PENNSYLVANIA GRADE CROSSING HAZARD INDEX
RESEARCH AND REVIEW OF EXISTING PRACTICES AND INDICES

PREPARED FOR
PENNSYLVANIA DEPARTMENT OF TRANSPORTATION

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Introduction

To adequately develop a grade crossing hazard index formula tailored to the specific needs, situations, operations, laws, and requirements for safe highway-rail grade crossings within Pennsylvania, research was conducted to obtain general data and methodologies other states and agencies use to categorize rail-highway grade crossing characteristics. The researchers reviewed existing methodologies of PennDOT, other state DOTs, and Federal grade crossing hazard indices. The researchers also reviewed ten state action plans to understand how other states implement hazard indices for grade crossings. In addition, the research team reviewed studies and reports completed by agencies such as the Transportation Research Board (TRB) and American Public Transit Association (APTA) for additional insight on the process of developing an appropriate hazard index. The findings of these reviews are further explained below.

Research Findings

Existing PA Rail Index Rate

The rail index rate that Pennsylvania developed in 1992 was a step forward in addressing the safety issues with rail-highway grade crossings within Pennsylvania. The basic methodology used by this Index consisted of recommending candidate projects, categorizing the recommended projects, and applying the Rail Index Rate to prioritize the grade crossings. This index is able to recommend rail projects by categorizing crossings based on several factors such as the Average Daily Traffic (ADT), number of accidents, number of tracks, and train movements. The research of indices used by other states revealed that many variables used in the PA Rail Index Rate are used in other formulas as well.

More information on the PA Rail Index Rate can be found in **Appendix A.**

State Action Plans, Interviews, and Research

In 2008, the ten states with the most highway-rail grade crossing collisions from 2006-2008 were required to complete grade crossing action plans. These states are Alabama, California, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Ohio, and Texas. These action plans were reviewed and through the research, several common themes among the ten states emerged. One of these themes was an emphasis on driver education through Operation Lifesaver, local agencies, and rail safety campaigns. Enforcement through local, state, and railroad police was another common topic among the plans. Each state described their use of a hazard index or an accident prediction model and associated process to identify crossings prioritized for improvements. More details on the state action plans can be found in **Appendix B.**

To provide more detailed information on the hazard index or prediction model used by peer states, railroad specialists from five states were contacted by phone to provide more information on the type of methodologies their state employs. Specialists from the states of Illinois, Michigan, Ohio, New Hampshire, and Missouri were interviewed. Each state's accident prediction formula and an associated process to rank the crossings was discussed.

<u>Significant Findings</u>

Some similar practices used by multiple states as well as innovative practices were revealed during the interviews and review of state action plans. These practices represent significant findings that should be considered by Pennsylvania for inclusion in an updated hazard index. These significant findings include the following:

- **Data Reliability** - The accuracy and reliability of grade crossing data is essential. Incorrect crossing data will lead to improper results from the hazard index. Ohio has begun using tablet computers to update crossing data when inspectors are in the field. Crossings that have a high hazard index should be reviewed for the accuracy of their crossing data.
- **Accident History** - States that use a hazard index that does not include accident history as a factor often conduct a secondary analysis that includes a review of accident history.
- **Protection Factor** - Consideration of the type of protection (i.e., no protection, crossbucks, traffic signal preemption, flashers, flashers and gates) may provide an indication of a grade crossing that can benefit from a safety project (e.g., crossings with an accident history that only have crossbucks could benefit from improved warning devices).
- **Crash Severity** - Considering the severity of crashes in a hazard index can prioritize crossings with the most severe crashes.
- **Crash Data Reporting**- Not all crashes near grade crossings are reported to FRA. Police crash reports should be reviewed for non-reported crashes.
- **Average Crash Analysis** - Analysis of multi-year crash history can be used to create a profile of the "average crash" for each type of crossing. Crossings that have crashes outside of the average range should be reviewed for needed improvements. This type of analysis is usually done in addition to the calculation of a hazard index and can help identify crossings in need of upgrades that otherwise do not have a high hazard index rating.
- **Crash Frequency** - Crashes are much more infrequent today than years ago. One or two crashes at a grade crossing can skew the results of a hazard index or crash analysis.
- **Sight Distance** - Sight lines, sight distance, roadway offsets, and curves and skews have often not been adequately considered in a hazard index or in subsequent analyses. More effective hazard indices will include an analysis of these factors. Reference **Appendix C** NC DOT Index Formula and MoDOT Selection Study, expert panel review of stopping sight and approach sight distances.
- **Field Inspector Knowledge** - Field inspectors have in-depth knowledge about crossings that should be utilized to identify needed crossing upgrades. For example, Michigan allows each inspectors to select one or two crossings for upgrades based on their personal knowledge and experience.
- **Field Views** - several DOTs use a diagnostic team or conduct site visits to develop solutions to hazard factors at the crossings. Michigan allows field safety inspectors to select 1 or 2 crossings to be considered for upgrades, regardless of hazard index rating, as part of the prioritization.

- **Geospatial Data** - Texas DOT is planning to transition a grade crossing safety database to integrate geospatial date along with new safety analysis tools.

In addition to the phone interview held with Missouri's specialist, researchers reviewed a study MoDOT had performed on their Exposure Index. The information within the study provides insight on how they tested the index for accuracy and how they compared MoDOT's index to other states indices.

NCDOT's Investigative Index Formula was also reviewed as part of this task. NCDOT uses a simple formula that looks at three factors of the crossing; exposure, accident history, and sight distance. After a crossing is identified as needing improvement by using this formula, a field investigation is done to verify the results.

Summary of Indices and Formulas Used

The table below summarizes the type of hazard index or accident prediction formula used by the states researched through action plans, interviews, and index formula research.

	USDOT Accident Prediction Formula	Peabody-Dimmick	State Developed Index or Formula	Benefit-Cost Formula	Modified New Hampshire Index	Other
Alabama	X					
California			X			
Florida			X			
Georgia		X				
Illinois	X		X			
Indiana	X					
Iowa				X		
Louisiana						X
Michigan					X	
Missouri			X			
New Hampshire						X
North Carolina			X			
Ohio	X					
Texas			X			

Additional information on the phone interviews, Missouri's Exposure Index study, Michigan's Hazard Index, Iowa's Benefit-Cost Ratio, and the North Carolina Investigative Index Formula can be found in **Appendix C.**

Review of Federal Methodologies

The Railroad-Highway Grade Crossing Handbook, the GradeDec Reference Manual, and a study completed for the Federal Railroad Administration (FRA) on the Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents were reviewed to understand the methodologies the Federal Government recommends when improving safety at grade crossings.

The **GradeDec** manual notes that GradeDec.Net is a web-based application and decision support tool that evaluates the cost-benefit of grade crossing improvements after a specific crossing has been selected for improvement. As part of the analysis, the program predicts accidents by using the U.S. DOT Accident Prediction and Severity Model as well as the VOLPE High-Speed Rail Accident Severity Model. GradeDec's intention is to assist state and local planners in identifying the most efficient grade crossing investment strategy.

The 2007 **Railroad-Highway Grade Crossing Handbook** developed by the Federal Highway Administration provides in-depth explanations of the standards and best practices for development of highway-rail grade crossings. The handbook explains that some of the major design components used to design a safe crossing include its volume, geometric features, and the crossing surface, to name a few. The handbook also explains the basics of how Hazard Indices and Accident Prediction Models can be used to determine which crossings need safety improvements. Some of the indices and models that were discussed in the handbook include:

- **New Hampshire Index and its modifications** - A simple formula that uses three variables (annual average daily traffic, average daily train traffic, and a protection factor) to produce a hazard index. The handbook explains some states add additional factors to the New Hampshire Index like, Train Speed, Sight Distance, Number of Tracks, and Vertical Alignment, to receive a more tailored output for their needs.
- **NCHRP Report 50 Accident Prediction Formula** - A complex formula that can be reduced to a more simple equation of coefficients that are taken from tables and graphs to calculate the expected number of accidents at a crossing per year.
- **Peabody-Dimmick Accident Prediction Formula** - A simple equation used to predict the number of accidents in a five year period of time.
- **Florida Department of Transportation Accident Prediction Model** - An elaborate model that predicts the amount of accidents that would happen at a specific crossings and then rates the crossing on a scale of 0 to 90 where a rating of 70 or above is considered safe.
- **U.S. Department of Transportation Accident Prediction Model** - An in-depth equation used to predict the likelihood of a collision occurring over a given period of time.

Additional research revealed an FRA study entitled *Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents,* which examined the causes behind the drop in injuries, fatalities, and collisions at highway-rail grade crossings. This study expanded on a variety of factors that ultimately assisted in the decrease of accidents experienced at highway-rail crossings. As seen in the state action plans, it was determined that a proactive approach to safety through education and enforcement played the biggest part in increasing safety. Additional factors that were found to decrease incidents included upgrades to crossings, crossing closures, better sight distance, and making the locomotive more visible.

Supplementary information on the Railroad-Highway Grade Crossing Handbook, GradeDec Manual, and the Success Factors study can be found in **Appendix D.**

Transportation Research Board Report Review

The National Cooperative Highway Research Program (NCHRP) Report 600 completed for the Transportation Research Board (TRB) addresses key factors that affect driver decision at grade crossings. The report provided discussion on human factors that can lead to incidents at grade crossings, and which of these factors to consider when evaluating a grade crossing for potential improvements. These factors include:

- Ensure consistent and reliable operation of traffic control devices and warning systems to promote driver adherence.
- Avoid excessively long delays between activation of warning systems and train arrival to minimize driver non-compliance
- Provide adequate sight distance and clear sight lines to promote good driver decision-making.

