1.00	1.25	2.00	77.17	84
833580U	RENO	Parr Cir	0	0	Passive	2	1,300	50.99	1.00	1.00	1.00	1.00	1.00	1.50	76.49	85
913200G	NORTH LAS VEGAS	STATZ AVE	0	0	Passive	2	1,800	60.00	1.00	1.00	1.00	1.00	1.25	1.00	75.00	86
833591G	RENO	SEVENTH STREET	0	0	Flashing Lights	2	450	30.00	1.00	1.00	1.00	1.00	1.25	2.00	75.00	86
833590A	RENO	EIGHTH STREET	0	0	Flashing Lights	2	450	30.00	1.00	1.00	1.00	1.00	1.25	2.00	75.00	86
740842P	CARLIN	M1 - 4TH STREET	0	0	Gates	42	350	121.24	1.00	0.30	1.00	1.00	1.00	2.00	72.75	89
740782H	LOVELOCK	IRISH AMERICAN RD	0	1	Gates	32	300	97.98	1.09	0.30	1.00	1.50	1.00	1.50	72.18	90
740791G	IMLAY	JUNGO-MAGUBA RD	0	0	Gates	32	200	80.00	1.00	0.30	1.00	1.50	1.00	2.00	72.00	91
913203C	NORTH LAS VEGAS	Range Rd	1	0	Flashing Lights	0	600	24.49	1.30	1.00	1.50	1.00	1.00	1.50	71.65	92
762095N	SPARKS	IND-CONEY IS DR E	0	0	Passive	2	400	28.28	1.00	1.00	1.00	1.00	1.25	2.00	70.71	93
762082M	SPARKS	IND CONEY IS W	0	0	Passive	2	400	28.28	1.00	1.00	1.00	1.00	1.25	2.00	70.71	93
740834X	CARLIN	PALISADE RD	0	0	Passive	27	80	46.48	1.00	1.00	0.50	1.50	1.00	2.00	69.71	95
833522Y	WELLS	CLOVER VALLEY	0	1	Gates	14	150	45.83	1.09	0.30	1.50	1.50	1.00	2.00	67.52	96

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
913216D	NORTH LAS VEGAS	BERG STREET	0	0	Passive	2	250	22.36	1.00	1.00	1.00	1.00	1.50	2.00	67.08	97
804094B	MOAPA	IND- MOAPA POWER	0	0	Passive	2	250	22.36	1.00	1.00	1.00	1.00	1.50	2.00	67.08	97
911091Y	BABBIT	Main Gate	0	0	Gates	8	2,600	144.22	1.00	0.30	1.50	1.00	1.00	1.00	64.90	99
906539G	LAS VEGAS	VALLEY VIEW BOULE	0	11	Gates with Medians	2	13,500	164.32	2.62	0.15	1.00	1.00	1.00	1.00	64.50	100
762087W	ELKO	M1-HOT SPRINGS RD	0	1	Gates	42	400	129.61	1.09	0.30	0.50	1.50	1.00	2.00	63.66	101
833519R	WELLS	PACIFIC STREET	0	1	Gates	14	300	64.81	1.09	0.30	1.00	1.50	1.00	2.00	63.66	101
906540B	HENDERSON	STEPHANIE	0	1	Gates with Medians	2	32,500	254.95	1.09	0.15	1.50	1.00	1.00	1.00	62.61	103
833472X	ELKO	M2-HOT SPRINGS RD	0	1	Gates	40	400	126.49	1.09	0.30	0.50	1.50	1.00	2.00	62.12	104
833509K	HALLECK	M2-SR229	0	0	Gates	15	250	61.24	1.00	0.30	1.50	1.50	1.00	1.50	62.00	105
913087R	RUTH	RUTH HWY	0	0	Passive	1	750	27.39	1.00	1.00	1.50	1.00	1.00	1.50	61.62	106
833583P	RENO	SOCRATES ROAD	0	0	Gates	2	3,300	81.24	1.00	0.30	1.00	1.00	1.25	2.00	60.93	107
833401B	GERLACH	FLANIGAN-DOYLE	0	0	Passive	10	40	20.00	1.00	1.00	1.00	1.50	1.00	2.00	60.00	108
740705H	VERDI	BRIDGE STREET	0	0	Gates	18	550	99.50	1.00	0.30	1.00	1.00	1.00	2.00	59.70	109
