Using *Railroad-DOT Mitigation Strategies* Case Study

SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Photos courtesy: Arkansas State Highway & Transportation Department, Missouri DOT, Oregon DOT, and FHWA

Improving Grade Crossing Safety Using Predictive Analytics and New Technologies

In 2017, the Federal Railroad Administration (FRA) reported that 2,105 collisions occurred between vehicles and trains at grade crossings in the United States, with 274 fatalities and 807 injuries. Overall, 94 percent of all rail-related fatalities and injuries occur at railroad crossings or are due to trespassing. Sadly, many of these deaths and injuries were preventable.

Although the number of fatalities has been reduced by 60 percent over the last two decades, FRA, the Federal Highway Administration (FHWA), state departments of transportation (DOTs), and the nation's railroads are continually seeking new ways to prevent these types of incidents. This case study looks at two different types of technologies that may go a long way towards achieving this goal.

The first is a pilot project being undertaken by the North Carolina DOT (NCDOT) that uses a radar-based highway vehicle detection system at grade crossings. The second is a grade crossing module and assessment process used by Union Pacific Railroad (UPRR).

North Carolina Looks at New Grade Crossing Technologies

North Carolina has seen a reduction in fatalities at gated crossings over time but crashes continue to occur. As a result, the NCDOT wanted to investigate if the use of dynamic gate operations could reduce these casualties and the violations that were occurring when vehicles, pedestrians, or bicyclists attempted to go around the crossing gates.

What are *Railroad-DOT Mitigation Strategies* (R16)?

Thousands of highway projects intersect with railroad crossings. By using the tools included in ***Railroad-DOT Mitigation Strategies*** (R16), public agencies and railroads can identify and work through possible sources of conflict and develop agreements to advance these projects in a timely manner.

This product was developed through the second Strategic Highway Research Program (SHRP2) and takes a collaborative approach to identifying strategies to improve performance. It includes case studies of best practices in developing master agreements, Section 130 program implementation, and working with railroads on design-build projects. An online Innovation Library houses examples from state departments of transportation and several Class 1 railroads of manuals, agreements, and other materials.

A Community of Interest was formed with 20 states and several railroads and short lines, as well as relevant federal agencies, to share best practices and identify common problem areas.

Four-quadrant gates are an active warning system that that consists of entry and exit gates that control and block road users on all lanes entering and exiting the grade crossing. They are used to discourage motorists from running around lowered gates. North Carolina has approximately 95 of these four-quadrant gates, primarily along the higher-speed rail corridors, which also provide Amtrak services.

As train traffic volumes as well as speeds increase, the risk for collisions at highway-rail grade crossings increases due to a smaller window of response, longer stopping distances, and more train momentum. The safest solution is either closing the crossing or separating the rail and roadway completely, but in many cases site constraints or cost do not enable these solutions. Instead, four-quadrant gates can be used as an alternate to deter motorists from driving around active entrance gates, effectively sealing a crossing while it is active.[1]

In North Carolina where four-quadrant gates are in operation, once a train is detected, the entry gate will begin its descent first and then at a predefined set interval, the exit gate will begin its descent. This offset will range from 7 to 12 seconds, and, statistically, these four-quadrant gate installations have shown to reduce lane running violations by 84 percent.

Crashes at these and other types of crossings continue to occur, however. Although the number of incidents at highway-rail grade crossings in North Carolina has decreased steadily throughout the last decade, in 2016 the 43 incidents that did occur resulted in seven fatalities.

Looking at New Technologies to Address the Problem

Installation of external communication box (above) and finished radar installation (right).

Photos courtesy NCDOT

Richard E. Mullinax is the rail signals manager for the NCDOT Rail Division. In a recent webinar sponsored by FHWA and the American Association of State Highway and Transportation Officials (AASHTO) for state DOTs and railroads, he said, "We decided we would look at dynamic gate operations as a way to prevent these violations. This would allow us to drop all four gates simultaneously, sealing the crossing sooner by 12 seconds, while providing a barrier that would strongly discourage drivers to race around the gates. However, without some type of vehicle detection system controlling the exit gate descent when they're dropping simultaneously, there is an increased likelihood of vehicles getting caught between the gates."