A summary of Chapter 14 of the NCHRP Report 600 can be found in **Appendix E.**

APTA Rail-Highway Grade Crossing Safety Assessment

In this article, APTA put together a set of guidelines on how to best assess the safety of new and existing grade crossings. It was explained that an assessment is best made by forming a diagnostic team that specializes in various aspects of rail and highway operations, engineering, and safety. This team would study crossings and document certain characteristics such as the ADT, number of tracks, speed of trains, geometry of the highway, warning signals, school busses, etc. to determine potential hazards within the crossing. If any safety risks are identified, the team would provide design recommendations to mitigate the potential hazards.

Further review of APTA's Rail-Highway Grade Crossing Safety Assessment can be found in **Appendix F.**

Assessment of Factors Used in Hazard Index Formulas

A matrix was developed to track the variables that were used in the different formulas and models that were encountered throughout the research process. In total, 13 models, equations, formulas, and indices were reviewed and 42 different variables were discovered. The majority of these variables only saw one instance of occurrence, while others were more common. The table below shows all the variables that were used in at least 3 of the formulas reviewed.

Variable	Number of Occurrences
Annual Average Daily Traffic	13
Protection Factor	7
Average Daily Train Traffic	6
Number of Accidents (fatal, injury, and property damage)	6
Speed of Train (Freight, Passenger, General)	5
Number of Tracks	4
Sight Distance Actual	4

Device Type (Passive, Active, Gates, Flashing Lights, etc.)	3
Number of Highway Lanes	3
Train Movements	3

It was found that eight equations contained eight or fewer variables. Five equations had more than eight variables. The more complex models like the ones used in GradeDec and the Iowa Benefit-Cost Ratio demanded more variables, whereas some of the state formulas, which were loosely based off the New Hampshire Index, required fewer.

Number of Variables	Number of Occurrences
3	1
4	4
5	1
8	2
9	1
10	1
11	1
12	1
13	1

The table on the following page gives more detail on the variables that are used in the models that were reviewed.

Variable Description	PA Rail Index Rate 1992	Missouri Exposure Index Formula	New Hampshire Index	North Carolina Investigative Index Formula 2003	GradeDec	U.S. DOT Collision Prediction Equation	Peabody-Dimmick Accident Prediction Formula	Floridia Accident Prediction Model	NCHRP Report 50 Accident Prediction Formula	Iowa Benefit-Cost Ratio	Kansas Design Hazard Rating Formula	Conn. Hazard Rating Formula	California Hazard Index	Variable Occurrence
Additional Parameter							X							1
Adequate/Inadequate Current Protection	X													1
Angle of Intersection											X			1
Annual Average Daily Traffic	X	X	X	X	X	X	X	X	X	X	X	X	X	13
Average Daily Train Traffic			X		X		X		X	X			X	6
Average Daily Truck Traffic	X													1
Average Yearly Train Traffic								X						1
Crossing Characteristics										X				1
Device Type (Passive, Active, Gates, Flashing Lights, etc.)					X	X			X					3
Effectiveness Multiplier					X									1
Environmental Factors										X				1
Exposure of Crossing					X									1
Fatal and Injury Accident Prediction	X													1
Hazardous Material Use	X			X										2
Highway Paved?						X								1
Highway Peak Time					X									1
Local Funding Available	X													1
Major Safety Mobility Project	X													1
Maximum Timetable Speed						X				X				2
Number of Accidents (fatal, injury, and property damage)	X			X	X					X		X	X	6
Number of Freight Trains		X												1
Number of Highway Lanes					X	X		X						3
Number of Passenger Trains		X		X										2
Number of Predicted Accidents					X			X						2
Number of Railroad Movements	X			X										2
Number of Tracks	X				X	X					X			4
Percent of Truck					X									1
Protection Factor			X	X			X		X	X		X	X	7
Roadway Characteristics										X				1
School Bus Use	X			X										2
Sight Distance Actual		X		X				X			X			4
Sight Distance Clear								X						1
Sight Distance Required		X						X						2
Speed of Train (Freight, Passenger, General)		X		X	X			X			X			5
Speed of Vehicles		X						X						2
Switching Movements		X								X				2
Time-of-Day Distribution					X					X				2
Train Factor				X										1
Train Movements						X				X		X		3
Type of Highway (Urban or Rural Interstate, Arterial, Etc.)						X								1
Type of Railroad	X													1
Variable Occurrence:	12	8	3	10	13	8	4	9	4	11	5	4	4	

Conclusion

Many methodologies and factors presented in the studied resources can be easily utilized in some form to achieve a Hazard Index Formula that is suited to the specific needs, situations, operations, laws and requirements for safe highway-rail crossings in Pennsylvania. After completing the preliminary research, a few items were common to multiple approaches. One such item included a **diagnostic team of rail and highway experts** for input and recommendations on the safety of grade crossings. Alabama and California include a team like this as part of their action plans. In addition, the study that was done to verify the accuracy of Missouri's Exposure Index utilized a group of experts to determine vital factors of a crossing and the best way to test the accuracy of the index. APTA's Safety Assessment and the Railroad-Highway Grade Crossing Handbook also indicated that a diagnostic team is crucial in identifying potential hazards within a crossing.

When developing the Hazard Index for Pennsylvania, it is possible to modify the existing PA Rail Index, adopt an index developed by another state, or use an established accident prediction model. It was found that **half of the variables in the existing PA Rail Index are also used in formulas developed by other states**. Common variables like ADT, accident history, and number of tracks seem to be a common theme amongst all state developed indices. Although not utilized in the existing PA Index, **sight distance** was another common variable often considered in other state formulas. The research also found that out of the 14 states analyzed, seven used their own index, and five used an accident prediction model such as the U.S. DOT or Peabody-Dimmick Formula. The remaining two states (Louisiana and New Hampshire) utilize other types of techniques inconsistent with a typical hazard index. **Additional crossing data** that could also be considered for a hazard index formula, or in the review of contributing factors includes: hazardous materials routes, school bus routes, percent trucks, condition of highway rail grade crossing surface, and near miss history.

Hazard Index Development Consideration

PennDOT could develop a formula best suited for Pennsylvania using the methodology discovered in the Missouri Exposure Index study. The resulting formula could be part of a multi-step process where the formula would select the highest hazard crossings and a follow-up field view would verify the results. A procedure like this is similar to what other states follow and would provide a standardized process that would produce output that could be further analyzed by PennDOT Central Office and Districts to make sound investment decisions.

Hazard Index Development Approach

The Central Office Grade Crossing Unit is pursuing the use of the WBAPS accident prediction ranking, and supplementing that data with additional information from GC-EDMS such as number of trucks, speeds, crossing angle, protection type, development type and number of trains. The additional data fields are loaded into an Excel spreadsheet that provides conditional formatting to draw attention to key factors such as total tracks, type of protection, signs and signal, and crossing angle. The list can be summarized by district and/or county to help gain input from the District Grade Crossing Engineers/Administrators.

Appendix A

PA Rail Index Rate 1992

Appendix A - PA Rail Index Rate 1992

Summary: This memorandum outlines the guidelines to be followed for developing a list of candidate projects for consideration for the 1992 Federal Rail-Highway Crossing Safety Program. Candidate projects were submitted through a Candidate Project Selection (CPS) process under three categories: warning devices, high-type crossing surfaces, and short-line corridors. Each of these categories had their own set of guidelines and sources to determine which crossing should be considered for improvement. In addition to this, a Rail Index Rate (RIR) was used to assist in evaluating and recommending rail projects. It was mentioned that the RIR was not intended on being the only source to be used in selecting projects. Other things to be considered when selecting a crossing for an improvement includes whether or not the involved railroad line will continue to be in operation and the estimated cost of the project. Ultimately, candidate projects in each District were determined by using both the CPS and RIR and listed in priority order. These projects were then evaluated on a statewide basis, listed, and presented for approval.

Additional Information: The following provides additional information that describes each category and the process of the CPS and how the RIR and its values were developed.

Candidate Project Selection: In order for a project to be selected, it must be a public grade crossing on a federal, state, or local road. There was no limit on the number of projects that could be submitted. A greater emphasis was placed on warning devices and short-line corridor improvement projects. All projects selected are to be field checked to verify if the selection of the project was appropriate. The following are descriptions and guidelines of each category of grade crossing improvement projects.

Warning devices: This category applies to all rail-highway grade crossings. The sources of the possible projects consist of:

- Accident records for the preceding five years.
- RR crossings having the highest hazard potential
- Locations identified by RRs
- Locations identified by the public utility commission
- Locations identified by local Municipalities

Crossings with the highest fatal and injury accidents should be reviewed and strongly considered as candidate projects. The RIR should also be calculated for each project to assist in prioritizing the project. The railroads, utility commission and municipalities should be notified for possible project recommendations. Local municipalities are to provide matching funds if the project is located on a local road. Improvements of this category would include the upgrading of existing or installation of new signing, markings, signals, gates, etc.

High type crossing surfaces: This category is used to select projects in order to considerably improve the rail crossing surface. Due to the high cost, it was planned to replace them only on roadways with high traffic volumes. The factors that are considered when selecting this type of grade crossing improvement project include:

1. Current ADT greater than 7500
2. Truck Traffic greater than 750
3. History of accidents related to the condition of the crossing surface
4. Evidence of railroad maintenance issues due to:
    - High truck traffic volumes
    - Adverse railroad or highway geometry
    - Drainage problems

Factors 1 and 2 were used to determine potential candidates whereas factors 3 and 4 were used to prioritize/reduce the list. Improvements of this category include replacing the existing roadway surface at the grade crossings with an improved surface. For example, replacing bituminous-timber crossings with concrete.

