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Effects of In-Pavement Lights on Driver Compliance with Grade Crossing Safety Equipment

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13. ABSTRACT (Maximum 200 words)

The U.S. Department of Transportation's (DOT) John A. Volpe National Transportation Systems Center, under the direction of DOT's Federal Railroad Administration (FRA), Office of Research, Development and Technology, evaluated the effectiveness of in-pavement lights in improving driver compliance with grade crossing safety signals. In-pavement lights were installed at a grade crossing in Elk City, Oklahoma. This crossing had flashing lights but not gates. Data was collected for 6 months before and after the lights were installed. Results indicated a slight reduction in violations occurring in excess of 5 seconds after the signals were activated, from an average of 0.314 violations per activation before the lights were installed, to 0.288 after the lights were installed. Additionally, post-train violations also slightly declined, from 81.20 percent of lead vehicles in each lane crossing before the signals were deactivated to 75.45 percent. Though these results seem to indicate that this safety enhancement is somewhat effective in improving driver compliance with the grade crossing signals, note that this study only provides results from one unique crossing. Additional field testing is necessary before recommendations for wider use can be made.

14. SUBJECT TERMS

Highway-rail, grade crossing, pedestrian behavior, trespass, enhancement, safety, in-pavement lights, violations

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Executive Summary

The John A. Volpe National Transportation Systems Center was tasked by the Federal Railroad Administration Office of Research, Development and Technology with evaluating the effectiveness of an in-pavement lighting system in enhancing driver compliance with existing grade crossing safety equipment. Researchers deployed the system at a Farmrail grade crossing on East 7th Street in Elk City, Oklahoma (Crossing ID 597456M). This crossing had flashing lights but no gates. East 7th Street is a four-lane road with a posted speed limit of 35 mph.

To evaluate the effectiveness of the in-pavement lights, researchers collected video data at the grade crossing prior to deployment from September 2016 through April 2017. They deployed the system in September 2017, and collected post-deployment video data from September 2017 through April 2018. They also deployed a TRAFx magnetometer adjacent to the tracks nearby, which recorded the date and time of each train that passed. This enabled the data analysis team to know when safety equipment activations occurred, saving a great deal of time by not having to comb through the video searching for crossing events.

When the grade crossing safety equipment was activated, the in-pavement lights (which were red light-emitting diodes) flashed on and off for the first 5 seconds, then remained steady red until the signals were deactivated.

The analysis showed that for each signal activation prior to deployment of the in-pavement lights, an average of 0.314 drivers who reached the crossing more than 5 seconds after initial activation violated the crossing. After the in-pavement lights were installed, this number fell to 0.288 violations per activation, an 8.4 percent decrease.

These results indicate that this in-pavement lighting system was marginally effective in reducing the likelihood that a driver will violate the active safety equipment. It should also be noted that there are other commercially available in-pavement lighting systems, and their effectiveness has not yet been tested.

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe) provides technical support to the Federal Railroad Administration (FRA) on all aspects of grade crossing safety and trespass prevention research. This support includes key research associated with all aspects of the railroad rights-of-way (ROW), including the highway-rail intersections (HRI) and trespass issues.

In 2017, there were 824 rail-related fatalities in the U.S.[1] Approximately 95 percent resulted from grade crossing collisions and trespass incidents. Of the fatalities, 273 resulted from grade crossing collisions and 512 resulted from trespass incidents. (These figures do not include suicide fatalities.)

The FRA Office of Research, Development and Technology (RD&T) tasked Volpe with evaluating the effectiveness in-pavement lighting systems in improving driver compliance with grade crossing safety equipment. Crossings not equipped with gate arms are considered particularly good candidates for this technology because the lights would provide the same type of visible alert across the roadway as that provided by lighted gates.

1.1 Background

In 2017, there were 2,117 collisions between vehicles and trains at highway-railroad grade crossings, resulting in 273 deaths and 833 injuries.[1] While these numbers have held relatively constant in recent years, grade crossing deaths represent about one-third of all rail-related fatalities (excluding suicides).

While most grade crossings in the U.S. have gates, those with low vehicle or rail traffic often do not. Many have lights and bells only, and others (usually in rural, lightly trafficked areas) have only warning signs. FRA is interested in testing the effectiveness of in-pavement lights in reducing collisions between trains and highway vehicles. These lights are often used at crosswalks to alert drivers to pedestrians. The FRA tasked Volpe with conducting a study to test a system at a grade crossing and measure the changes in driver compliance.