[1] *Evaluation of Radar-Based Vehicle Detection System at Four Quadrant Gated Highway-Rail Crossings*, by Daniel J. Findley, PhD. PE, and Daniel G. Coble. Institute for Transportation Research and Education, North Carolina State University, March 20, 2017

NCDOT sought out a dynamic gate detection system that would reliably detect highway vehicles and, at the same time, if a vehicle was detected within the crossing, keep an exit gate open to allow the vehicle to exit the crossing prior to the train entering the crossing. NCDOT evaluated several different options, selecting Island Radar's Dual Radar Train Detection System, SmartSensor-Rail Radar, with video recording capabilities as the best fit.

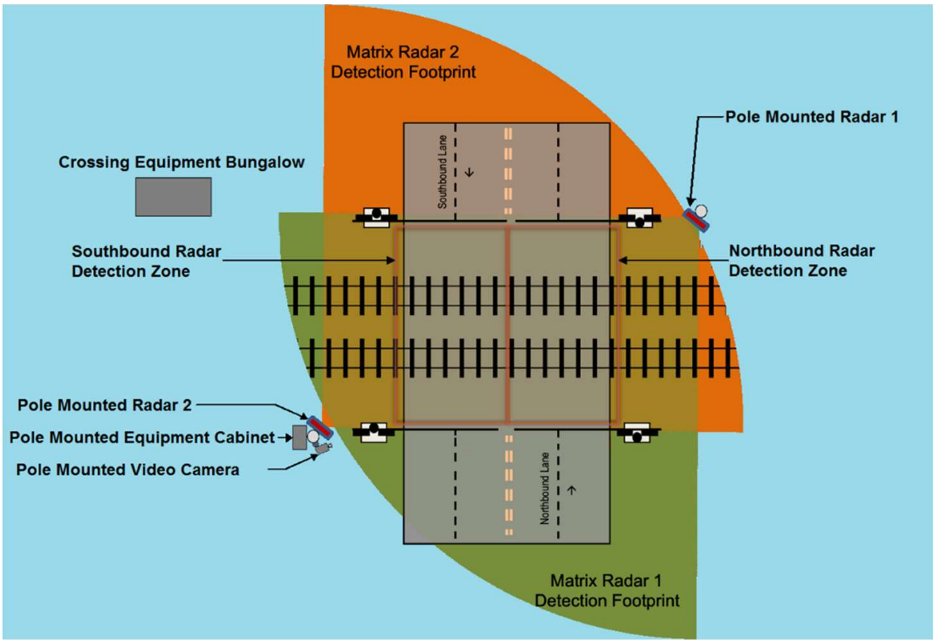
"The system detection would be completely out of the pavement, so any track and surface work would have minimal impact to the system operations and its detection capabilities," Mullinax said.

"The system would not rely on pavement quality, especially in an environment where train and motor vehicle traffic movements could cause pavement shifting."

As part of the project, seven radar systems were installed at four-quadrant locations along the H line, between Salisbury and Durham, North Carolina. Between 14 to 22 freight train movements and six- to eight-passenger trains travel along this line each day, including Norfolk Southern (NS) and Amtrak. NCDOT owns, operates, and maintains the radar systems, while NS operates and maintains the crossing signal warning systems. The first three locations were activated in March 2014, and the next four locations between February and April 2016.

How It Works

Crossings with the radar systems are composed of three major components: the radar system, the highway traffic signal system, and the crossing signal system. Each major component has its own independent ground, with the radar system sharing a power source with highway traffic signal and the crossing signal system having its own independent power source.



Vehicle Detection System from Island Radar
Courtesy NCDOT

At right is a schematic of the radar system layout. The orange and green colors show the footprint of each of the radar unit's detection. The overlapping colored area, which is within the crossing between the gates and extending just beyond the edges of the pavement, is where the radar system is programmed to continuously check to make sure that each radar unit is seeing the same thing as the other one.

When a train approaching the crossing is detected by the crossing signal system, the crossing signal system sends a notification to both the radar system and the highway traffic signal system. If a vehicle is detected by the radar system within the detection zone, the radar system will communicate back to the crossing signal system, at which point the crossing signal system would in theory either raise the exit gate or keep the exit gate in an upright position to maintain a clear route off the tracks for the vehicle. Each crossing can have up to four detection zones.

