U.S. Department of Transportation

Federal Railroad Administration

Effect of an Active Another Train Coming Warning System on Pedestrian Behavior at a Highway-Rail Grade Crossing

Office of Research
and Development
Washington, DC 20590

DOT/FRA/ORD-14/21

Final Report
July 2014

<table>
<tr><td colspan="3">REPORT DOCUMENTATION PAGE</td><td>Form Approved
OMB No. 0704-0188</td></tr>
<tr><td colspan="4">Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</td></tr>
<tr><td>1. AGENCY USE ONLY (Leave blank)</td><td>2. REPORT DATE
April 2014</td><td colspan="2">3. REPORT TYPE AND DATES COVERED
Technical Report
April 2012 – September 2013</td></tr>
<tr><td colspan="3">4. TITLE AND SUBTITLE
Effect of an Active Another Train Coming Warning System on Pedestrian Behavior at a Highway-Rail Grade Crossing
6. AUTHOR(S)
Scott H. Gabree, Ph.D. and Marco daSilva</td><td>5. FUNDING NUMBERS
RR97A6-LT925</td></tr>
<tr><td colspan="3">7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142</td><td>8. PERFORMING ORGANIZATION REPORT NUMBER
DOT-VNTSC-FRA-13-06</td></tr>
<tr><td colspan="3">9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
Office of Research and Development
1200 New Jersey Avenue, SE
Washington, DC 20590</td><td>10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DOT/FRA/ORD-14/21</td></tr>
<tr><td colspan="4">11. SUPPLEMENTARY NOTES
Safety of Highway-Rail Grade Crossing series</td></tr>
<tr><td colspan="3">12a. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the FRA Web site at http://www.fra.dot.gov.</td><td>12b. DISTRIBUTION CODE</td></tr>
<tr><td colspan="4">13. ABSTRACT (Maximum 200 words)
The Federal Railroad Administration (FRA) was interested in evaluating a type of grade crossing safety enhancement which alerts pedestrians at the crossing to the presence of a second train. The system chosen for this analysis, known as an Another Train Coming Warning System (ATCWS), consists of signage and an accompanying aural alert which is activated by the presence of multiple trains during gate activation. The ATCWS was installed at a crossing in Garfield, NJ, to assess the impacts of such a warning system on pedestrian behaviors during gate activations with multiple trains. Pedestrian violations were therefore tracked before and after the installation of the ATCWS. No difference was found in the number of violators during a second train activation before and after the installation of the ATCWS. However, small sample sizes and extreme weather during the data collection period indicate that further testing is necessary before strong conclusions about the effects of an ATCWS can be reached.</td></tr>
<tr><td colspan="3" rowspan="2">14. SUBJECT TERMS:
highway-rail, grade crossing, pedestrian behavior; second train, violations, enhancement, safety, Train Activations</td><td>15. NUMBER OF PAGES
33</td></tr>
<tr><td>16. PRICE CODE</td></tr>
<tr><td>17. SECURITY CLASSIFICATION OF REPORT
Unclassified</td><td>18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified</td><td>19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified</td><td>20. LIMITATION OF ABSTRACT</td></tr>
</table>

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by
ANSI Std. 239-18
298-102

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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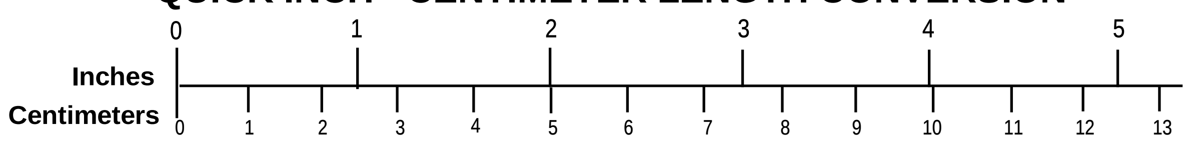

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSIO

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 6/17/98

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Acknowledgements

The U.S. Department of Transportation (U.S. DOT) Federal Railroad Administration (FRA) Office of Research and Development sponsored the work leading to this report. The authors would like to thank Sam Alibrahim, Chief of the Train Control and Communications Division, FRA, and Tarek Omar, D.Sc., Program Manager, Train Control and Communications Division, FRA, for their guidance during the project and in developing this report.

The authors would like to thank Ryan Brown, Systems Safety and Engineering Division, U.S. DOT Research and Innovative Technology Administration's John A. Volpe National Transportation Systems (Volpe Center) for his support in data collection and analysis. Additional thanks to William Baron, Security and Emergency Management Division, and Alan Kauffman of Computer Science Corporation, Volpe Center onsite contractor, for their technical support in data collection system development, installation, and maintenance.

The authors would also like to thanks Jeff Kovacs, Deputy General Manager, New Jersey (NJ) Transit Rail Safety & Training Department, and Geoff Hubbs, Chief Engineer (formerly), NJ Transit Rail Signals Department, as well as acknowledge the contributions of all NJ Transit Rail field personnel for their part in supporting this evaluation effort. Additionally, the authors wish to acknowledge Todd Hirt, Project Engineer, NJ Department of Transportation, and Lou Frangella, FRA Region I Grade Crossing Manager, for their contributions.

Executive Summary

The John A. Volpe National Transportation Systems Center (Volpe Center) was tasked by the FRA Office of Research and Development with evaluating the effectiveness of an active Another Train Coming Warning System (ATCWS) to mitigate pedestrian violations at a double track highway-rail grade crossing. Specifically, the Volpe Center was tasked to determine the effectiveness of a second train warning signage system at a New Jersey Transit Rail (NJ Transit Rail) grade crossing.