Short-line corridors: A Short-line railroad corridor is referred to as a 25 mile segment of a railroad in which the total trackage of the railroad is 200 miles or less and operates entirely within the confines of the commonwealth. The purpose of this category is to cover work at several crossings along the corridor simultaneously to bring each crossing up to standard and if possible, reduce the maintenance burden for the railroad. This is beneficial because by reviewing all of the crossings in a corridor, it might be feasible to close some, install active warning devices at more heavily traveled adjacent crossings, and adjust the warning intervals. The most common improvements for this category include:

- Adequate signing and markings
- Adjusting track circuits to make the operation of existing warning devices conform to the current volume and speed of the trains
- Upgrading the existing flashing light signals and/or gates to more modern facility
- Adding motion sensing or speed predictability to track circuits

Rail Index Rate: The RIR used data from 12 sources with the raw data in each above category converted to a point value. This point value is totaled to provide a rating for the railroad crossing. The 12 sources of raw data include:

1. Major Hazardous Material Use – Rail/Highway
2. Average Daily Traffic
3. Average Daily Truck Traffic
4. Number of Daily Railroad Movements
5. Type of Railroad Movements
6. Number of Tracks
7. School Bus Use
8. Number of Accidents (Fatal, Injury, Property Damage)
9. Related to a Major Safety Mobility Project
10. Adequate/Inadequate crossing Protection

11. Local Funding Available
12. Fatal and Injury Accident Prediction

During the development of the RIR, the accident predictions were obtained through the National Institute of Health and the number of accidents were obtained from the Center for Highway Safety.

Below are pages from the memorandum detailing how values are allocated for each evaluation item and an example of totaling a RIR.

6. The assigned values for each evaluation item are listed as follows:

HAZ MAT

Range	Rating
Daily HWY Use	5
Daily RR Use	5
Daily HWY/RR Use	10

ADT

Range	Rating
0-200	2
201-1,000	4
1,001-5,000	6
5,001-7,500	8
> 7,500	10

TRU #

Range	Rating
<50	2
50-100	4
101-200	6
201-400	8
> 400	10

RR MVT

Range	Rating
<1	2
1-5	4
6-10	8
> 10	10

RR TYPE

Range	Rating
Not Active	0
Switching	4
Freight	6
Passenger	10

TRK

Range	Rating
None	0
1	3
2	5
> 2	10

SCH BUS

Range	Rating
Yes	10
No	0

NO OF ACCIDENTS 1987 - 1991 (BY TYPE)

FA

Range	Rating
Per Fatality	10

IN

Range	Rating
Per Injury	3

PD

Range	Rating
Per PD Accident	1

MAJOR RELATED SAFETY AND MOBILITY PROJECT

Range	Rating
Yes	10
No	0

CURR PROT

Range	Rating
Adequate	0
Inadequate	10

LOC FND

Range	Rating
Y-Yes	10
X-State	5
N-No	0

FATAL/INJURY ACCIDENT PREDICTION RANKING

Range	Fatal	Range	Injury
1-20	10	1-100	10
21-40	8	101-200	8
41-60	6	201-300	6
61-80	4	301-400	4
81-100	2	401-500	2
> 100	1	> 500	1

7. The following example provides a sample of the Index Rate calcutation.

Project: Lehigh, 853988006, Harrison St. Conrail, 9900-Local Street

Item Code	Raw Data	/	Range Value	Data Description
a. *HAZ MAT	10	/	10	Chemicals and petroleum products cross daily by vehicles and trains
b. ADT	2,550	/	6	Highway ADT at the project within 1,000-5,000 range
c. TRU #	127	/	6	Highway Truck ADTT at project within 101-200 range
e. RR MVT	28	/	10	Railroad movements at project in the > 10 range
e. RR TYPE	Freight	/	6	Type of railroad useage
f. # TRK	2	/	5	Number of tracks at project
g. SCH BUS	Yes	/	10	Crossing used by school buses
h. NO OF ACCIDENTS				
FA	0	/	0	Number of fatal accidents
IN	0	/	0	Number of injury accidents
PD	0	/	0	Number of property damage accidents
i. *S & M Proj	NO	/	0	No association with a major Safety and Mobility project
j. *CURR PROT	10	/	10	Inadequate protection at this crossing
k. *LOC FUD	Yes	/	10	Available Local or State Funds
l. *FATAL/INJ				
FATAL	0	/	0	No fatality predictions listed
INJ	440	/	2	Prediction listed in within 401-500 range
Total Index Rate			75	

Appendix B

State Action Plans

Appendix B - Review of State Action Plans

Introduction

The Rail Safety Improvement Act of 2008 directed the U.S. Secretary of Transportation to identify the ten states that had the most highway-rail grade crossing collisions over the previous three years. These ten states were required to complete a Highway-Rail Grade Crossing Action Plan for review and approval by the Federal Railroad Administration. The plans were required to identify specific solutions for improving safety at crossings and focus on crossings that have experienced multiple accidents or are at a high risk for accidents. The ten states that were required to complete a state action plan are: Alabama, California, Florida, Georgia, Illinois, Indiana, Iowa, Louisiana, Ohio, and Texas.

The ten state action plans were reviewed for relevance to upgrades to Pennsylvania's Hazard Index and Grade Crossing Ranking Process. Summaries of the plans' principle points are noted below.

Alabama

Hazard Index and Grade Crossing Ranking Process

- Alabama uses the US DOT Accident Prediction Formula Index to identify high priority crossings for improvements.
- Diagnostic reviews are performed at the high priority crossings to determine the appropriate upgrades
- Diagnostic reviews include ALDOT, local officials, and railroad personnel.

Other Notes on the Plan

- The analysis of collision data at public crossings is very brief
- Alabama has a program to provide incentive payments (up to $7,500) to local governments for the closure of grade crossings.
- Alabama uses the US DOT Accident Prediction Formula Index to prioritize multiple-collision crossings for installation of active warning devices.
    - Section 130 federal funds are used to provide signalization at approximately 30 grade crossings with only passive warnings per year.
- Alabama installed a Stop Gate Barrier Arm system at one location recently and is evaluating its effectiveness in reducing collisions at that crossing.

California

Hazard Index and Grade Crossing Ranking Process

- California uses a Hazard Index that has been customized for their state
- High-hazard crossings are also analyzed by observing them for hazards that are typical to the area, sightline obstructions, near-miss data, and use by school buses and hazmat vehicles.
- Specific modifications for each location are determined by a diagnostic team that includes the California Public Utility Commission (CPUC), the railroad, local roadway agencies, and Caltrans and FRA, if needed.

Other Notes on the Plan

California has created a set of ten strategies to improve grade crossing safety in the state.

1. Development and implementation of a comprehensive rail programs database, including a rail crossing inventory system, for the Commission's rail safety programs that will allow enhanced integration and analysis of all available crossing data sources;
2. Identifying funding to undertake a state-wide comprehensive crossing inventory project to populate the new CPUC database solution with complete and accurate data on every California crossing, including sightline analysis of existing passive crossings for STOP/YIELD sign placement;
3. Refining and enhancement of objective data-driven risk-analytic processes for evaluation of crossings for Section 130 and other funding;
4. Continuation and further development of CPUC program and resources for evaluating environmental documents for actual or potential safety impacts to rail crossings and rail corridors, for the purpose of identifying those impacts and requiring mitigations of project proponents or their local agency sponsors to address them;
5. Undertake a comprehensive review of all crossings with traffic signal preemption installed to identify deficiencies in device warning time or traffic signal configuration (reference FRA Safety Advisory 2010-02);
6. Continue commitment to education and to the California Operation Lifesaver and the national Operation Lifesaver organizations to promote rail crossing safety and trespass prevention and continue to participate in activities that promote rail crossing safety;
7. Broaden communication and interaction between other involved state and federal agencies to identify funding opportunities, safety initiatives to pursue, and laws and regulations that should be modified or updated to improve rail crossing safety;
8. Develop and publish an annual rail accident report;
9. Review and update Commission General Orders relating to rail crossing safety;
10. Continue to provide and sponsor training opportunities for California roadway authority and railroad personnel to improve knowledge and skills in crossing design and traffic signal preemption fields.

The plan also lists a number of data points about grade crossing collisions. The data is not as detailed as some of the states have provided.

Florida

Hazard Index and Grade Crossing Ranking Process

- Florida uses a Safety Index to prioritize crossings for safety improvements. The safety index includes factors such as: crashes, traffic counts, posted vehicle speed, number of trains per day, maximum train speed, and existing warning devices.
- Crossings prioritized by the safety index undergo a diagnostic field review to determine appropriate improvements.
- Florida has developed a graphical table that suggests the most appropriate grade crossing improvements based on the main factors contributing to crashes. These tables are included at the end of Appendix B.