807069D	PANACA	NV-75	0	1	Passive	11	30	18.17	1.09	1.00	1.00	1.50	1.00	2.00	59.48	110
740768M	LOVELOCK	DERBY AIRPORT RD	0	0	Gates	32	60	43.82	1.00	0.30	1.50	1.50	1.00	2.00	59.15	111
804202V	JEAN	PRISON ROAD	0	0	Gates	28	150	64.81	1.00	0.30	1.00	1.50	1.00	2.00	58.33	112
928050V	DAYTON	Linehan Rd	0	0	Gates	18	900	127.28	1.00	0.30	1.00	1.00	1.00	1.50	57.28	113
833409F	GERLACH	GERLACH RD	0	0	Gates	10	400	63.25	1.00	0.30	1.00	1.50	1.00	2.00	56.92	114
804045E	OVERTON	WHITMORE STREET	0	0	Passive	2	400	28.28	1.00	1.00	1.00	1.00	1.00	2.00	56.57	115
911092F	BABBIT	Bonanza Rd	0	0	Passive	4	350	37.42	1.00	1.00	1.00	1.00	1.00	1.50	56.12	116
804097W	CALIENTE	Carp Pass Rd	0	0	Passive	26	30	27.93	1.00	1.00	1.00	1.00	1.00	2.00	55.86	117
911096H	BABBIT	Thorne Road #3	0	0	Passive	12	50	24.49	1.00	1.00	1.50	1.00	1.00	1.50	55.11	118
804186N	HENDERSON	GIBSON ROAD	0	3	Gates with Medians	2	17,500	187.08	1.30	0.15	1.00	1.00	1.00	1.50	54.72	119
740982S	FALLON	SODA LAKE ROAD	0	0	Gates	2	2,100	64.81	1.00	0.30	1.50	1.00	1.25	1.50	54.68	120
740918T	SILVER SPRINGS	US-95-A	0	1	Gates	2	2,700	73.48	1.09	0.30	1.50	1.00	1.00	1.50	54.14	121
740925D	WABUSKA	US 95-A	0	1	Gates	2	2,700	73.48	1.09	0.30	1.50	1.00	1.00	1.50	54.14	121
833571V	RENO	N VIRGINA STREET	0	0	Gates	2	4,500	94.87	1.00	0.30	1.50	1.00	1.25	1.00	53.36	123
804006N	NORTH LAS VEGAS	WALNUT ROAD	0	0	Passive	1	450	21.21	1.00	1.00	1.00	1.00	1.25	2.00	53.03	124
834548E	RENO	GOLDEN VALLEY RD	0	0	Gates	2	2,500	70.71	1.00	0.30	1.00	1.00	1.25	2.00	53.03	124
833422U	WINNEMUCCA	JONES LANE	0	0	Passive	10	30	17.32	1.00	1.00	1.00	1.50	1.00	2.00	51.96	126
807213T	NORTH LAS VEGAS	LOSEE ROAD	0	0	Gates with Medians	2	17,000	184.39	1.00	0.15	1.50	1.00	1.25	1.00	51.86	127
804238D	LAS VEGAS	WARM SPRINGS ROAD	0	1	Gates with Medians	2	21,500	207.36	1.09	0.15	1.50	1.00	1.00	1.00	50.92	128

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
913074P	VIRGINIA CITY	Gold Hill Hwy	0	0	Gates	18	1,600	169.71	1.00	0.30	0.50	1.00	1.00	2.00	50.91	129
740985M	FALLON	GUMMOW DRIVE	0	0	Gates	2	2,300	67.82	1.00	0.30	1.00	1.00	1.25	2.00	50.87	130
804060G	LAS VEGAS	EL CAMPO GRANDE	0	1	Passive	2	300	24.49	1.09	1.00	1.00	1.00	1.25	1.50	50.13	131
855866Y	CURRIE	CURRIE	0	0	Passive	0	1,100	33.17	1.00	1.00	1.50	1.00	1.00	1.00	49.75	132
804046L	OVERTON	PERKINS STREET	0	0	Passive	2	300	24.49	1.00	1.00	1.00	1.00	1.00	2.00	48.99	133
740989P	FALLON	VENTURACCI LANE	0	0	Gates	2	2,000	63.25	1.00	0.30	1.00	1.00	1.25	2.00	47.43	134