In North Carolina, the radar systems provide recording capability as an enhanced feature. Currently, a video clip is stored of every train activation at the crossing and is available for download and analysis, as necessary. The clips start about 30 seconds prior to the train entering the crossing approaches and are used to evaluate the radar system performance and to analyze and observe motorists' behaviors. When requested, video clips are also shared with the railroad to help them diagnose malfunctions that are called in by the public. At the top of each of the video clips, a system status bar is provided that has indications that light up at various stages and are used to provide a visual verification of the performance of the radar system inputs.

As an additional feature in North Carolina, the systems are set up to send email alerts to the equipment vendor and the research team evaluating the system whenever an atypical movement occurs, such as whenever a vehicle violates the crossing warning devices by entering the crossing after the warning device has been activated, which is relatively frequent.

The crossing signal system, consisting of gates, flashing lights, and bells, has its own backup power supply, so they can continue to function without power. Similarly, the radar system has a 12-hour, backup power supply.

Insight into Driver and Pedestrian Behavior

Mullinax said that the videos provided some insight into driver and pedestrian behaviors at grade crossings.

Below left, a person walks a dog between the gates as a passenger train travelling up to 79 miles per hour is arriving at the crossing.

Below right, a pedestrian runs across the tracks as an Amtrak train is entering the crossing. One of the detection sensors lit up red capturing the presence of the pedestrian.

Images courtesy NCDOT

Who Owns the Equipment and How Much Did It Cost?

The railroads own and maintain the gates, the flashing lights, bells, and the train detection approach circuits as well as all components associated with the crossing signal system. NCDOT owns, operates, and maintains the radar systems as well as the traffic signal system, which are located outside the rail space in an external cabinet.

NCDOT used both state funds and FHWA grants to purchase, install, and evaluate the radar systems. Installation of the systems by the equipment vendor and subsequent analysis by North Carolina State University's Institute for Transportation Research and Education (ITRE) were funded through an FHWA Section 1103(f) grade-crossing grant (SAFETEA-LU) of $757,800.

According to Mullinax, the systems cost approximately $100,000 per location. The radar equipment itself was about $30,000. The video monitoring and the external cabinets were approximately $20,000 and the metal posts were approximately $2,000 each. NS labor, materials expenses, and researcher expenses comprise the additional costs. During the research pilot, NCDOT placed a company under contract to inspect and maintain the systems at a cost of approximately $10,000 per year.

What NCDOT Learned

Under the Code of Federal Regulations, the use of new technologies that are processor-based signal systems and subsystems requires the railroad to file either a product safety plan or an information filing with FRA. According to Mullinax, these regulations are in place to ensure the safe operation and application of new technologies in an environment where failure could have tragic consequences. NCDOT is currently working with NS and FRA to provide the required documentation needed to implement the dynamic gate operations.

In the interim, and during the pilot, the radar systems are working at the seven sites and their performance and reliability in the field are being evaluated by ITRE. Each system includes two radar units, which continuously interact with each other. Once fully implemented, if any discrepancy is noted between the radar unit inputs during dynamic gate operations, such as if one unit detects a vehicle and the other does not, the system would revert back to pretimed gate operations.

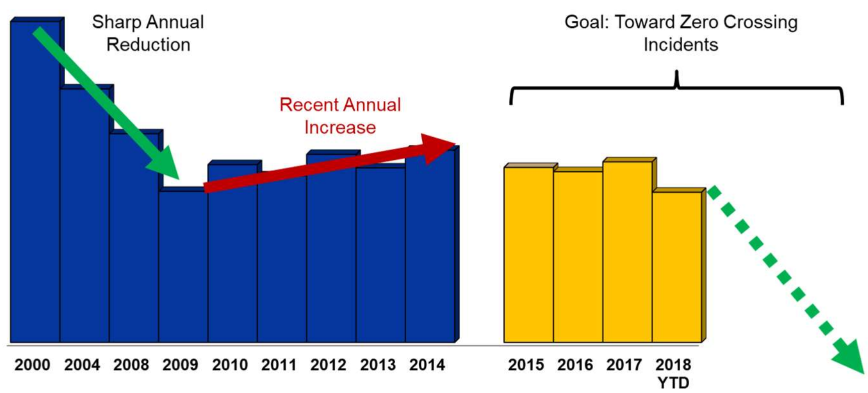
ITRE evaluated all seven sites and found the radar system to be 99.8 percent accurate, which is equivalent to the performance of inductive loop detection. The researchers and the vendor continue to monitor the systems, which, at present, continue to function accurately and reliably including during multiple extreme weather events such as ice, snow, high humidity, and heavy wind gusts and rain associated with hurricane-like conditions. Mullinax said he anticipates safety benefits from the radar systems once the dynamic gate operations are implemented, both for addressing crossing violations and for the railroads that can use the video clips to enhance their maintenance operations.