1.1.1 Past Research

In May 2015, the Federal Highway Administration (FHWA) sponsored a study by the Los Angeles County Metropolitan Transportation Authority (LA Metro) to evaluate the effectiveness of in-roadway lights to reduce the frequency of left-turn violations. In this application, transit trolleys travel along the median of a divided roadway, and passenger vehicles that make illegal left turns create hazardous conditions. Results, although limited, indicated the lights were

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[1] Obtained from the FRA Office of Safety Analysis website on September 24, 2018: https://safetydata.fra.dot.gov/OfficeofSafety/default.aspx

effective in reducing left-turn violations.[2] However, this application is very different from the heavy rail highway grade crossing application being studied in this effort.

In April 1998, FHWA and the State of California Office of Traffic Safety sponsored a study of the effectiveness of in-pavement lights in alerting drivers to the presence of pedestrians in crosswalks.[3] This study also found the lights to be highly effective, but this application differed in that pedestrians are often difficult to see, especially at night or in congested areas. The current study looks at improvements in compliance to the existing flashing lights and bells that already exist at most grade crossings.

In-pavement lights have rarely been used in heavy rail applications. Two such deployments were at Rosecrans Avenue in Paramount, California and at North Milwaukee Street in Boise, Idaho. However, they were not independently studied and the systems are no longer in operation.

1.1.2 Approach

The Volpe Center surveyed railroads to see if they were planning to install in-pavement lights. Volpe found that while several streetcar transit operators had plans to deploy in-pavement lights, no freight or heavy rail operators had any such plans. FRA agreed to provide funding to deploy a lighting system at a willing test site.

The Volpe Center approached several State DOTs about the project and found several with interest in finding candidate crossings. Nevada, Texas, and North Carolina showed interest, but for various reasons, either the railroad or local municipality chose to not proceed. Finally, contacts with the Oklahoma DOT yielded a cooperative railroad (Farmrail) and a cooperative municipality (Elk City, Oklahoma). Volpe engaged in a memorandum of understanding with Farmrail and the City of Elk City agreeing to install and test the lighting system at the East 7th Street grade crossing, with the intention of transferring the system to Farmrail at the conclusion of the test.

1.2 Objectives

Volpe sought to determine the effectiveness of in-pavement lights in improving driver compliance with railroad grade crossing safety equipment, and to better understand the installation and maintenance costs and requirements of the lighting system.

1.3 Overall Approach

To evaluate the effectiveness of the in-pavement lights, Volpe set up a video camera prior to their installation on September 15, 2016 to collect baseline data. The camera was located adjacent to the south shoulder of the road and attached to a Farmrail sign. This location was as far from the crossing as possible without requiring excavation of the Farmrail driveway. The

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[2] Memorandum from Lia Yim and Jonathen Hofert, LA Metro to Duane Thomas, FHWA, *Experiment 8(09)-8 (E),* September 10, 2018 http://www.dot.ca.gov/trfficops/ctcdc/docs/Final-Report-IIRPM-Los-Angeles-091018.pdf

[3] Whitlock & Weinberger Transportation, Inc. An Evaluation of a Crosswalk Warning System Utilizing In-Pavement Flashing Lights. April 1998.

objective was to view as much queueing in lanes one and two as possible; however, this location only yielded about one car length in the camera's view for these two lanes.

The DVR was an analog system that produced AVI files and recorded nonstop as long as power and video signal were present, and it had an internal battery that allowed it to record without grid power for about 3 hours. Once recording stopped, it did not restart automatically. The DVR was located inside a fiberglass enclosure affixed to the outside of the Farmrail signal bungalow. Farmrail provided the video system with 120 VAC power.

The device collected data continuously 24 hours per day through May 16, 2017, until a tornado struck Elk City, causing a long power outage that depleted the backup battery of the DVR, disabling it. However, sufficient pre-deployment data had already been collected to make statistically significant evaluations of driver compliance. In fact, only data collected through April 30, 2017 was processed.

For each train crossing event, researchers recorded all violations of the safety equipment by motorists, including the lane number and time after activation to the nearest 0.2 second, using a frame counter in the DVR. They also recorded each time a vehicle crossed the tracks after the train had passed but before the warning signals had deactivated.

In December 2016, the Volpe Center determined that detecting train crossing events on video was time-consuming and prone to missed events, so it deployed a magnetometer logger to aid in the detection. This addition proved invaluable in saving time while processing the video data.

The in-pavement lighting system was installed in September 2017. The post-deployment data collection began on September 20 and continued through April 2018. The same process for data collection and processing was used in the post-deployment process.

1.4   Scope

This study investigated the effect of in-pavement (sometimes referred to as in-roadway) lights on improving driver compliance with grade crossing safety equipment that does not include gate arms. Crossings that have gates and crossings that have no bells or lights were not studied. Also, this study was limited to a single crossing in Elk City, Oklahoma, and the results may or may not have been different had the study occurred elsewhere.