Other Notes on the Plan

- As of July 2011, there are 3,549 (79%) public and 954 (21%) private active at-grade highway-rail grade crossings in Florida.
- Of the state's 4,503 at-grade highway-rail crossings, approximately 65 percent have active warning devices and 35 percent have passive warning devices. For public at-grade highway-rail crossings, approximately 80% have active warning devices and 20% have passive warning devices.
- Florida is a populous state with a relatively high population density
- Florida receives approximately $7.5 million per year for crossing improvement
- Florida created a Safety Index, updated annually to identify crossings with higher risk. (Quick Google search did not turn up any documentation on the safety index)
    - The Safety Index is used to identify crossings for field review that will identify potential upgrades.
- Crossings with signal interconnection are reviewed for potential upgrades
- Multi-Collision locations were reviewed for potential improvements
- A list of crossings for grade separation is part of the 2010 Florida Rail Needs Assessment
- FDOT identifies corridors that have had increased train volumes or speeds to review for improvements and crossing closures that can be made.
- Crossing field views also review the crossing for pedestrian ADA accessibility
- Operation Lifesaver does public education and awareness
- FDOT works with law enforcement to enforce crossings

Georgia

Hazard Index and Grade Crossing Ranking Process

- GDOT utilizes the Peabody-Dimmick formula in the objective portion of its prioritization process for installation of gates in administering the Section 130 Program.
- The formula result, referred to as the Hazard Index, is then adjusted for five year crash history and crash severity, and school bus use of crossings, resulting in an Adjusted Hazard Index (AHI). AHI is thus a prioritization tool with a crash experience element. The decrease in total crashes indicates it is useful in prioritizing the installation of gates.

Other Notes on the Plan

- The greatest crash decline experienced from late 1970s to 1998 then a levelling. The decline picked up in 2007, perhaps due to great recession.
- There is a very limited analysis of crash data in the plan.
- GDOT continues a close examination of multiple-crash crossings using diagnostic analysis at each.
- Plan Action items include:
  - Education
  - Engineering
  - Enforcement
  - Data Analysis
- Education
  - Georgia will work with Operation Lifesaver and Governor's office of Highway Safety to prepare educational materials regarding crossing safety.
  - Will work with Department of Driver Services to review driving publications for crossing content
  - Will make presentations to large fleet operators regarding crossing safety.
- Engineering
  - GDOT attempts to package together projects that include both crossing closures and active warning improvements at nearby crossings
  - Grade separations are pursued where justified, often in conjunction with new or relocated highways.
  - Grade crossings upgraded with gates are prioritized using the Peabody-Dimmick formula as a starting point.
  - Local match is not required for Section 130 funds, but local authorities are often asked to upgrade signs, markings, and paving in association with the installation or upgrade of active warning devices.
- Enforcement
  - Georgia trains law enforcement and first responders to respond to vehicle-train collisions
  - Training is offered to school bus and truck drivers
  - GDOT works with Georgia State Patrol and local law enforcement to enforce grade crossing laws.
- Data Analysis

- GDOT maintains an inventory of grade crossings and associated crash data for ongoing analysis
- The following types of locations have a high incidence of multiple-crashes and will be observed for the need to upgrade the warning devices
  - Amtrak crossings
  - Flasher-only crossings, especially with multiple tracks
  - Irregular or poor highway/railroad alignment
- GDOT has often studied grade crossings at a corridor level to identify crossings for upgrades and closing.

Illinois

Hazard Index and Grade Crossing Ranking Process

- This plan does not identify any specific hazard index or ranking process used.
- In the data analysis portion, the plan references an exposure index, which is daily trains multiplied by average annual daily traffic. This exposure index is then compared to actual collisions for various crash factors.
- The plan analyzes crashes in great detail, helping Illinois better understand their crashes and contributing factors.

Other Notes on the Plan

- Action Plan Strategies
  - Grade Crossing Closures/Consolidations
  - Highway and Pedestrian Grade Separations
  - Analyze Corridors for Grade Crossing Closures and Consolidations
  - Conduct Public Education and Awareness Programs
  - Promote Automated Enforcement and Increase Illinois State Police Enforcement
  - Conduct Research and Analysis to Maintain Crossing Inventory, Identify Collision Trends, and Evaluate the Effectiveness of Countermeasures
  - Verify the Posting of Emergency Notification Information at Crossings
- Projects are selected based on:
  - High Collision History/Multiple Collisions
  - Interconnected Crossings
- Detailed analysis of Grade Crossing Collisions
  - Type of Collision
  - Type of Warning Device
  - Age and Gender
  - Type of Highway User
  - Action of Highway User in Causing the Collision
  - Position of Highway User on Crossing When Struck
  - Month
  - Time of Day
  - Weather
  - Functional Class of Roadway
  - Whether or Not Collision Occurred on a State Highway
  - Annual Average Daily Highway Traffic (AADT)
  - Vehicle Speed
  - Reporting Railroad
  - Comparison of Crossings and Collisions by Reporting Railroad
  - Type of Train
  - Type of Railroad Operation
  - Type of Track
  - Number of Daily Trains Over the Crossing
  - Train and Highway Vehicle Speed

The plan then provides a snapshot of the "average" collision.

The "average" collision occurred when a freight train struck an automobile at a highway/rail crossing in a large metropolitan area. The highway vehicle, most likely an automobile, was driven by a male between the ages 20 and 29. The driver ignored the warning provided at the grade crossing and was moving over the crossing surface when struck by the train at a highway-rail crossing equipped with gates.

The collision occurred in December between 6:00 p.m. and 6:59 p.m. on a clear day on a local road that is not part of the state maintained system of highways. The automobile was traveling at a slow rate of speed (less than 10 miles per hour) on a roadway with annual average daily traffic volume of less than one thousand vehicles per day.

The automobile was struck by a freight train operating on a main track owned by a railroad where ten to nineteen trains operate daily. The train was traveling between 40 and 49 miles per hour at the time of collision. The highway user was injured in the collision.

Indiana

Hazard Index and Grade Crossing Ranking Process

- Indiana uses the US DOT Accident Prediction formula, which is then modified by applying the actual number of crashes at each grade crossing, producing what Indiana calls the Final Hazard Index
- After the calculation of the Final Hazard Index, other factors are considered in the selection of the highest priority projects for improvements. Other factors include: grade crossing protection already on the rail corridor, existing and new development within the vicinity, motorist expectancy of train movements, poor crossing geometrics or sight distance, and increased rail traffic.

Other Notes on the Plan

- Plan is linked with the state's Strategic Highway Safety Plan, which states a goal of a reduction of 12 grade crossing collisions over the previous year.
- Grade crossing collisions are less than 1% of total statewide collisions.
- Many busy rail lines traverse Indiana leading to the large freight rail hub in Chicago.
- Three performance measures are used for the plan
  - Reduction of three-year collision average to below 100 by 2017
  - Reduce the annual total of injury and fatality producing collisions to 25 or fewer by 2017
  - Reduce the number of multiple collision crossings that experience more than two collisions to ten or fewer by 2017.
- Collision data (2003-2011)
  - Collisions at all grade crossings
  - Collisions at public grade crossings
  - Grade crossing collisions 1975-2011
  - Collisions by warning device
  - Primary factors in grade crossing collisions
  - Crossings with multiple collisions
  - Multiple collisions crossing with nearby signalized intersections
  - Multiple collision crossings by warning device
  - Multiple collision crossing by railroad class
  - County multiple collision crossing percentage

Plan Findings

- Indiana has the third highest density of public grade crossings per freight track mile
  - Countermeasures: Grade crossing closure and separation
- Reduction of collisions, injuries and deaths has slowed in recent years
  - Countermeasures: improve train activated warning devices and passive warning devices
- Driver violations of train-activated warning devices has increased.
  - Countermeasures: rapid crossing evaluation and priority programming of treatments

- Five northwest counties account for the greatest concentration of grade crossings
  - Countermeasures: Target education and enforcement in these counties

Action Plan Strategies

- INDOT applies a portion of the Railroad Grade Crossing Fund to encourage grade crossing closure – incentive payments of generally $15,000 to $60,000.
- Grade Separation is pursued at high priority intersections
- Train-activated warning device improvements (Section 130 funds)
- Passive warning device improvement – includes adding a stop or yield sign as required by updated MUTCD
- Multiple collision crossings – crossings with 2 or more collisions within a 5-year period received greater scrutiny
- Rapid review – all grade crossing collision reports are routed to INDOT rail office for review.
- Priority programming (hazard index) – Hazard index is calculated for each grade crossing annually using the Railroad-Highway Grade Crossing Handbook (revised second edition)
- Education – Operation Lifesaver, Driver Education, and Stakeholder Coordination
- Enforcement – Work with municipal police and railroad police for targeted enforcement.

Iowa

Hazard Index and Grade Crossing Ranking Process

- Iowa has created a benefit-cost ratio formula that includes seven steps in order to prioritize grade crossings for improvements. The benefit-cost ratio calculation is described in the document *Use of a Benefit-Cost Ratio to Prioritize Projects for Funding, January 2006.*
- This formula takes into account the severity of past crashes to prioritize locations with the most severe crashes.
- Iowa undertook a detailed analysis of crash data to identify types of crashes or crash factors that appear to have a significant impact on crashes.

Other Notes on the Plan

- Iowa uses "Use of a Benefit-Cost Ratio to Prioritize Projects for Funding"
- Iowa receives approximately $4.5 million each year for eliminating hazards at grade crossings
  - Cities, counties, and railroads are told of the crossings with high b/c ratio and asked to consider applying for a grant
  - Grants provide 90% of cost with 10% funded by applicant/railroad
  - Projects are funded until all funds are disbursed.
- Operation Lifesaver
  - Collision data showed the following (Iowa did some interesting analysis):
  - Drivers under 25 are overrepresented in collisions
  - 78% of collisions are by male drivers
  - Collisions are significantly higher than traffic volumes from 11pm to 3am
  - Many collisions occur in December and January
  - Many collisions occur at low vehicle and train speeds
  - Active protection does result in lower collision levels
  - Rural secondary paved roads and urban local streets have disproportionately high collisions rates
- Action items to reduce collisions
  - College and HS Education Campaigns
  - Family Education partnerships
  - Enforcement/judicial awareness campaign
  - Rumble strips on paved secondary roads
  - Verify engineering for pre-emption signal timing
  - Crossing signal light LED conversion study
  - Develop closure rating criteria
  - Closure as part of the Grade Crossing Surface Repair Program
  - Closure incentives for Section 130 program
  - Decrease reallocation of Section 130 funds
  - Passenger rail
  - Advocate continuation of 23 USC130 and increased railroad safety funding.