740773J	LOVELOCK	8TH STREET	0	0	Gates	17	150	50.50	1.00	0.30	1.00	1.50	1.00	2.00	45.45	135
804185G	HENDERSON	GREEN VALLEY PKWY	1	1	Gates with Medians	2	22,500	212.13	1.42	0.15	1.00	1.00	1.00	1.00	45.15	136
855883P	ELY	Lackawanna Rd	0	0	Flashing Lights	1	900	30.00	1.00	1.00	1.00	1.00	1.00	1.50	45.00	137
833402H	GERLACH	HIGH ROCK ROAD	0	0	Passive	10	40	20.00	1.00	1.00	1.00	1.50	1.00	1.50	45.00	137
740951T	HAWTHORNE	THORNE	0	0	Passive	10	50	22.36	1.00	1.00	1.00	1.00	1.00	2.00	44.72	139
906430R	HENDERSON	VALE VERDE DRIVE	0	1	Gates with Medians	2	9,000	134.16	1.09	0.15	1.00	1.00	1.00	2.00	43.93	140
740990J	FALLON	TAYLOR STREET	0	0	Gates	2	3,000	77.46	1.00	0.30	1.00	1.00	1.25	1.50	43.57	141
740988H	FALLON	REGAN PLACE	0	0	Passive	2	150	17.32	1.00	1.00	1.00	1.00	1.25	2.00	43.30	142
911098W	HAWTHORNE	Dock 5	0	0	Gates	0	2,300	47.96	1.00	0.30	2.00	1.00	1.00	1.50	43.16	143
804070M	MOAPA	COUNTY ROAD	0	0	Passive	12	30	18.97	1.00	1.00	1.00	1.50	1.00	1.50	42.69	144
740912C	SILVER SPRINGS	US 50	0	0	Gates	2	1,900	61.64	1.00	0.30	1.50	1.00	1.00	1.50	41.61	145
906534X	NORTH LAS VEGAS	PECOS ROAD	0	0	Flashing Lights	2	550	33.17	1.00	1.00	1.00	1.00	1.25	1.00	41.46	146
740756T	SPARKS	PAINTED ROCK ROAD	0	0	Gates	20	100	44.72	1.00	0.30	1.00	1.50	1.00	2.00	40.25	147
740770N	LOVELOCK	MEADOW ROAD	0	0	Passive	16	20	17.89	1.00	1.00	1.00	1.50	1.00	1.50	40.25	147
855907B	MCGILL	A Ave	0	0	Passive	0	400	20.00	1.00	1.00	1.00	1.00	1.00	2.00	40.00	149
945404G	FERNLEY	IRELAND	0	0	Passive	1	250	15.81	1.00	1.00	1.00	1.00	1.25	2.00	39.53	150
855878T	MCGILL	Club 50	0	0	Gates	0	3,400	58.31	1.00	0.30	1.50	1.00	1.00	1.50	39.36	151
740722Y	RENO	DEL CURTO DRIVE	0	1	Gates	18	200	60.00	1.09	0.30	1.00	1.00	1.00	2.00	39.29	152
855856T	MONTELLO	Montello Hwy	0	0	Passive	0	300	17.32	1.00	1.00	1.50	1.00	1.00	1.50	38.97	153
804128T	HENDERSON	HORIZON DRIVE	0	0	Gates with Medians	0	18,500	136.01	1.00	0.15	1.50	1.00	1.25	1.00	38.25	154
855900D	ELY	Avenue D	0	0	Passive	0	350	18.71	1.00	1.00	1.00	1.00	1.00	2.00	37.42	155
913086J	ELY	Avenue C	0	0	Passive	0	350	18.71	1.00	1.00	1.00	1.00	1.00	2.00	37.42	155
833576E	RENO	RANGER ROAD	0	0	Gates	2	4,900	98.99	1.00	0.30	1.00	1.00	1.25	1.00	37.12	157
913081A	CARSON CITY	Fairview Drive #2	0	0	Flashing Lights	16	150	48.99	1.00	1.00	0.50	1.00	1.00	1.50	36.74	158
833588Y	RENO	NINTH STREET	0	0	Gates	2	1,200	48.99	1.00	0.30	1.00	1.00	1.25	2.00	36.74	159