1.5   Organization of the Report

This report is organized as follows:

- Section 2 provides details about the test site
- Section 3 provides information about the in-pavement lighting system.
- Section 4 provides an overview of the data collection activities.
- Section 4.2 describes the analyses.
- Section 5 presents the results of the study.
- Section 6 is the conclusion.

2. Test Site

Elk City is located in western Oklahoma, about 100 miles west of Oklahoma City. The selected crossing is located on East 7th Street in Elk City (Crossing ID 597456M). The tracks are owned by the Oklahoma Department of Transportation and are operated by Farmrail System, Inc.

The grade crossing is a single-line track that has lights and bells, but not gates. This is due primarily to a relatively light volume of rail traffic, and the fact that trains move relatively slowly across this roadway. East 7th Street is a four-lane east-west concrete road with a posted speed limit of 35 mph, as shown in Figure 1. The crossing is adjacent to a Farmrail facility where railcars are routinely added and removed from trains.

Figure 1 – Aerial view of Elk City crossing
(Source: Google Maps)

The diagram above shows the location of the Volpe camera (bottom left), the approximate field of view (green shading), the identification of each travel lane, and the location of the stop lines. Seventh Street in Elk City serves as a bypass to the more congested 3rd Street, formerly U.S. Route 66. East 7th Street has its own exit off of Interstate 40. The Farmrail tracks in Elk City are a single-line Class II spur which terminates near Erick, Oklahoma, about 20 miles to the west. At one time these tracks were part of the Chicago, Rock Island & Pacific's main line, which paralleled U.S. Route 66 through Amarillo, Texas, but they no longer intersect any other rail lines to the west of Elk City. The tracks cross East 7th Street at a 52-degree angle, with a maximum timetable speed of 20 mph. While it primarily conducts freight rail operations, Farmrail owns several passenger cars which it uses for occasional charters and other events.

2.1 Changes in Site Conditions

Aside from the addition of the in-pavement lights, other changes occurred over time that should be noted in considering the results of this long-term test.

Commercial development has been occurring on the east end of 7th Street for several years, and this trend continued during the course of this test. While a Wal-Mart Superstore, Hobby Lobby and Hampton Inn hotel were established to the east of the crossing prior to the start of baseline data collection, two new restaurants opened during the course of the test. Some new housing was developed just east of there also. As a means of obtaining a measure of the growth in vehicular traffic on East 7th Street from one year to the next, Volpe counted all vehicles that crossed the tracks in a 24-hour period on the first Thursday in November in both 2016 and 2017 (Figure 2). In 2016, there was a total of 3,391 vehicles, and in 2017 there was a total of 3,685 vehicles—an 8.7 percent increase. While this change probably had no effect on compliance rates, it did increase the likelihood that vehicles would be present when train crossing events occurred.
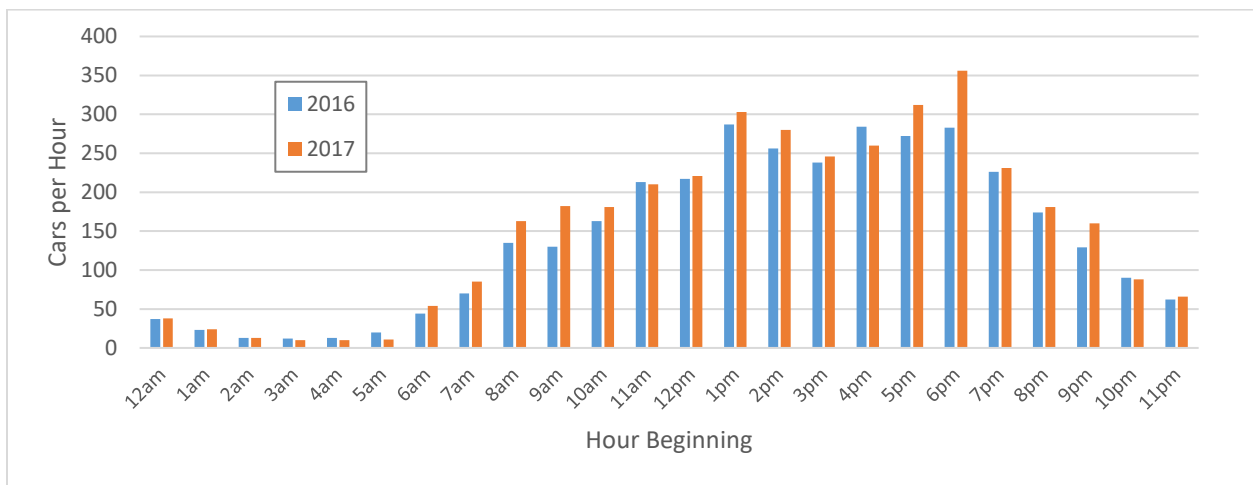
Figure 2 – Comparison of traffic volumes on East 7th Street (first Thursday in November, 2016 and 2017)

Researchers found it interesting that most of the increases in traffic occured during rush hours in the morning and late afternoon. Since there was a slightly higher level of traffic in the post-deployment phase of this task, it was more likely for vehicles to have been present during crossing events. However, this should have had no significant impact on compliance rates.