Resources: Matthew Simmons, Manager of Rail Design & Construction, NCDOT, mbsimmons@ncdot.gov
Webinar: Improving Grade Crossing Safety using Predictive Analytics and New Technology, November 7, 2018:
http://shrp2.transportation.org/Documents/Renewal/SHRP2%20R16%20Webinar%20-%20Improving%20Grade%20Crossing%20Safety.pdf
Evaluation of Radar-Based Vehicle Detection System at Four Quadrant Gated Highway-Rail Crossings, Daniel J. Findley, PhD. PE, and Daniel G. Coble, Institute for Transportation Research and Education, North Carolina State University
http://shrp2.transportation.org/Documents/R16_Innovation_Library/NC_DOT/NCSU-ITE+Eval+of+VDS+at+Crossings.pdf

Union Pacific's Crossing Assessment Process

Union Pacific Railroad (UPRR) is working hard to reduce incidents at grade crossings towards a goal of zero crossing incidents. According to Paul D. Rathgeber, UPRR's director of industry and public projects, "We believe very strongly that everyone has an equal part to play in crossing safety. As long as crossings are maintained properly, they are set up for a driver to cross safely. The vast majority of incidents are attributed to driver behavior.

"To date, efforts to improve crossing safety have been extremely successful in reducing the number of grade crossing incidents. From 2000 to 2009, we saw an 80 percent reduction in incidents, but from 2010 until 2018 we have seen this trend flatten off and rise in some instances," Rathgeber said in a recent FHWA/AASHTO-sponsored webinar.



All tables courtesy of UPRR

Crossing Assessment Model

As a result, UPRR has developed a "Crossing Assessment Program Model," a zero-inflated regression model that correlates past incidents with crossing characteristics to understand activities at their crossings. The model does not predict which crossing is going to have an accident; nor does it rank the crossings. Instead, it identifies which statistically relevant factors have an impact on frequency or severity of incidents, and which crossings have those factors.

The model uses data on incidents across a five-year period and analyzes a multitude of recorded data such as statistics and inventory data, correlating them with characteristics at the crossings.

The process is as follows:

- UPRR inputs all available data on the five-year incident history and the crossing attributes for all at-grade vehicular crossings.
- The model analyzes the period's data to identify which factors are statistically significant.
- The model groups crossings into tiers, with Tier 1 crossings having more statistically significant factors.
- Tier 1 and 2 crossings may not have experienced any actual incidents in the data history, but the risk for them is determined based on incidents at other crossings with similar attributes.

More than 30 data categories were initially included. The model determined that eight were relevant for frequency; five for severity. Data included in the Frequency Model Significant Factors include most restrictive warning devices, preemptive crossings, daily traffic counts and total train counts, minimum typical speed, vehicle-on-track event counts, unsafe-motorist event counts, and rough-crossing event counts. The Severity Model Significant Factors include daily traffic counts, total train counts, vehicle-on-track event counts, unsafe-motorist event counts, and rough-crossing event counts. The model can be adjusted to add any new data source that becomes available.

Frequency Model Significant Factors

#	Frequency variable name	Count Model *Public*	Count Model *Private*	Zero Inflated Model *Public*	Zero Inflated Model *Private*
1	Most restrictive warning device	✓	✓		
2	Preemptive crossing	✓			
3	Daily traffic count	✓	✓		
4	Total train count	✓		✓	
5	Minimum typical speed			✓	✓
6	Vehicle on track event count	✓	✓	✓	
7	Unsafe motorist event count	✓		✓	✓
8	Rough crossing event count			✓	

Severity Model Significant Factors

#	Severity variable name	Significant in public model	Significant in private model
1	Daily traffic count	✓	✓
2	Total train count	✓	✓
3	Vehicle on track event count	✓	✓
4	Unsafe motorist event count	✓	✓
5	Rough crossing event count	✓	✓

Tier 1 crossings may have no reported incidents; however, since they contain several of these factors, they will be included for further assessment. More than 98 percent of the Tier 1 sites were already equipped with active monitoring devices at the time of the initial model assessment.