740703U	VERDI	CRYSTAL PARK ROAD	0	0	Gates	18	200	60.00	1.00	0.30	1.00	1.00	1.00	2.00	36.00	160

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
740986U	FALLON	COLEMAN ROAD	0	0	Gates	2	2,000	63.25	1.00	0.30	1.00	1.00	1.25	1.50	35.58	161
740936R	SCHURZ	Farm Rd	0	0	Passive	0	250	15.81	1.00	1.00	1.50	1.00	1.00	1.50	35.58	161
906425U	RENO	ECHO AVENUE	0	0	Gates	2	1,100	46.90	1.00	0.30	1.00	1.00	1.25	2.00	35.18	163
804101J	CALIENTE	ELGIN	0	0	Passive	26	30	27.93	1.00	1.00	0.50	1.00	1.25	2.00	34.91	164
804242T	LAS VEGAS	BERMUDA ROAD	0	1	Gates with Medians	2	5,600	105.83	1.09	0.15	1.00	1.00	1.00	2.00	34.65	165
913078S	CARSON CITY	Fairview Drive #1	0	0	Flashing Lights	8	150	34.64	1.00	1.00	0.50	1.00	1.00	2.00	34.64	166
740881F	WELLS	METROPOLIS ROAD	0	0	Gates	33	60	44.50	1.00	0.30	1.00	1.00	1.25	2.00	33.37	167
740980D	FALLON	LUCAS ROAD	0	0	Passive	2	350	26.46	1.00	1.00	1.00	1.00	1.25	1.00	33.07	168
833439X	VALMY	M2-WHITE HOUSE RA	0	0	Passive	24	20	21.91	1.00	1.00	1.00	1.50	1.00	1.00	32.86	169
804240E	LAS VEGAS	PARADISE VALLEY R	0	5	Gates with Medians	2	10,000	141.42	1.55	0.15	1.00	1.00	1.00	1.00	32.85	170
911097P	HAWTHORNE	Dock 3	0	0	Gates	0	2,300	47.96	1.00	0.30	1.50	1.00	1.00	1.50	32.37	171
906525Y	LAS VEGAS	Arville St	0	0	Gates with Medians	2	5,700	106.77	1.00	0.15	1.00	1.00	1.00	2.00	32.03	172
833581B	RENO	COMSTOCK DRIVE	0	1	Gates	2	1,300	50.99	1.09	0.30	1.00	1.00	1.25	1.50	31.30	173
740715N	RENO	2 MOGUL ROAD	0	0	Gates	18	150	51.96	1.00	0.30	1.00	1.00	1.00	2.00	31.18	174
740716V	RENO	1 MOGUL ROAD	0	0	Gates	18	150	51.96	1.00	0.30	1.00	1.00	1.00	2.00	31.18	174
833411G	GERLACH	COUNTY ROAD-GERLA	0	0	Passive	10	10	10.00	1.00	1.00	1.00	1.50	1.00	2.00	30.00	176
833412N	GERLACH	HOT SPRINGS ROAD	0	0	Passive	10	10	10.00	1.00	1.00	1.00	1.50	1.00	2.00	30.00	176
833414C	WINNEMUCCA	SULPHER ROAD	0	0	Passive	10	10	10.00	1.00	1.00	1.00	1.50	1.00	2.00	30.00	176
834509N	WINNEMUCCA	ANTELOPE	0	0	Passive	10	10	10.00	1.00	1.00	1.00	1.50	1.00	2.00	30.00	176
833420F	WINNEMUCCA	PRONTO ROAD	0	0	Passive	10	10	10.00	1.00	1.00	1.00	1.50	1.00	2.00	30.00	176
804113D	CALIENTE	ECCLES	1	0	Passive	13	40	22.80	1.30	1.00	1.00	1.00	1.00	1.00	29.64	181
833417X	WINNEMUCCA	STARVATION SPRING	0	0	Passive	10	20	14.14	1.00	1.00	1.00	1.00	1.00	2.00	28.28	182
740804F	GOLCONDA	Sibbald Ave	0	0	Gates	17	50	29.15	1.00	0.30	1.00	1.50	1.00	2.00	26.24	183
855908H	MCGILL	FIRST ST	0	0	Passive	0	300	17.32	1.00	1.00	1.00	1.00	1.00	1.50	25.98	184
740876J	DEETH	M1- DEETH ROAD	0	0	Flashing Lights	15	20	17.32	1.00	1.00	0.50	1.50	1.00	2.00	25.98	184