Louisiana

Hazard Index and Grade Crossing Ranking Process

- Plan does not include any information on the use of a hazard index or ranking process.
- Louisiana places a priority on updating the data for each crossing in the state to allow accurate decision-making on projects.

Other Notes on the Plan

- Developed first Highway-Rail Grade Crossing Safety Action Plan in 2006
- This plan updates the 2006 version and includes a detailed evaluation of data from 2005 to 2009
- Document primarily focuses on an Action Plan
- Action Plan
  - FRA report and data review
  - Multi-Collision Locations – Preliminary Field Reviews
  - Highway/Rail Safety Program Documentation
  - Create and Update Crossing Inventory Database
  - Develop and Refine Closure and Consolidation Policy
  - Develop Closure/Consolidation Project List
  - Identify and Prioritize Signal Preemption Locations
  - Conduct the Crossbuck Assembly Program
  - Continue Enforcement and Education Programs with Operation Lifesaver and Louisiana State Police
  - Conduct Local Outreach to Roadway Officials
  - Host a Bi-Annual Railroad Safety Conference
  - Establish a new Statewide Railroad Coordinator Position
  - Determine Selection Criteria for Utilizing Innovative Technology for Rail Safety
  - Develop and Implement a New Railroad Grade Separation Program

Ohio

Hazard Index and Grade Crossing Ranking Process

Plan does not include any information on the use of a hazard index or ranking process.

Other Notes on the Plan

- Minimal analysis of crash data
- Majority of study dedicated to describing existing safety programs
- Safety programs are run by Public Utility Commission of Ohio and Ohio Rail Development Commission
  - PUCO
    - Railroad Inspections
    - Grade crossing warning device safety upgrades
    - Federal funding
    - State Grade Crossing Protection Program
    - Supplemental Funding Assistance
    - Grade Crossing Consolidation Program
    - School Initiative Program
    - PUCO also has the power to close crossings
    - PUCO special initiatives
  - Ohio Rail Development Commission
    - Corridor Sealing Program
    - Preemption Program
    - Grade Crossing Consolidation Program
    - County Task Force/Constituent Initiated
    - Fatal Crash Upgrade Program
    - Crossbuck Assembly Program
    - Railroad-Highway Grade Separations
- Safety Program Objectives
  - Improve passive grade crossings
  - Install lights and gates where warranted but ineligible for federal funding
  - Partner with organizations to address education and engineering
  - Partner with railroads to upgrade crossings with state of the art active warning devices
  - Interconnect grade crossing warning devices and adjacent intersection traffic signals
  - Upgrade crossbucks to MUTCD standards

Texas

Hazard Index and Grade Crossing Ranking Process

- Texas uses the Texas Priority Index formula, which is an exposure index that is customized for the state. It incorporates the following factors: Average annual daily traffic, average daily school bus traffic, average daily train traffic, maximum train speed, existing warding device, and five-year crash history.
- Texas planned to transition to a new grade crossing safety database that integrated with geospatial data and provided new analysis tools.

Other Notes on the Plan

- Focuses heavily on analysis of crash data
- Analyzed collision data from 2003 to 2007
    - 1,328 collisions, average of 266 per year. 1,044 unique locations
    - 466 collisions were at multiple-incident locations
    - 182 multiple-incident locations resulted in 140 fatalities and 509 injuries
    - Multi-incident locations had 39.5% of the fatalities
- Plan goes on to detail significant findings for multiple collision locations including a breakout of:
    - Active vs. passive devices present
    - Located adjacent to traffic intersection
    - Presence of interconnection between active device and adjacent traffic signal
    - Type of train: passenger, commuter, freight, etc.
    - Track class
    - Type of vehicle
    - “trapped on crossing”
- Recommended a range of evaluation, engineering, education, and enforcement strategies to reduce grade crossing collisions.

Florida Remedial Measures for Contributing Causes of Crashes

Table 12. Railroad Crossings with Multiple Collisions - Remedial Measures for Given Driver Contributing Causes

		Gates / Systems Improvements			Grade Crossing Signs / Signal Improvements							Adjacent Intersection Signs / Signals Improvements						Education	Enforcement	
	Number of Incidents	Install Automatic Gates	Install Crossing Cantilevers (> 2 Lanes)	Full-Quad Gate System	Interconnect with Simul. Preemption	Advanced Preempt Sequence	Install Pre-Signals	Install Co-Locate Signal Heads	Install Queue-Cutter Signal	Install Median Raised Curb Island	Install Crossing Edge Striping	Warrant 9 Signalization	Install NO TURN ON RED signs	Turn / Storage Lane Additions	Relocate Stop / Pavement tinting	Blank Out Signs on Parallel Str.	Remove Vegetation	Operation Lifesaver Education	Video Surveillance	Police Enforcement
Driving off Road onto Tracks	4	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Yellow	Green	Red	Red	Red	Red	Red	Yellow	Red	Green	Red
Driving around Gates	3	Red	Red	Yellow	Red	Red	Yellow	Yellow	Red	Green	Red	Red	Yellow	Red	Yellow	Yellow	Red	Green	Yellow	Green
Stopped on Crossing; Auto (Occupied)	32	Yellow	Yellow	Yellow	Green	Yellow	Green	Green	Green	Red	Red	Green	Red	Green	Green	Red	Red	Green	Green	Green
Stopped on Crossing; Auto (Unoccupied)	5	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Green	Yellow
Vehicle Collides with Side of Train	1	Green	Green	Yellow	Red	Red	Green	Green	Red	Yellow	Red	Red	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Red	Red

Legend for Table 12 and Table 13

- Green: Indicates a solution that will have a beneficial effect on the given contributing cause for collision
- Yellow: Indicates a solution that will have a marginal effect on the given contributing cause for collision
- Red: Indicates a solution that will have no effect on the given contributing cause for collision

Table 13. Railroad Crossings with Multiple Collisions - Remedial Measures for Given Physical Contributing Causes

			Gates / Systems Improvements			Grade Crossing Signs / Signal Improvements							Adjacent Intersection Signs / Signals Improvements						Education	Enforcement	
		Number of Incidents	Install Automatic Gates	Install Crossing Cantilevers (> 2 Lanes)	Full-Quad Gate System	Interconnect with Simul. Preemption	Advanced Preempt Sequence	Install Pre-Signals	Install Co-Locate Signal Heads	Install Queue-Cutter Signal	Install Median Raised Curb Island	Install Crossing Edge Striping	Warrant 9 Signalization	Install NO TURN ON RED signs	Turn / Storage Lane Additions	Relocate Stop / Pavement tinting	Blank Out Signs on Parallel Str.	Remove Vegetation	Operation Lifesaver Education	Video Surveillance	Police Enforcement
Distance between Crossing & Adjacent Signalized Intersection	< 50' or < 75' for (High Truck Traffic)	4	Green	Green	Red	Green	Red	Yellow	Green	Red	Green	Red	Red	Green	Green	Yellow	Green	Yellow	Yellow	Green	Green
	50' - 200' or 75' - 200' (Truck)	6	Yellow	Yellow	Red	Green	Yellow	Green	Green	Yellow	Green	Red	Red	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Red	Red
	200' - 500'	3	Yellow	Yellow	Red	Yellow	Yellow	Yellow	Red	Green	Yellow	Red	Red	Red	Red	Red	Red	Red	Yellow	Red	Red
	> 500'	4	Yellow	Yellow	Red	Yellow	Red	Red	Red	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Red	Red
Distance between Crossing &Unsignalized Intersection	< 50' or < 75' for (High Truck Traffic)	5	Green	Green	Red	Red	Red	Red	Red	Red	Green	Red	Green	Red	Yellow	Red	Red	Yellow	Yellow	Green	Green
	50' - 140' or 75' - 140' (Truck)	3	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Green	Red	Yellow	Red	Red	Red	Red	Red	Yellow	Red	Red
	> 140'	2	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Yellow	Red	Yellow	Red	Red	Red	Red	Red	Yellow	Red	Red
Grade Crossing Conditions	No Active Warning Devices (Gates)	2	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Red	Red	Yellow	Yellow	Yellow	Red	Red
	Adjacent Driveways	2	Yellow	Yellow	Yellow	Red	Red	Yellow	Red	Red	Red	Red	Red	Red	Green	Red	Red	Yellow	Yellow	Red	Red
	Vegetation or Other Obstructions	13	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Yellow	Red	Red	Yellow	Green	Yellow	Red	Red
Intersection Conditions	Intersection Traffic Queues on Crossing	13	Green	Green	Yellow	Green	Yellow	Green	Green	Green	Yellow	Red	Green	Red	Red	Yellow	Red	Red	Yellow	Red	Green
	Parallel Street Traffic Blockage	2	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Green	Red	Green	Red	Yellow	Green	Green
	Parallel Street Pedestrian Phase	2	Red	Red	Red	Green	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

Appendix C

Additional State Hazard Indices

Appendix C - Review of Additional State's Hazard Index Methodologies

Phone Interview Responses

Illinois

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Greg Lupton, Project Implementation Engineer, IDOT
Contact Info: Email Greg.Lupton@illinois.gov , phone 217-785-1670

- What Hazard Index formula is your state using?
    - IDOT is responsible for federal transportation funds for rail crossings (approx. $6M/yr) throughout the state. ICC is responsible for state transportation funding (approx. $40M/yr) throughout the state. IDOT provides separate ranking to ICC for coordination purposes.
    - The ICC uses the USDOT/FRA Web Accident Prediction System formula.
    - IDOT uses a hazard index utilizing AADT, trains per day, number of tracks, and accident history.
- Is the Hazard Index formula calculated for all grade crossings in the state?
    - Yes, all public grade crossings in the state are included.
- Is the Hazard Index for grade crossings recalculated on a regular basis?
    - The ICC has a database that calculates the formula in real-time whenever updates are made. The database also has the ability to predict what a crossing's new value will be after upgrades are made.
    - IDOT ranks grade crossings on a yearly basis, however, they may move to a 2-year basis due to funding time constraints and the length of time it takes to move projects though the railroad coordination process.
- Is the Hazard Index Formula used by itself to rank projects for funding or are there other associated processes to produce a ranking?
    - For the ICC, the index is used to create a ranking. The top 100 crossings are then analyzed in greater detail.
    - Google street view is often used as part of this detailed analysis. Some field views may be used.
    - The accident history is reviewed for the crossings.
    - The approach grades are often examined and sight distance is analyzed.
    - IDOT uses the hazard index, a review of physical locations, and local and railroad input.
- Have you ever tried to evaluate the accuracy of your Hazard Index formula?
    - ICC has considered trying to change some of the factors in the formula to more accurately reflect the conditions in Illinois.
- Are you considering any updates to the formula?