UPRR ran the model with data for 30,000 at-grade road crossings, excluding grade separations and pedestrian-only crossings. Rathgeber said UPRR quickly recognized that if it focused on Tiers 1 and 2 crossings – or about 1,700 crossings – it could assess about 30 percent of the predicted incidents. "This is 5.5 percent of our total crossings and it gives us a way to focus on areas where enhancements can have a higher impact," he said.

The modeling was just one part of the overall diagnostic assessment conducted by UPRR. For this effort, the modeling outputs, UPRR's call center data, local interviews, and crossing inventory are reviewed and time-of-day and other charts are created to help digest the data. Items from the call center that are reviewed are signal trouble tickets that indicate issues with the signal systems, unsafe motorist reports, blocked crossing reports, and vehicles-on-track reports. The railroad also determines if any issues occur in a particular month or quarter, or at a particular time of day. For example, if more events occur between 8 PM and 10 PM, the railroad would hold the subsequent diagnostic inspection at that time of day.

Once on site, assessors trained in traffic and railroad engineering complete an inspection to ensure standards are met. If standards are not met, immediate action is taken. If standards are met, assessors drive and walk all approaches, and observe motorist behavior from an inconspicuous location. If the location has interconnected signals, assessors will ensure a train event is witnessed, to observe the timing and phasing of the pre-emption. This onsite assessment is combined with the collected data and an observation statement is created. A recommendation is made for each item in the observation statement.

Often the recommendations are as simple as refreshed pavement markings, signage, and better enforcement.

"Clearly, however, if the majority of incidents are still occurring at crossings that are equipped with active warning devices, we'll need the cooperation of our roadway partners and drivers to achieve our goal," Rathgeber added.

How This Process Worked in Colorado

Colorado has 1,500 miles of track and 658 public at-grade crossings used by several railroads, including UPRR, BNSF Railway, Amtrak, Denver's Regional Transportation District, and Great Northwestern Railroad. Up to 55 trains travel each day on one-to-eight different tracks with highway crossings that vary from one-to-six lanes of traffic, and the maximum train speeds are up to 70 miles per hour.

In assessing the crossings, UPRR identified one Tier 1 crossing at Havana Street in Denver, and 20 Tier 2s in Denver, Aurora, Lucerne, Florence, Colorado Springs, and Castle Rock. Using the model and subsequent assessments, several recommendations were developed. Many are being implemented, with the cooperation of the road authorities, including adding "Do Not Stop on Tracks" signage, refreshing line marketing, adding vehicle detection systems, targeting enforcement, and suggesting interchange reconfigurations.

Successes in California

In another instance in Fairfield, California, a field inspection found improper cueing of the crossing. The site saw 11,000 cars a day, with a history of 25 vehicle-on-track reports. These reports indicate that a vehicle either became stuck on the track, or drove off the road at the crossing, becoming stuck. The data indicated that vehicles were turning between the tracks and the visual inspection noted that the right turn arrow seemed to be directing motorists onto the track instead of across it before turning right.

In cooperation with the UPRR program, the road authorities agreed to add edge lines, changed the location of right-turn arrow pavement markings, and replaced delineators. After the enhancements, which were completed in December 2015, one vehicle stalled on the track; another inattentive driver drove off the edge of the crossing and became stuck. No further incidents or collisions took place where the data showed that, based on the past history and with no enhancement, another 30 accidents could have been expected.

"We want to use our model to help us predict rather than react to past accidents and not focus on the chaos theory to figure out where is the data telling us that we need to go. We are exploring adding proximity data to show where liquor stores and sporting venues and things like that are in correlation to the road crossing to see if that has any impact on the model," Rathgeber said.

UPRR can run the model state-by-state and can provide the analysis to those states that may want to include it in their state program reviews. UPRR is also willing to share this tool with other railroads.

"We have presented the model and the process in a fairly high level of detail with other railroads and to several state DOTs. We are happy to share the details of the model and the algorithms both to the public agencies and the other Class 1s," Rathgeber said, adding that Oregon is now using the model for Section 130 reviews.

Contact:	Paul D. Rathgeber, Director of Industry and Public Projects, UPRR, paulrathgeber@up.com *Improving Grade Crossing Safety using Predictive Analytics and New Technology*, November 7, 2018, http://shrp2.transportation.org/Documents/Renewal/SHRP2%20R16%20Webinar%20-%20Improving%20Grade%20Crossing%20Safety.pdf