740886P	WELLS	ICARUS ROAD	0	0	Passive	30	10	17.32	1.00	1.00	1.00	1.50	1.00	1.00	25.98	184
740892T	MONTELLO	TECOMA ROAD	0	0	Passive	30	10	17.32	1.00	1.00	0.50	1.50	1.00	2.00	25.98	184
740891L	MONTELLO	TECOMA ROAD	0	0	Passive	30	10	17.32	1.00	1.00	0.50	1.50	1.00	2.00	25.98	184
833586K	RENO	HIGHLAND AVENUE	0	0	Gates	2	2,300	67.82	1.00	0.30	1.00	1.00	1.25	1.00	25.43	189
804115S	CALIENTE	BEAVER DAM PARK R	0	0	Gates	26	30	27.93	1.00	0.30	1.00	1.50	1.00	2.00	25.14	190
833521S	WELLS	SHOSHONE AVENUE	0	0	Passive	14	20	16.73	1.00	1.00	0.50	1.50	1.00	2.00	25.10	191
740916E	SILVER SPRINGS	NINTH STREET	0	0	Gates	2	850	41.23	1.00	0.30	1.00	1.00	1.00	2.00	24.74	192

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
855877L	MCGILL	Larsen Rd	0	0	Passive	0	150	12.25	1.00	1.00	1.00	1.00	1.00	2.00	24.49	193
855886K	ELY	Avenue F	0	0	Passive	0	150	12.25	1.00	1.00	1.00	1.00	1.00	2.00	24.49	193
804039B	LOGANDALE	COTTONWOOD AVENUE	0	0	Passive	2	300	24.49	1.00	1.00	1.00	1.00	1.00	1.00	24.49	193
912600W	HENDERSON	FIESTA	0	0	Gates with Medians	0	4,100	64.03	1.00	0.15	1.00	1.00	1.25	2.00	24.01	196
804124R	BOULDER CITY	YUCCA ST	0	0	Gates	0	1,600	40.00	1.00	0.30	1.00	1.00	1.00	2.00	24.00	197
912593N	HENDERSON	GREENWAY	0	0	Gates with Medians	2	8,100	127.28	1.00	0.15	1.00	1.00	1.25	1.00	23.86	198
740841H	CARLIN	M1- B STREET	0	0	Gates	42	150	79.37	1.00	0.30	0.50	1.00	1.00	2.00	23.81	199
833577L	RENO	SENECA DRIVE	0	0	Gates	2	500	31.62	1.00	0.30	1.00	1.00	1.25	2.00	23.72	200
740933V	SCHURZ	VISTA DRIVE	0	0	Passive	0	100	10.00	1.00	1.00	1.50	1.00	1.00	1.50	22.50	201
740973T	GERLACH	FLANAGAN ROAD	0	0	Passive	2	40	8.94	1.00	1.00	1.00	1.00	1.25	2.00	22.36	202
804034S	LOGANDALE	BOWMAN RESERVOIR	0	0	Passive	2	250	22.36	1.00	1.00	0.50	1.00	1.00	2.00	22.36	202
804036F	LOGANDALE	WELLS ROAD	0	0	Passive	2	250	22.36	1.00	1.00	0.50	1.00	1.00	2.00	22.36	202
912594V	HENDERSON	COLLEGE	0	0	Gates with Medians	0	6,200	78.74	1.00	0.15	1.00	1.00	1.25	1.50	22.15	205
740941M	SCHURZ	SCHURZ	0	0	Gates	0	2,400	48.99	1.00	0.30	1.00	1.00	1.00	1.50	22.05	206
804044X	OVERTON	INGRAM STREET	0	0	Passive	2	60	10.95	1.00	1.00	1.00	1.00	1.00	2.00	21.91	207
911095B	BABBIT	Thorne Road #2	0	0	Passive	4	50	14.14	1.00	1.00	1.00	1.00	1.00	1.50	21.21	208
740914R	SILVER SPRINGS	FIR AVENUE	0	0	Gates	2	600	34.64	1.00	0.30	1.00	1.00	1.00	2.00	20.78	209
912599E	HENDERSON	ARROYO GRANDE BL	0	0	Gates with Medians	2	9,500	137.84	1.00	0.15	1.00	1.00	1.00	1.00	20.68	210