Note that rail traffic also increased between 2016 and 2017. In the pre-deployment data collection phase, there was an average of 2.21 trains per day. In the post-deployment data collection phase, there was an average of 2.79 trains per day—a 26.2 percent increase. This change too likely had no effect on driver compliance rates.

3. In-Pavement Lights

In-pavement lights have been used for several years, primarily to warn motorists of pedestrians in crosswalks. They have sometimes been used in rail applications where light rail trolleys pass through roadway intersections; however, they have not been widely used in heavy rail applications. It is for this reason that Volpe executed a procurement to have lights installed at the Elk City test site. Other municipalities and railroads have considered their use, but none were in the process of proceeding with a deployment during our test period.

Below are two photos of the in-pavement lights in Elk City. Figure 3 shows a nighttime view of the in-pavement lights, and Figure 4 shows a close-up of one of the light fixtures as embedded in the pavement.

Figure 3 – Elk City in-pavement lights, looking west

3.1   System Features

Volpe chose the Smart Crosswalk^{TM} in-roadway warning light (IRWL) system by LightGuard Systems of Santa Cruz, California. The fixtures have snowplow-resistant steel shrouds and were controlled by a panel in a weatherproof enclosure mounted to the side of the Farmrail bungalow. The lights were triggered by the Farmrail grade crossing safety system. The in-pavement lights were programmed to flash for 5 seconds when the Farmrail system was activated, and then remain steady red until the Farmrail system deactivated.

Figure 4 – Close-up of in-pavement light fixture in Elk City

The in-pavement lights were visible in daylight conditions, but there was no question they were easier to see at night. However, since Farmrail operates very few trains at night at this crossing, there were not enough grade crossing events for Volpe to make a statistically sound comparison of daytime versus nighttime driver compliance.

Upon installation in September 2017, researchers noticed the in-pavement lights only flashed for 3 seconds when activated. LightGuard sent Volpe a firmware chip to replace one in in the control unit. Once replaced in late September 2017, the flash time of the in-pavement lights was extended to 5 seconds.

The stop lines at the crossing were faded from the outset of the pre-deployment phase of this test, and became more faded over time. Researchers inquired if there was interest on the part of the City of Elk City to repaint the lines shortly after the lights were installed, but they declined. The observed effect on video seemed to be for traffic to stop far back from the stop line. This adversely affected the number of eastbound vehicles recorded as being present during grade crossing events due to limitations in the field of view. An example of the camera view is shown in Figure 5. The red car is heading eastbound. Cars stopping more than one car length from the stop bar could not be seen by the camera, and therefore were not recorded as being present during a particular crossing event. This means there were many more eastbound drivers that complied with the signals than our numbers indicate. Since this condition was essentially the same before and after the lights were installed, it likely had little effect on the comparative compliance percentages.

Figure 5 – Example of the video camera's field of view

There is a large swale on the west approach to the grade crossing on East 7th Street. Because of this, the in-pavement lights cannot be seen by eastbound drivers until they get within about 100 yards of the crossing. For this reason, the lights in the opposite lane were installed 32 feet further west than those in the eastbound lane, as shown in Figure 6. With this modification, the lights in the opposite lane were visible to drivers more than 200 yards from the crossing.

Figure 6 – Measurements of In-Pavement Light System in Elk City, Oklahoma
(Source: Google Maps)

The in-pavement lighting system was installed during the second week in September, 2017. Photos of the installation are shown below in Figure 7.

Figure 7 – Installation photos

3.2   System Cost

Volpe issued a contract with LightGuard for $62,055. Of this, $28,865 was for equipment, which included 18 plow-resistant light fixtures and a controller in a weatherproof housing. A total of

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$1,500 of the contract covered travel costs, and the balance ($31,690) was for a local contractor who installed the lighting system in the roadway.

3.3   Relevant State Laws and Federal Guidelines

Currently there are no guidelines in the FHWA Manual on Uniform Traffic Control Devices regarding in-pavement lights at grade crossings. The stakeholders of this project had a teleconference on July 20, 2017 to discuss potential options for configuring the lights. Options included wig-wag, flashing, and steady red. In the end, the team decided that for the first 5 seconds of the signal activation, the lights should flash on and off, then remain on (steady red) until the signals were deactivated. The consensus was that initial flashing for 5 seconds on activation would help bring drivers' attention to the signals, but then steady red would alleviate ambiguity about whether the driver should remain stopped or treat the flashing red lights like a stop sign, as they do in other situations.