    - ICC has considered trying to change some of the factors in the formula to more accurately reflect the conditions in Illinois.
    - IDOT tweaked their formula to reflect current conditions.
- Are there any specific data items or factors used in your formula that you believe are important?
    - None noted

Michigan
Kristian Foondle, Local Grade Crossing Program Manager
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- What Hazard Index formula is your state using?
  - Michigan uses a modified New Hampshire Index.
  - The formula is modified to include additional protection factors that are not used in the basic New Hampshire Index.
  - Michigan's protection factors account for the additional safety benefits of 12" flashing lights instead of 8" ones.
  - The additional protection factors are based on research documenting the additional safety afforded by various warning devices.
  - Protection factors are documented in a document entitled Appendix A - Safety Indices Used to Analyze Crossing Risk.
- Is the Hazard Index formula calculated for all grade crossings in the state?
  - Yes, all public grade crossings are given a hazard index.
- Is the Hazard Index for grade crossings recalculated on a regular basis?
  - Yes, each year the hazard index is recalculated based on updated traffic counts, train counts, and protection factors.
- Is the Hazard Index Formula used by itself to rank projects for funding or are there other associated processes to produce a ranking?
  - The hazard index is just the first step in the process of selecting grade crossings for upgrades.
  - Michigan also tracks a rolling 5-year crash history for each crossing. These crashes are summarized for each type of crossing (crossbucks only, flashers only, flashers and gates, etc.) and an average crash profile is created. Individual grade crossings that have crashes that deviate from the crash profile for that type of crossing are examined in more detail.
  - Crossings with multiple crashes are always prioritized for upgrades.
  - Field safety inspectors are allowed to select 1 or 2 crossings to be prioritized for improvements, regardless of each crossing's hazard index score.
  - The annual priority list for improvements and upgrades is created using a blend of the hazard index, the crash history analysis, multiple crash locations, and the inspector's choices. The list usually consists of 40-50 locations. These locations are then field viewed for a diagnostic study.
  - For each of the selection locations, Michigan also reviews the FRA Web Accident Prediction System output and performs a cost benefit analysis of the proposed crossing upgrades using the NCHRP Report 50 methodology.
- Have you ever tried to evaluate the accuracy of your Hazard Index formula?
  - The recent updates to the protection factors used in the formula are the result of concerns about the inaccuracy of the hazard index formula.
- Are you considering any updates to the formula?
  - Updates to the protection factors were made in 2015/2016.

- Are there any specific data items or factors used in your formula that you believe are important?
    - Reviewing police crash reports in addition to the FRA crash data is important. Some crashes are not reported to FRA and therefore are not counted in their data.
    - The crash profile that Michigan creates has helped persuade reluctant municipalities/road authorities to agree to a grade crossing upgrade. In Michigan, road authorities are required to pay for 50% of the operation and maintenance of a warning device. This requirement can lead to resistance to upgrades.

Missouri

Troy Hughes, Railroad Projects Manager, Missouri Department of Transportation
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- What Hazard Index formula is your state using?
  - Missouri uses an Exposure Index (EI) formula. This formula is documented in the 2003 Highway/Rail Crossing Project Selection report.
  - The report suggested moving to a new formula similar to that used by Kansas. Shortly after the report was produced, Kansas stopped using their formula, causing Missouri to reconsider changing their formula.
  - Missouri also uses the FRA Accident Prediction data because their EI doesn't consider accidents.
- Is the Hazard Index formula calculated for all grade crossings in the state?
  - Yes, the formula is calculated for all grade crossings. It is part of the data collected and reported for each grade crossing.
- Is the Hazard Index for grade crossings recalculated on a regular basis?
  - Yes, it is recalculated automatically whenever new data is added.
  - AADT is updated approximately every 5 years.
  - Train counts are updated annually.
- Are you considering any updates to the formula?
  - No changes are currently being considered, but Missouri is always willing to explore potential better formulae.
  - There are some recognized shortcomings of the EI
  - The accident history of the grade crossing are not considered
  - The existing warning devices are not considered
- Is the Hazard Index Formula used by itself to rank projects for funding or are there other associated processes to produce a ranking?
  - The EI is used by itself to program grade crossing improvement projects 3 to 4 years in the future.
  - Site visits are not part of the project ranking process. They are used for problem and solution diagnosis of the crossing.
  - Enough grade crossings are programmed to account for 60 to 80% of expected funds.
  - The remaining funds are reserved for grade crossing improvements that are identified by other means such as requests from municipalities and changes in AADT or land development that affect the safety of a grade crossing.
- Have you ever tried to evaluate the accuracy of your Hazard Index formula?
  - The 2003 report attempted to do this, but Missouri has not otherwise done so.
- Are there any specific data items or factors used in your formula that you believe are important?
  - The sight distance obstruction factor is important to account for sight distances at the crossing.

New Hampshire

Melodie Esterberg, Chief of Design Services
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- What Hazard Index formula is your state using?
  - The New Hampshire DOT does not use a Hazard Index formula to rank grade crossings. New Hampshire uses a spreadsheet with various field characteristics of the rail crossings to rank projects including: type of warning features, current road condition, ride quality, rail condition, roadway and rail alignment geometrics, local and railroad input. The spreadsheet is an improvement from more recent historical ranking methods.
- Is the Hazard Index formula calculated for all grade crossings in the state?
  - The same spreadsheet is used to rank all grade crossings.
- Is the Hazard Index for grade crossings recalculated on a regular basis?
  - No.
- Is the Hazard Index Formula used by itself to rank projects for funding or are there other associated processes to produce a ranking?
  - The spreadsheet data is used as well as the US DOT/FRA WBAPS and local and railroad input.
- Have you ever tried to evaluate the accuracy of your Hazard Index formula?
  - No.
- Are you considering any updates to the formula?
  - NH intends to incorporate additional input data into the spreadsheet including: accident data, AADT and train trip volume.
- Are there any specific data items or factors used in your formula that you believe are important?
  - Does not use Hazard index formula.

Ohio

Randall Schumacher, Rail Division Supervisor, Public Utilities Commission of Ohio
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- What Hazard Index formula is your state using?
  - Ohio is currently using the US DOT Accident Prediction Model
  - Ohio is considering a new formula and recently commissioned a research study to explore options.
- Is the Hazard Index formula calculated for all grade crossings in the state?
  - Yes, the formula is calculated for all public grade crossings.
- Is the Hazard Index for grade crossings recalculated on a regular basis?
  - Yes, twice a year the index is recalculated for each grade crossing.
  - All grade crossings are visited yearly by Public Utility Commission of Ohio staff. Currently they take notes on paper and update any information about the crossing in the office.
  - In the near future, field staff will have tablet computers and be able to verify and update crossing data in the field. These updates will be reflected in the hazard index when it is recalculated twice a year.
  - In association with the tablet upgrade, PUCO is switching over to a GIS database of grade crossings.
- Is the Hazard Index Formula used by itself to rank projects for funding or are there other associated processes to produce a ranking?
  - The formula is used as part of a larger process.
  - Twice a year the hazard index is recalculated for each grade crossing. Using the index, the highest 40 or so crossings are examined more closely. First, data such as traffic counts and trains counts are verified to ensure that they reflect up-to-date data. Then, field views are held that include local representatives where potential solutions are discussed.
- Have you ever tried to evaluate the accuracy of your Hazard Index formula?
  - The research study discussed earlier did so.
- Are you considering any updates to the formula?
  - The research study is addressing this.
- Are there any specific data items or factors used in your formula that you believe are important?
  - The accuracy of data used in the formula is very important.
  - Traffic counts should be updated as frequently as possible, given budget constraints
  - The updated formula that results from the research study recently conducted will likely take into account sight distance and/or visual obstruction.
- A new federal rule requires that all railroad grade crossing data be audited for accuracy every three years. Accurate data will improve the performance of any formula that is used.

Other State Resources

Missouri Department of Transportation Highway/Rail Crossing Selection Study

Summary: MODOT uses a formula called the Exposure Index to prioritize highway-rail crossings for safety upgrades. A study was done to determine the effectiveness of the existing formula and the possibility of updating the formula by adopting one from another state. The study goes into specifics on how the old formula and each additional model that was evaluated was tested for accuracy in predicting the ranking of crossings. In addition to this, it was explained that a panel of officials was assembled to identify what criteria should be used to select a "best" model and what key factors should be included in a formula. Ultimately, the technical report does a great job of determining the best method/process for selecting a highway-rail crossing project and identifies new crossing treatments that could be used to improve safety.