833585D	RENO	JODI AVENUE	0	0	Gates	2	1,500	54.77	1.00	0.30	1.00	1.00	1.25	1.00	20.54	211
740839G	CARLIN	M1-TOMERA RANCH R	0	0	Passive	40	10	20.00	1.00	1.00	0.50	1.00	1.00	2.00	20.00	212
740785D	LOVELOCK	POKER BROWN CAMP	0	0	Passive	16	40	25.30	1.00	1.00	0.50	1.50	1.00	1.00	18.97	213
740887W	COBRE	COBRE ROAD	0	1	Passive	30	10	17.32	1.09	1.00	0.50	1.00	1.00	2.00	18.90	214
740752R	SPARKS	EAGLE PICHER ROAD	0	0	Gates	22	20	20.98	1.00	0.30	1.00	1.50	1.00	2.00	18.88	215
855895J	ELY	CENTER ST	0	0	Passive	0	100	10.00	1.00	1.00	1.00	1.00	1.25	1.50	18.75	216
855896R	ELY	ORSON AVE	0	0	Passive	0	100	10.00	1.00	1.00	1.00	1.00	1.25	1.50	18.75	216
804127L	HENDERSON	ARROWHEAD TRAIL	0	0	Gates	0	2,500	50.00	1.00	0.30	1.00	1.00	1.25	1.00	18.75	216
855899L	ELY	Avenue C	0	0	Passive	0	350	18.71	1.00	1.00	1.00	1.00	1.00	1.00	18.71	219
855897X	ELY	NORTH ST	0	0	Passive	0	350	18.71	1.00	1.00	1.00	1.00	1.00	1.00	18.71	219
912601D	HENDERSON	NEVADA STATE DR	0	0	Gates with Medians	0	9,300	96.44	1.00	0.15	1.00	1.00	1.25	1.00	18.08	221
833525U	WELLS	COUNTY RD TOBAR R	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222
833526B	WELLS	VENTOSA AIRPOR	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222
833527H	WELLS	SPRUCE	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
833528P	WENDOVER	SAGE/FLOWRY LK RD	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222
833529W	WENDOVER	M2 -SAGE-SHAFTER	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222
833535A	WENDOVER	SHEEP HERDER ROAD	0	0	Passive	14	10	11.83	1.00	1.00	0.50	1.50	1.00	2.00	17.75	222
945406V	FERNLEY	PITTSBURGH ave	0	0	Passive	1	200	14.14	1.00	1.00	1.00	1.00	1.25	1.00	17.68	228
804028N	MOAPA	FRONTAGE ROAD	0	0	Passive	2	150	17.32	1.00	1.00	0.50	1.00	1.00	2.00	17.32	229
740919A	SILVER SPRINGS	FORT CHURCHILL PA	0	0	Passive	2	150	17.32	1.00	1.00	0.50	1.00	1.00	2.00	17.32	229
804037M	LOGANDALE	LISTON AVENUE	0	0	Passive	2	250	22.36	1.00	1.00	0.50	1.00	1.00	1.50	16.77	231
740915X	SILVER SPRINGS	5TH STREET	0	0	Gates	2	600	34.64	1.00	0.30	1.00	1.00	1.00	1.50	15.59	232
804054D	OVERTON	MAGNASITE AVENUE	0	0	Passive	4	60	15.49	1.00	1.00	1.00	1.00	1.00	1.00	15.49	233
804130U	HENDERSON	PACIFIC AVENUE	0	0	Gates with Medians	0	6,200	78.74	1.00	0.15	1.00	1.00	1.25	1.00	14.76	234
911094U	BABBIT	Thorne Road #1	0	0	Passive	4	50	14.14	1.00	1.00	1.00	1.00	1.00	1.00	14.14	235
762078X	SCHURZ	Double Springs	0	0	Passive	0	200	14.14	1.00	1.00	0.50	1.00	1.00	2.00	14.14	235