In Oklahoma, as in most (but not all) states, drivers are instructed to stop and remain stopped at active grade crossing warning signals. The Oklahoma Driver's Manual states the following: "Always stop when the lights are flashing. Remain stopped until the train has passed. If there is more than one track, be sure all tracks are clear before crossing."[4]

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[4] Oklahoma Driver's Manual. January 2014. Chapter 5, p. 7. Accessed on September 24, 2018. Available at https://www.ok.gov/dps/documents/driver_manual.pdf.

4. Data Collection and Analysis

4.1 Data Collection Equipment

Video data was collected using an analog video camera with a wide-angle lens mounted on a Farmrail sign on the west side of the crossing, shown in Figure 8. As mentioned earlier, the camera could not be mounted further west due to a paved driveway adjacent to the sign. This proved to be a limitation because researchers observed that vehicles stopping for trains sometimes stopped more than one car length from the stop line, and were not visible to the camera. This reduced the number of vehicles counted as being present during crossings and in compliance with the signals. Those that violated the signals were, of course, visible. However, this condition was the same for the pre-deployment data set as for the post-deployment data set, so the net effect on the results is believed to be negligible.

Figure 8 – Camera Mounted on Farmrail Sign

The video was recorded on a Lawmate PV-1000 DVR set to five frames per second. The recorder had a 500 GB hard drive, enabling it to record 2–3 months before needing to be replaced. The recorder was mounted inside a weatherproof fiberglass enclosure mounted to the side of the Farmrail signal bungalow. Farmrail provided AC power for the camera and DVR. The video data collection system installed at the crossing is shown in Figure 9 below.

Figure 9 – Video Data Collection System

After reviewing the first few weeks of video, it became clear that it was a very inefficient process to search for train crossing events by using only the fast-forward function. In December 2016, Volpe deployed a TRAFx magnetometer near the crossing in Elk City. The magnetometer is essentially a metal detector. It was placed adjacent to the tracks inside a small fiberglass waterproof enclosure about 80 yards south of the roadway, which was far enough away from the road to not detect vehicles, but close enough to the tracks to detect trains. The enclosure was chained to a tree to prevent theft. The TRAFx magnetometer (Figure 10) was configured as follows:

- Period = 0
- Mode = VEH-4d
- Threshold = 012
- Delay = 016
- Rate = Slow

Figure 10 – TRAFx Magnetometer

The magnetometer proved to be very valuable in saving time while processing data. The key setting here was the period, which causes the magnetometer to collect time-stamped data for each detection. Other settings create totals per hour or day, which was not as helpful. However, there were occasional false detections (no train present), likely due to settings that were too sensitive. In April 2017, Volpe changed the settings as follows:

- Period = 0
- Mode = VEH-2s
- Threshold = 005
- Delay = 016
- Rate = Slow

These settings produced very few false detections, and most of those were attributable to nearby thunderstorms.

4.2   Data Analysis Method

The pre-deployment video dataset processed by Volpe ran from September 15, 2016 through April 30, 2017. The post-deployment video data processed by Volpe ran from September 20, 2017 through April 30, 2018. Certain crossing events deemed to be anomalies (such as trains stopping in the roadway for long periods, situations where a flagman was in the roadway, or signal activations where a train never crossed) were rare conditions and were not used in the analysis.

For each crossing event, the following information was recorded:

Pre-Train Data:
- Number of lead vehicles in each lane that stopped (did not violate the signals)

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- Number of vehicles that violated the signals in each lane
- Number of seconds that elapsed after the signals were activated when each violating vehicle crossed the tracks (to the nearest 0.2 second)

Train Data:
- Time of the signal activation
- Type of train (freight or passenger)
- Direction of travel
- Daytime or night

Post-Train Data:
- Number of lead vehicles in each lane that remained stopped (did not violate the signals)
- Number of vehicles that violated the signals in each lane
- Number of seconds that elapsed after the train exited the roadway when each vehicle crossed the tracks (to the nearest 0.2 second)

Table 1 shows the number of train crossing events that occurred in the pre-installation and post-installation periods.

Table 1 – Project Phases and Train Events

Phase	Start Date	End Date	Total Days	Number of Trains	Number of Events Not Used	Average Trains per Day
Pre-Installation	9/15/2016	4/30/2017	188	416	8	2.21
Post-Installation	9/20/2017	4/30/2018	180	503	30	2.79

Violators of the grade crossing signals were divided into two categories: pre-train violators and post-train violators. The pre-train violations were considered to be more critical because the crossing is a single-line track, so the risk of being struck by a train is far greater during the pre-train period.