Additional Information: MODOT's original equation has two parts; one is a relationship between highway and train factors, and the second adjusts for sight distance. The formula uses the following factors to determine the Exposure Index (EI):

1. Number of vehicles
2. Speed of vehicles
3. Number of passenger trains
4. Number of freight trains
5. Speed of passenger trains
6. Speed of freight trains
7. Switching movements
8. Required sight distance
9. Actual sight distance

Since the EI is computed differently for an active protection crossing than a passive crossing, 12 crossings, six active and six passive, were categorized using the equation. The ranking of these crossings were then used as a baseline when comparing results from other models. The same 12 crossings were then categorized using six other hazard index models. These models included:

1. USDOT Accident Prediction Model
2. California's Hazard Rating Formula
3. Connecticut's Hazard Rating Formula
4. Modified New Hampshire Formula
5. Kansas's Design Hazard Rating Formula
6. Illinois's Modified Expected Accident Frequency Formula

The expert panel that was assembled for this study agreed that the following pieces of information should exist in the best model:

1. Annual Daily Traffic (ADT)
2. Number of Passenger Trains

3. Stopping Sight Distance vs. Recommended Sight Distance
4. Approach Sight Distance vs. Recommended Sight Distance
5. Speed of Train
6. Total Number of Trains
7. Speed of Highway Traffic
8. Number of Quadrants Sight is Restricted From
9. Clearance Time

North Carolina 2003 Investigative Index Formula

https://connect.ncdot.gov/resources/safety/Teppl/TEPPL%20All%20Documents%20Library/I-7_e.pdf

Summary: NCDOT originally used a hazard index in the early 1970's that consisted of basic design elements that were present at railroad grade crossings. The Investigative Index formula that is now used, improves upon the old hazard index and includes more operational and safety factors that are experienced at existing crossings. Approved by the FHWA, NCDOT uses this formula to systematically select which crossings need to be improved. After the candidate projects are selected, a field investigation is done at each crossing to verify the results.

The Investigative Index formula is divided into three parts:

1. Exposure
2. Accident History
3. Sight Distance

Each part of the formula has a constant so that each share contributes to about 33% of the overall index value. The Accident History portion of the formula is squared to provide a greater emphasis on the accident history of the crossing. The Sight Distance is simply added at the end of the formula.

Additional Information:

Exposure is derived using the following formula: $Exposure = \frac{(PF)*(ADT)*(TV)*(TSF)*(TF)}{160}$

1. Protection Factor (PF): A reduction factor applied to those locations which already have some form of active protection. The following factors are assigned to what is currently at the crossing:

VALUE	TYPE OF PROTECTION
1.0	NO PROTECTION
1.0	CROSSBUCKS
0.5	TRAFFIC SIGNAL PREEMPTION
0.2	FLASHERS
0.1	FLASHERS AND GATES

2. Average Daily Traffic (ADT): The average traffic volume the crossing experiences in a day. The ADT is adjusted for the following reasons:
   a. School Busses: If school busses use the crossing, the ADT is increased by the number of passengers on the bus divided a constant of 1.2.
   b. Hazardous Cargo: The ADT is increased by 20% when hazardous cargo is known to be present at the crossing.
   c. Passenger trains: The ADT is increased by 20% when passenger trains are known to use the crossing.

3. Train Volume (TV): A factor based on the number of train movements through the crossing (both through and switching).
4. Train Speed Factor (TSF): A value based on the maximum train speed that is allowed at the crossing. The factor can be determined using this equation: $TSF = \frac{Train\ Speed}{50} + 0.8$
5. Train Factor (TF): A factor that establishes the relative danger of combinations of through and switching tracks. For example, a factor of 3 is applied to a four track crossing where all tracks are mainline (through) tracks. A factor of 2 is applied if all but one of the four tracks are low-speed (sidings). The following table lists the factors used for each scenario:

NO. OF TRACKS	NO. OF THROUGH TRACKS				
	0	1	2	3	4
1	1.00	1.00	-	-	-
2	1.50	1.75	2.00	-	-
3	1.60	1.85	2.25	2.50	-
4	1.75	2.00	2.50	2.75	3.00

Accident History is based on the number of accidents per year for the previous 10 years. If active warning devices were added in the past 10 years, only the years since the improvement are considered.

Ultimately, the Accident History part of the formula is represented as $\left(70 * \frac{A}{Y}\right)^2$, where:

1. Accidents (A): The number of accidents experienced at the crossing.
2. Years (Y): The number of years the accidents have occurred (Maximum of 10).

The final part of the formula is a value derived from the available sight distance at the crossing. This value is obtained during a field view of the crossing location. This variable can have the following values based on what is observed in the field:

VALUE	SIGHT DISTANCE EXPERIENCED
0	SIGHT DISTANCE IS NOT A FACTOR
1	ABOVE AVERAGE SIGHT DISTANCE
2	AVERAGE SIGHT DISTANCE
3	BELOW AVERAGE SIGHT DISTANCE
4	POOR SIGHT DISTANCE

The full equation is expressed as:

$$Investigative\ Index = \frac{(PF)(ADT)(TV)(TSF)(TF)}{160} + \left(70 * \frac{A}{Y}\right)^2 + SDF$$

Appendix D
Federal Hazard Methodologies

Appendix D - Review of Existing FHWA Grade Crossing Hazard Index Methodologies

GradeDec.net Reference Manual – System for Highway-Rail Grade Crossing Investment Analysis

Summary: GradeDec.net is an online tool that is used to evaluate the cost-benefit of grade crossing improvements along a corridor of track or within a region. It can be found at the following link: https://gradedec.fra.dot.gov/. This tool evaluates grade crossings and their contributing factors, and in return, provides the best suited improvement that benefits the crossing. These improvements can include a device type change, additional measures to gated crossings (photo enforcement, gates with detection, barrier curbs, etc.) and changes to highway traffic flows (signage and signaling to divert traffic way from high-risk crossings). GradeDec is intended to assist state and local planners in identifying the most efficient grade crossing investment strategies.

GradeDec uses two models to determine the appropriate improvement for a crossing. If the crossing is located on a single, continuous alignment of track, it is evaluated as part of a "corridor". The Corridor model will analyze the impact to the adjacent crossings along the corridor in addition to the crossing originally evaluated. This shows how closing a crossing would affect other crossings within the same railroad alignment.

A Regional Model looks at the all the crossings in a geographic region, which may or may not be part of the same alignment. This model is unable to provide as much information as the Corridor model, however it is simpler to use.

For each model to develop a safety index, the following characteristics are used:

- Forecast of the average daily highway and rail traffic for the crossing.
- Exposure of the crossing (the probability of a train and highway vehicle at the crossing at the same time)
- Time-of-Day distribution (the time when the most highway/rail traffic occurs)
- Predicted Number of Accidents
- Number of Accidents by Severity Category (DOT & HSR formulas).
- Effectiveness Multipliers (value assigned to each improvement to be applied to the predicted accidents of the crossing).
- Supplementary Safety Measures (gated crossings only)

Some additional data variables that play a role in the decision of the improvement include:

- Grade Crossing Type (ex. No device, cross bucks, flashing lights, gates, etc.)
- Number of Highway Lanes
- Number of Railroad Tracks
- Highway traffic AADT

- % Trucks
- Highway Peak Times
- Highway Speed limit
- Max Train Speed
- Average number of trains
- Number of Accidents at crossing in past five years

Non-safety factors that are considered when developing a cost-benefit include:

- Time-in-Queue
- Environmental Benefits
- Local Benefits
- Network Benefits

Additional Information:

The predicted accidents by severity category is estimated using the U.S. Department of Transportation (DOT) Accident Prediction and Severity Model (APS) and Resource Allocation Method and/or the Volpe National Transportation System Center (VNTSC) High-Speed Rail (HSR) Accident Severity Model. The DOT APS is used in both Regional and Corridor models, whereas the VNTSC HSR is only used in the Corridor Model.

Many of the safety characteristics listed above are derived from equations explained in the manual. Ultimately, the safety benefits of the crossing are used as a reduction to the predicted accidents at the crossing and their severity. When combined with the other cost saving characteristics (queuing times, reduced emissions, operating costs, etc.) an overall cost-benefit of the improvement is calculated.

Railroad-Highway Grade Crossing Handbook

Summary: Revised in 2007, the Railroad-Highway Grade Crossing Handbook provides standards and best practices for highway-rail grade crossings. It also includes general information of physical and operational improvements that make the crossing safer for both highway and rail traffic. In addition, the handbook has chapters that explain the components of a crossing, assessment of crossing safety, and an example of New Hampshire's Hazard Index.

The handbook explains that a major component of the crossing consists of the physical aspects of the highway. The following characteristic are relevant to the design and control of the crossing:

- Urban or Rural Location
- Type of Road (arterial, collector, local)
- Traffic Volume
- Geometric Features (no. of lanes, alignment, sight distance, crossing angle)
- Crossing Surface
- Nearby Intersecting Highways
- Illumination

It is mentioned that a lot of the geometric features could affect traffic operations at the crossing and consequently, affect sight distances. The handbook provides some remedies for the above characteristics. For example, crossings with more than two lanes are usually candidates for cantilevered flashing light signals. Crossings with sight distance issues could require advanced signing or active advance warning devices.

It was noted that illumination could be effective in reducing collisions at night by assisting road users, including pedestrians and bicyclists, traverse the crossings at night. It was stated that in 2004, 1,214 of 3,063 collisions at crossing occurred during darkness, and that commercial power is available at more than 90% of public crossings, making lighting feasible at most crossings.