740945P	SCHURZ	Walker Lake North	0	0	Passive	0	50	7.07	1.00	1.00	1.00	1.00	1.00	2.00	14.14	235
740946W	SCHURZ	Nolan	0	0	Passive	0	50	7.07	1.00	1.00	1.00	1.00	1.00	2.00	14.14	235
740947D	HAWTHORNE	Nolan	0	0	Passive	0	50	7.07	1.00	1.00	1.00	1.00	1.00	2.00	14.14	235
740948K	HAWTHORNE	Walker Lake South	0	0	Passive	0	50	7.07	1.00	1.00	1.00	1.00	1.00	2.00	14.14	235
833427D	WINNEMUCCA	WESO ROAD	0	0	Gates	10	90	30.00	1.00	0.30	1.00	1.50	1.00	1.00	13.50	241
748695G	HENDERSON	CASSIA WAY	0	0	Gates with Medians	0	1,200	34.64	1.00	0.15	1.00	1.00	1.25	2.00	12.99	242
804026A	MOAPA	MOAPA WYE	0	0	Passive	2	20	6.32	1.00	1.00	1.00	1.00	1.00	2.00	12.65	243
740937X	SCHURZ	Mesquite Rd	0	0	Passive	0	40	6.32	1.00	1.00	1.00	1.00	1.00	2.00	12.65	243
924161Y	NORTH LAS VEGAS	BRUCE STREET	0	0	Gates	2	550	33.17	1.00	0.30	1.00	1.00	1.25	1.00	12.44	245
833513A	DEETH	M2 -MAIN ST-DEETH	0	0	Gates	15	50	27.39	1.00	0.30	0.50	1.50	1.00	2.00	12.32	246
804114K	CALIENTE	BARCLAY	0	0	Passive	26	10	16.12	1.00	1.00	0.50	1.00	1.00	1.50	12.09	247
740931G	SCHURZ	Weber Reservoir R	0	0	Passive	0	30	5.48	1.00	1.00	1.00	1.00	1.00	2.00	10.95	248
740932N	SCHURZ	Weber Reservoir R	0	0	Passive	0	30	5.48	1.00	1.00	1.00	1.00	1.00	2.00	10.95	248
913085C	ELY	Ely	0	0	4quadgates	0	5,300	72.80	1.00	0.15	1.00	1.00	1.00	1.00	10.92	250
855871V	CHERRY CREEK	CHERRY CREEK HWY	0	0	Passive	0	50	7.07	1.00	1.00	1.50	1.00	1.00	1.00	10.61	251
913210M	FERNLEY	IND-E NEWLANDS DR	0	0	Gates with Medians	2	1,500	54.77	1.00	0.15	1.00	1.00	1.25	1.00	10.27	252
855884W	ELY	SEVENTH ST	0	0	Passive	1	100	10.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	253
834532H	RENO	LINK LANE	0	0	Gates	2	150	17.32	1.00	0.30	1.00	1.00	1.25	1.50	9.74	254
855873J	MCGILL	Warm Springs Rd	0	0	Passive	0	20	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
740906Y	HAZEN	BANGO ROAD	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255

Crossing No.	City	Street or Road Name	5-year Crashes	3-year Near Misses	Warning Devices	TADT	ADT	SQRT(EI)	Crash/ Near Miss Factor	Protection Factor	Highway Speed Factor	Rail Speed Factor	Track Factor	Crossing Angle Factor	Proposed Index Score	Crossing Rank
740907F	HAZEN	CITY STREET	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
740920U	WABUSKA	ADRIAN VALLEY	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
740922H	WABUSKA	CHURCH HILL	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