For pre-train violations, vehicles in each lane were recorded as either having stopped for the warning signals or violating them. The number of lead vehicles in each lane that stopped for the signals were recorded, and the number of seconds that elapsed after the each vehicle that violated the signals was also recorded.

For post-train violations, lead vehicles in each lane that remained stopped throughout the warning signal duration were recorded, and the number of seconds that elapsed after the train passed when violators crossed the tracks was also recorded.

5. Results

5.1 Pre-Train Violations

When grade crossing warning signals are activated by an approaching train, the red lights flash and bells sound. Unlike traffic signals, which have a yellow light to indicate a red light (and a required stop) will soon occur, there is no advance warning. Volpe captured all violations of the grade crossing system regardless of how long after activation; however, in order to separate those who intended to violate from those who determined they didn't have enough time to stop, it makes sense to filter out those occurring within the first few seconds of activation. Given the site conditions at this crossing, Volpe chose to exclude all violations that occurred within the first 5 seconds of signal activation.

A total of 408 train events were assessed prior to the deployment of the in-pavement lights. There was a total of 225 pre-train violations, of which 128 occurred 5 or more seconds after the signals were first activated. This yielded an average violation rate of 31.37 percent per train event. Note that some train events had more than one violation.

In the post-deployment phase, there was a total of 473 train events assessed. There were 262 pre-train violations, with 136 occurring 5 or more seconds after signal activation, which makes for an average violation rate of 28.75 percent. This was a decrease of 2.62 percent. These numbers are shown in Figure 11.
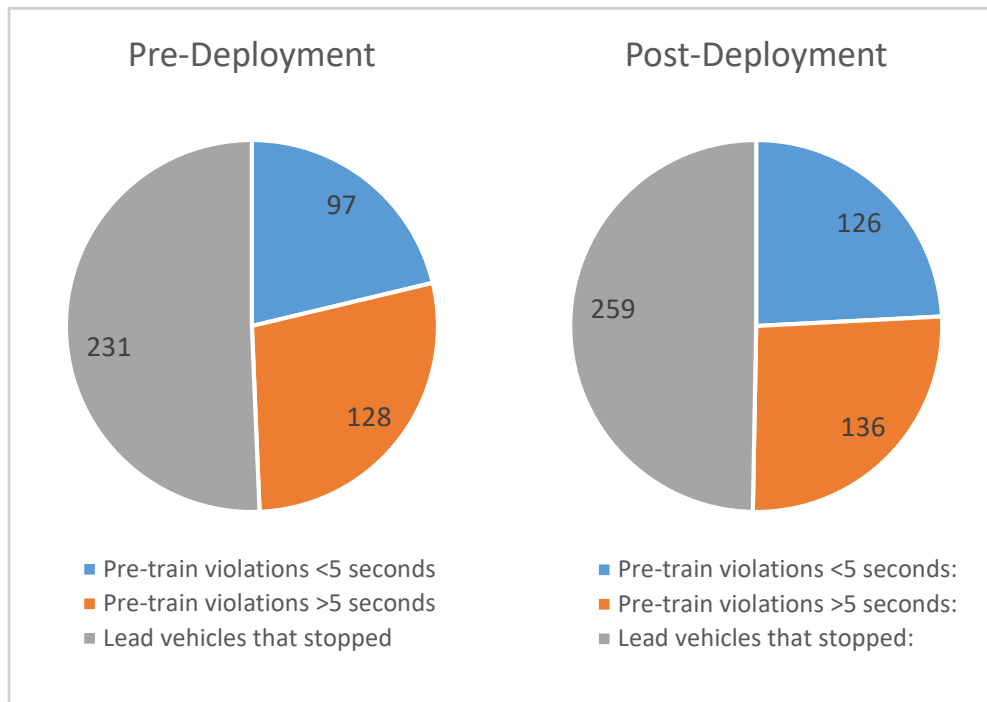

Figure 11 – Comparison of Pre- and Post-Deployment Vehicle Behavior

Next, we calculated compliance as a percentage of vehicles present. To arrive at the number of vehicle present that have the potential of violating the signals, the number of lead vehicles in each lane that stopped for the warning signals were added to the total number that did not stop. In the pre-installation phase, this number totaled 456. With 128 of these vehicles violating the signals 5 or more seconds after activation—a rate of 28.07 percent.

After the in-pavement lights were installed, the total number of vehicles present before a train arrived was 520. With 136 vehicles violating five or more seconds after signal activation, the violation rate was 26.15 percent. This was a decrease of 1.92 percent.