The Federal Rail Administration (FRA) maintains an inventory of information on all crossings throughout the country. Information on highway-rail grade crossing collisions can also be provided by the FRA. This data can be obtained at the following web address:

http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx.

Collisions involving trains are essential in locating potentially hazardous crossings. However, collisions near highway-rail crossings not involving trains should be taken into consideration as well. These types of accidents could indicate roadway geometric deficiencies that could be addressed to improve safety.

The National Highway Traffic Safety Administration (NHTSA) also provides data on fatal highway traffic collisions at highway-rail grade crossings through their Fatal Accident Reporting System (FARS).

The handbook also explains how a Hazard Index could be used to identify crossings that have the most need for safety improvements. It explains that the New Hampshire Index is a common ranking method. The New Hampshire Hazard Index (NHHI) uses three variables: Annual Average Daily Traffic, Average Daily Train Traffic, and a protection factor of the existing warning system (gates, flashing lights, etc.). Additional factors that are included into variations of the NHHI include:

- Train speed
- Highway speed
- Sight distance
- Crossing angle
- Crossing width
- Type of tracks
- Surface type
- No. of Buses/School buses
- No. of tracks,
- No. of accidents
- Hazardous materials

An accident prediction model can also be used to rank or identify hazardous highway-rail crossings. The U.S. DOT collision prediction formula uses three independent calculations to produce a collision prediction value. Ultimately, the formula produces a hazard ranking based on a crossing's characteristics, a collision prediction value that is based off of actual collision history, and a normalizing constant. Additional prediction formulas include the National Cooperative Highway Research Program Report 50 Accident Prediction Formula, the Peabody-Dimmick Accident Prediction Formula, and the Florida Department of Transportation Accident Prediction Model.

There are a variety of safety and operational improvements that can be utilized to improve the quality of a highway-rail crossings. These improvements include crossing elimination, passive traffic control devices, active traffic control devices, site improvements, and surface improvements to name a few. Passive traffic control devices include signage and pavement markings to direct attention to the crossing. This can include the use of a Stop or Yield prior to a crossing and stop bars signalizing where to stop. Appropriate devices are described in the MUTCD. It is federal law that signs are provide at all crossings. Typically, the crossbucks and corresponding signing are provided and maintained by the railroad, whereas any additional signing and pavement markings are installed and maintained by the DOT.

Active traffic control devices include those that give advance notice of the approach of a train. These include flashing light signals, gates, non-mountable curb islands with escape zones, warning bells, etc. They have been proven as an effective method of improving safety and operations at highway-rail grade crossings. This is based off of the percentage reduction in collisions due to a crossing improvement. There are some low-cost active devices that can be used at crossings that lack active traffic control devices. Some of these technologies include video imagery, radar, and fiber optic system

Success Factors in the Reduction of Highway-Rail Grade Crossing Incidents

Summary: In the past 20 years, the Federal Railroad Administration (FRA) noticed a large decrease in highway-rail collisions, despite an increase in both vehicle and train traffic. The FRA states that collisions at grade crossings decreased approximately 65 percent, fatalities by 63 percent and injuries by 65 percent. The corresponding research determined 11 safety factors that contributed to the reduction incidents. These factors include:

1. Commercial Driver Safety – Additional legislation put emphasis into increasing the safety of commercial drivers.
2. Locomotive Conspicuity – By making the locomotive easier to see, motorists are able to better judge the distance and speed of the oncoming train.
3. More Reliable Motor Vehicles – Reduced the possibility of breaking down at grade crossings.
4. Sight Lines Clearance – Providing adequate sight distance allows motorists to observe the tracks further away stop safely, therefore reducing the risk of collision.
5. Grade Crossing Maintenance – Additional maintenance inspection and testing at active crossing warning systems reduce the risk of warning device failure.
6. Freight Car Reflectorization – Additional retroreflective sheeting on the sides of freight cars and locomotives increase visibility of the entire train.
7. Pedestrian Safety – Additional devices and technologies installed at crossings increase protection of pedestrians at the crossing.
8. Crossing Closure and Grade Separation – Removal or separation of an at-grade crossing reduces the risk of collision to nearly zero.
9. Warning Device Upgrades – Upgrading the warning devices at grade crossings increases their effectiveness and reduces the risk of incident.
10. Education and Enforcement – A proactive approach that discourages risky behavior around grade crossings.
11. Crossing Improvement Programs – A State's implementation of their own improvement plan to close, separate, and upgrade crossings.

Additional Information: Through analysis of the research, it was determined that improvements in commercial driver safety and locomotive conspicuity made the largest contributions to the reduction in incidents. Crossing closures also showed a significant impact on the reduction of incidents.

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Appendix E
Transportation Research Board Report Review

Appendix E - Review of documents prepared by the Transportation Research Board

NCHRP Report 600 Human Factors Guidelines for Road Systems - Second Edition - 2012

Key Takeaways/Summary Points: When diagnosing a grade crossing for potential improvements, consider human factors that can lead to train-vehicle collisions. Key human factor considerations include the following:

- Drivers are more likely to obey traffic control devices if they are reliable and consistent in operation.
- Traffic control devices with excessively long delays between activation and train arrival can lead to driver disobedience.
- Adequate sight distance at crossings helps motorists make good crossing decisions.

Chapter 14 - Rail-Highway Grade Crossings

- Addresses key factors found to affect driver decision about obeying traffic control devices at grade crossings.
- Driver Factors
  - Familiarity – Drivers using crossing on a regular basis are more likely to violate a traffic control device
  - Expectations – Alert drivers that the crossing is operational
  - Credibility – Only use active devices where they will provide a predictable, consistent alert
  - Reliability – Crossing devices should be reliable
- Traffic Control Devices (TCD)
  - Timing – long delay times between gate activation and train arrival decrease compliance
  - TCD selection – TCD should support time available for drivers to make go/no go decision
  - Train Speed Perception – Drivers must be able to accurately judge train speed at the crossing
  - Sight Lines – Provide adequate sight lines to support the TCD.
- Passive Crossing Locations
  - Crossbucks alone are not adequate to provide drivers needed information
  - The addition of a stop or yield sign is recommended, but a yield sign has limitations.
- Timing of Active Control Devices
  - Gate Delay and Gate Descent - Gate delay is time between start of flashing lights and start of gate descent. Gate descent is time taken for gate to fully descend.

        - As combined time increases, driver disobedience increases. Optimal time is 10-12 sec.
    - Train Delay - Time between gate descent and gate arrival
        - As delay increases, driver disobedience increases. Driver's expected delay is approximately 14 sec.
- Four Quadrant Gate Timing
    - Gates must be timed properly to eliminate entrapment
- Gate Rushing Countermeasures
    - Centerline flexible barriers
    - Four quadrant gates
    - Decreased warning times - improve credibility of warning devices

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Appendix F

APTA Rail-Highway Grade Crossing Safety Assessment

Appendix F - Review of APTA RT-RGC-RP-003-03

APTA RT-RGC-RP-003-03 – Recommended Practice for Rail Transit System Highway Rail Grade Crossing Safety Assessment

Summary: This article provides guidance for assessing the safety of new and existing rail grade crossings. An assessment is best made by forming a diagnostic review team that has experience in:

- Rail and highway traffic operations
- Rail and highway traffic engineering
- Rail and highway signals and their interconnection
- System safety
- Administration

This diagnostic team studies, reviews, and inspects the crossing's data, location, and surrounding area to determine the characteristics and factors that affect safety. During the grade crossing evaluation, the following characteristics are documented:

- Maximum speed of trains
- Number of tracks
- Number and types of trains during peak periods
- Multiple trains approaching crossing simultaneously
- Types of existing warning and traffic control devices
- Sight distances of motor vehicles
- Number of traffic lanes
- Condition of highway rail grade crossing surface
- ADT of roadway
- School bus use
- Hazmat use
- Emergency vehicle use
- Speed of vehicles over tracks
- Queuing potential across tracks
- Accident information/history
- Number of crossings in close proximity
- Nearby facilities that could generate additional vehicle and pedestrian traffic
- Geometry of highway (horizontal and vertical)
- Impact on highway/street operations
- Rail operating characteristics (braking distances)
- Rail operating rules (horn blowing or station stops)
- Signal interconnection

- Visibility of warning devices
- Switching operations

Once any potential hazards are acknowledged, recommendations to eliminate or control them should be identified and documented. The article suggests three considerations to remediate the hazards:

1. Closure or consolidation of existing crossings
2. Grade separation of existing crossings
3. Design recommendations

Design recommendations can include:

- Improve sight distance
- Raised median or divider
- Signage
- Pavement markings
- Curbs
- Improve roadway surface
- Realign highway
- Improve approach grade of roadway
- Illuminate crossing
- Improve crossing surface
- Rehabilitation of highway or track; including drainage
- Installation of active traffic control and warning devices

Implementation of the recommendations are to be done prior to operation of the crossing and included into the project safety certification process. In addition, the following programs and procedures should be implemented into the rail grade crossing system safety program plan:

- Operating and maintenance procedures
- Training programs
- Safety education programs
- Law enforcement programs

A follow-up should be completed soon after a grade crossing has been installed or improved. This is to ensure that the recommendations were implemented in accordance with the proposed design. In addition, the grade crossing inventory should be updated to include the new features.

Finally, periodic reviews of new and existing crossings should be done on a regular basis. The review should focus on factors that may have changed or are emerging so that new hazards can be mitigated. These reviews should also be done after the following occurs:

- Changes in safety factors
- System expansion
- Accidents and near misses