740923P	WABUSKA	THOMPSON SMELTER	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
740927S	WABUSKA	Bybee Ln	0	0	Passive	0	20	4.47	1.00	1.00	1.00	1.00	1.00	2.00	8.94	255
945407C	FERNLEY	DENMARK	0	0	Passive	1	40	6.32	1.00	1.00	1.00	1.00	1.25	1.00	7.91	262
911090S	SCHURZ	Heartfalls Ln	0	0	Passive	0	10	3.16	1.00	1.00	1.50	1.00	1.00	1.50	7.12	263
913070M	VIRGINIA CITY	V and T Depot	0	0	Passive	0	50	7.07	1.00	1.00	0.50	1.00	1.00	2.00	7.07	264
804048A	OVERTON	LOST CITY MUSEUM	0	0	Flashing Lights	2	90	13.42	1.00	1.00	0.50	1.00	1.00	1.00	6.71	265
748694A	HENDERSON	WIGWAM PKWY	0	0	Gates with Medians	2	950	43.59	1.00	0.15	1.00	1.00	1.00	1.00	6.54	266
855879A	ELY	Shooting Range Rd	0	0	Passive	0	10	3.16	1.00	1.00	1.00	1.00	1.00	2.00	6.32	267
855858G	WENDOVER	Shafter Rd	0	0	Passive	0	10	3.16	1.00	1.00	1.00	1.00	1.00	2.00	6.32	267
740930A	SCHURZ	Parker Butte Rd	0	0	Passive	0	10	3.16	1.00	1.00	1.00	1.00	1.00	2.00	6.32	267
935771M	HENDERSON	River Mtn. Loop	0	0	Passive	0	40	6.32	1.00	1.00	0.50	1.00	1.00	1.50	4.74	270
855872C	CHERRY CREEK	SCHELLBOURNE	0	0	Passive	0	10	3.16	1.00	1.00	1.00	1.00	1.00	1.50	4.74	270
804030P	MOAPA	COUNTY ROAD	0	0	Passive	2	10	4.47	1.00	1.00	0.50	1.00	1.00	2.00	4.47	272
804032D	MOAPA	COUNTY ROAD	0	0	Passive	2	10	4.47	1.00	1.00	0.50	1.00	1.00	2.00	4.47	272
804050B	OVERTON	GRAVEL PIT ROAD	0	0	Passive	2	10	4.47	1.00	1.00	1.00	1.00	1.00	1.00	4.47	272
740840B	CARLIN	Tomera Rd	0	0	Passive	2	10	4.47	1.00	1.00	0.50	1.00	1.00	2.00	4.47	272
945408J	FERNLEY	PERU DR	0	0	Passive	1	10	3.16	1.00	1.00	1.00	1.00	1.25	1.00	3.95	276
912605F	SPARKS	WALTHAM WAY EAST	0	0	Gates	0	40	6.32	1.00	0.30	1.00	1.00	1.00	2.00	3.79	277
740974A	HAZEN	HAZEN ROAD	0	0	Passive	2	1	1.41	1.00	1.00	1.00	1.00	1.25	2.00	3.54	278
855868M	CURRIE	CORDANO RANCH RD	0	0	Passive	0	10	3.16	1.00	1.00	1.00	1.00	1.00	1.00	3.16	279
935772U	BOULDER CITY	River Mtn. Loop	0	0	Passive	0	10	3.16	1.00	1.00	0.50	1.00	1.00	1.50	2.37	280
740971E	FERNLEY	IND INDUSTRIAL WA	0	1	Passive	2	-	1.41	1.09	1.00	0.50	1.00	1.50	2.00	2.32	281
804059M	LOGANDALE	NAVAJO AVENUE	0	0	Passive	2	10	4.47	1.00	1.00	0.50	1.00	1.00	1.00	2.24	282
913214P	NORTH LAS VEGAS	TROPICAL	0	0	Passive	2	1	1.41	1.00	1.00	0.50	1.00	1.25	2.00	1.77	283
924258V	SPARKS	INDWALTHAM WAY 2	0	0	Passive	2	-	1.41	1.00	1.00	0.50	1.00	1.25	1.00	0.88	284

Nevada Department of Transportation
Rudy Malfabon, P.E. Director
Ken Chambers, Research Division Chief
(775) 888-7220
kchambers@dot.nv.gov
1263 South Stewart Street
Carson City, Nevada 89712