5.2   Post-Train Violations

For post-train violations, researchers looked at each lane individually and determined if the lead vehicle in that lane crossed the tracks before the signals were deactivated. This was because if the lead vehicle violated, the following vehicles also tended to violate. Rather than assessing the total number of violations (which are really just a measure of how much traffic is present when the train passes), we focused on the behavior of each lead vehicle.

In the 408 train events assessed prior to the installation of the in-pavement lights, there were 963 vehicles present in one of the four lanes after the train had passed. 782 of the lead vehicles in each lane violated the signals before they were deactivated, for a violation rate of 81.20 percent. In the 473 train events assessed after the lights were installed, there were 1,010 vehicles present in one of the four lanes. 762 lead vehicles violated, or 75.45 percent—a decrease of 5.75 percent.

5.3   Severity of Violations

Prior to the arrival of each train, there is a certain amount of time after the signals were activated before a train entered the roadway. During the pre-deployment phase, that time averaged 34.4 seconds, and in the post-deployment phase it averaged 33.3 seconds. Clearly, the more time that elapses between the signal activation and a vehicle crossing the tracks, the likelier it is that a collision will occur.

In Figure 12 below, the number of vehicles crossing the tracks after selected amounts of time elapsing between signal activation and vehicles crossing the tracks is shown.
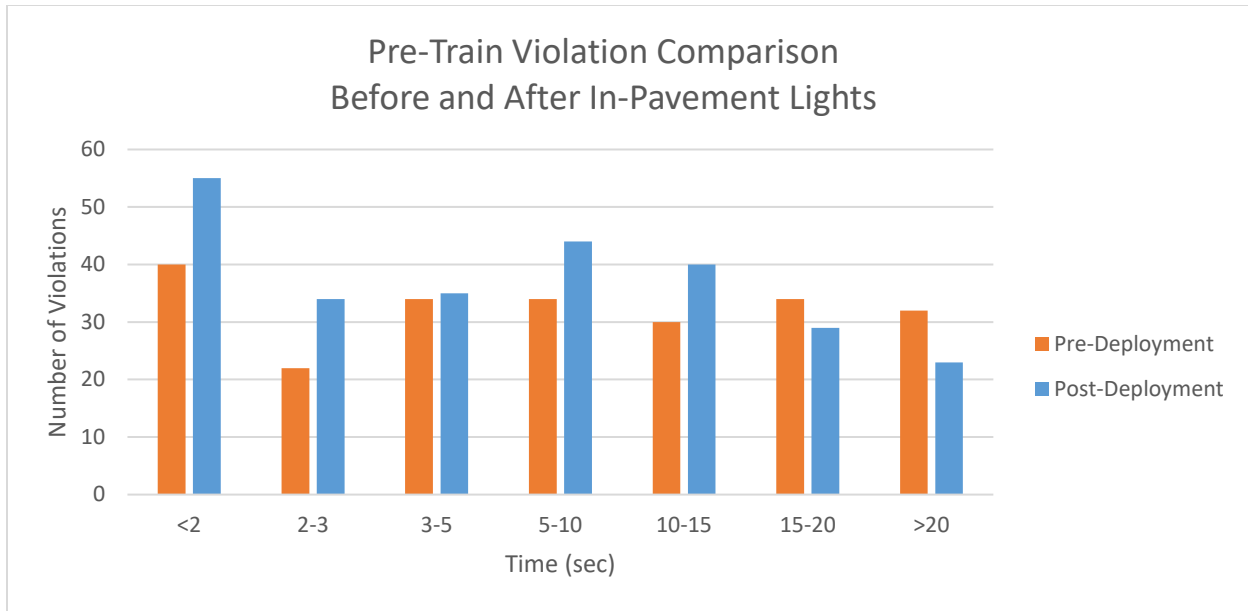
Figure 12 – Comparison of Violation Times Before and After In-Pavement Lights

Keeping in mind there was a 26.2 percent increase in the number of train events in the post-deployment phase, it was clear that the number of late violations (vehicles crossing more than 15 seconds after the signals were activated) decreased after the in-pavement lights were installed. This suggested the in-pavement lights were helpful in deterring the most dangerous types of grade crossing violations.

5.4   System Reliability and Maintenance

The LightGuard IRWL system operated continuously throughout the test period (September 2017–June 2018) without failure. However, there were two maintenance issues to note:

- A few weeks after installation, Elk City experienced heavy rains which caused a significant amount of soil to accumulate on the roadway. Some of this soil accumulated on the lights, obstructing them. After sweeping them off, they remained mostly clear, but over time they periodically become obstructed again. LightGuard stated that traffic passing over the lights should blow the dirt off them; however, the lights are situated mid-lane and between lanes, where tires rarely strike them. The lights closest to the shoulder and those on the east side of the crossing tended to accumulate the most dirt.

Figure 13 – Example of dirt accumulating on in-pavement light fixture

Although this problem was less severe in the dry season, Farmrail kept a broom on-site to keep them clean.

- On two occasions, one of the lights needed to be replaced. The first one occurred in November 2017 and was believed to be a faulty connection made during installation. The other was related to LEDs that burned out in one of the fixtures. Each light is comprised of about eight high intensity LEDs, and by June, 2018, one of the lights had lost five of them. Because the system was still under warranty, LightGuard arranged to replace the light free of charge. Two other fixtures had only lost one of the eight. Strangely, none of the fixtures on the west side of the crossing have lost any LEDs.

Figure 14 – Light with Burned out LEDs

5.5 Summary of Findings

To evaluate the effectiveness of the in-pavement lights at the East 7th Street crossing, researchers sought answers to the following questions:

- Do the in-pavement lights cause drivers to be more likely to comply with the warning signals by not crossing the tracks when they are active?

  Yes, but only marginally so. Pre-train violations in excess of 5 seconds decreased by 2.62 percent, and post-train violations decreased by 6.4 percent.

- Is the system reliable?

  Yes, but some cleaning and periodic lamp replacement can be expected.

- Is the system suitable for all weather conditions?

  We believe so; however, the winter of 2017-2018 did not produce snow or ice accumulation in Elk City, so the lights did not have to survive impacts from snow plows.

Table 2 below shows all of the data collected and calculated for this project.

Table 2 – Summary of Data

Before In-Pavement Lights			After In-Pavement Lights		
• Number of Days Processed:		188	• Number of Days Processed:		180
• Number of Activations Used		408	• Number of Activations Used:		473
• Number of Pre-Train Violations:		225	• Number of Pre-Train Violations:		262
• Number of Post-Train Violations:		1014	• Number of Post-Train Violations:		1017
• Average Pre-Train Violations per Activation:		0.55	• Average Pre-Train Violations per Activation:		0.55
• Average Post-Train Violations per Activation:		2.49	• Average Post-Train Violations per Activation:		2.15
• Number of Pre-Train Violations after 5 seconds:		128	• Number of Pre-Train Violations after 5 seconds:		136
• Average 5+ second Violations per 100 Activations:		31.37	• Average 5+ second Violations per 100 Activations:		28.75
• Number of Pre-Train events with Vehicles Present:		268	• Number of Pre-Train events with Vehicles Present:		388
• Pre-Train Lead Vehicle in Lane Stopped:	231	21.5%	• Pre-Train Lead Vehicle in Lane Stopped:	259	21.0%
• Pre-Train Lead Vehicle in Lane Violated:	210	19.6%	• Pre-Train Lead Vehicle in Lane Violated:	249	20.1%
• Number of Post-Train events with Vehicles Present:		352	• Number of Post-Train events with Vehicles Present:		388
• Post-Train Lead Vehicle in Lane did not Violate:	181	12.9%	• Post-Train Lead Vehicle in Lane did not Violate:	248	16.0%
• Post-Train Lead Vehicle in Lane Violated:	782	55.5%	• Post-Train Lead Vehicle in Lane Violated:	762	49.1%
• Total Vehicles on the first Thursday in Nov. 2016:		3391	• Total Vehicles on the first Thursday in Nov. 2017:		3685
• Average Trains per Day		2.17	• Average Trains per Day		2.63

6. Conclusion

The in-pavement lights installed in Elk City, Oklahoma caused drivers to be more compliant with grade crossing safety equipment. However, these differences were marginal, with most metrics producing single-digit percentage improvements in driver compliance. There was a more pronounced reduction in late violations (those occurring more than 15 seconds after the warning system was activated). However, it appears that the vast majority of drivers who violated the crossing signals did so intentionally, so the improved visibility of in-pavement lighting had only a marginal effect on the likelihood that motorists stop for the signals.

It should be noted that this is only one crossing in one community, and it is possible that in-pavement lights installed at another location with different conditions such as train speed, traffic patterns, grade crossing layout, etc. may produce different results. Also, Elk City has not had a fatal rail accident in the recent past, so the community may not be as sensitive to rail safety as would be others. FRA should look for other communities planning to install in-pavement lights at grade crossings to conduct a similar before-and-after study.

Abbreviations and Acronyms

Abbreviation or Acronym	Name
DVR	Digital Video Recorder
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
HRI	Highway-Rail Intersection
IRWL	In-Roadway Warning Light
LED	Light-Emitting Diode
LA Metro	Los Angeles County Metropolitan Transportation Authority
RD&T	Railroad Development and Technology
ROW	Right-of-Way
DOT	U.S. Department of Transportation
Volpe	John A. Volpe National Transportation Systems Center