NJ Transit Rail selected a grade crossing along the Bergen County Line at Outwater Lane (grade crossing ID# 263413V) in Garfield, NJ, to pilot test the second train signage safety enhancement. The enhancement, consisting of an active visual second train sign complemented by an auditory warning, became operational on August 6, 2012. The Volpe Center research team collected video data on pedestrian movements before and after the installation to observe any changes in pedestrian behavior.

Data were collected between April 11, 2012, and May 2, 2013. A total of 438 second train events, 193 before installation and 245 after installation, were recorded during this data collection process. Overall, the percent of pedestrians who chose to violate the crossing (either while the gates were descending, horizontal, or ascending) did not change after the installation of the second train warning system. In fact, the total number of violators increased from 120 prior to the installation of the signage to 130 after the signage had been installed, though this change was not statistically significant ($Z = 0.904$, $P>0.05$). There was, however, a notable change in the number of pedestrians who violated while the gates were horizontal and crossed the tracks between the two trains. These incidents were reduced by 50 percent—from 22 prior to the signage to 11 after the signage. Equally noteworthy was the number of pedestrians who violated while the gates were horizontal and crossed the tracks prior to the arrival of Train 1. That number increased from zero prior to the installation of the signage to nine after. Though the sample size is too small to offer definitive conclusions, the findings seem to indicate that the warning system may have altered pedestrians' decisionmaking about *when* to violate (i.e., violate prior to either train arriving instead of waiting to violate between trains) and not *if* they should violate.

There are several limitations that make it difficult to conclusively determine the effectiveness of this type of warning system from the data provided in the report. First, Hurricane Sandy caused very significant changes in the schedules of the NJ Transit system in the fall of 2012. Secondly, the small sample size and changes in ridership in this data collection make it difficult to assess any differential effects that the signage has on groups. It may be possible that pedestrians in large groups will act differently than those alone at the crossing. However, the limited data collection period and variation in the number of pedestrians at the crossing (from zero to nine) made assessments of the impacts of groups difficult. Lastly, in addition to the installation of the signage and speakers, other large changes were made to the crossing during the study timeframe, including the addition of channelizing guard rails in one location and lengthening of existing guard rails in another. The actual impact of those other modifications is unknown, but does make it difficult to assess the true impact of the second train warning system alone.

Ultimately, this study does not provide any conclusive evidence that the system implemented at Outwater Lane was effective in promoting cautious pedestrian behavior. Because of the aforementioned limitations, further testing will be needed to determine the actual impact of the ATCWS.

1. Introduction

The John A. Volpe National Transportation Systems Center (Volpe Center) provides technical support to Federal Railroad Administration's (FRA) Office of Research and Development in the area of railroad infrastructure research. This support includes key research associated with all aspects of the railroad right-of-way (ROW), including the highway-rail intersection (HRI) and trespass issues. One major effort is to develop a more precise understanding of the risks presented by the railroad ROW and then determine how best to mitigate (i.e., decrease or eliminate) those risks.

The Volpe Center was tasked by FRA's Office of Research and Development with evaluating the effectiveness of an active Another Train Coming Warning System (ATCWS) to mitigate pedestrian violations at a double track highway-rail grade crossing. Situations where two trains pass through a crossing during a single gate activation may be particularly confusing or dangerous for pedestrians and drivers. A pedestrian or driver may choose to proceed after the passage of the first train, unaware of the presence of a second train, even if the grade crossing protection devices are still active.

1.1 Background

In response to a series of trespass fatalities in late 2011, the New Jersey Department of Transportation (NJDOT) Leadership Oversight Committee composed of senior State, Federal, and transit transportation officials set up an engineering subcommittee to address safety concerns at the State's rail crossings. The goal was to draw on expertise and look at best practices to develop effective and measurable strategies to improve safety along the State's rail lines. The Volpe Center participated at the request of FRA and contributed to the development of the New Jersey Safety Along Railroads Short-Term Action Plan [1] released by the NJDOT Commissioner in February 2012. As stated in the plan, the Volpe Center engineering research team was tasked with providing support to NJDOT with implementation of the engineering action items. This combined effort included a pilot program of enhanced engineering safety treatments in which an active sign warning of a second train approaching would be trialed.

1.2 Objectives

The Volpe Center was specifically tasked, according to the action plan, to determine the effectiveness of the addition of a second train warning signage system at a New Jersey Transit Rail (NJ Transit Rail) grade crossing. The purpose of this research effort is to determine if the addition of an ATCWS (depicted in Figure 1) with an auditory component will reduce the number of pedestrians who violate the crossing when two trains pass through the crossing during the same activation.

Figure 1. Another Train Coming Warning Sign and Auditory Alert Speaker

1.3 Overall Approach

To analyze the effects of the ATCWS on pedestrian behavior, video data of pedestrian actions at one crossing in Garfield, NJ were collected before and after the system was installed. The data were collected 24 hours per day although only data from second train events were analyzed.

1.4 Organization of the Report

This report is organized as follows:

- Chapter 2 provides a description of the test site location.
- Chapter 3 provides an overview of the ATCWS and data collection activities.
- Chapter 4 presents research findings.
- Chapter 5 presents the conclusions of the study.

2. Test Site Location

NJ Transit Rail selected a grade crossing along the Bergen County Line at Outwater Lane (grade crossing ID# 263413V) located in Garfield, NJ, to pilot test the second train signage safety enhancement. The crossing, shown in Figure 2, is adjacent to the NJ Transit Plauderville Train Station, which is located at the top of this depiction.

Figure 2. Outwater Lane Grade Crossing in Garfield, NJ

At the start of data collection, the crossing at Outwater Lane was already equipped with several pedestrian safety enhancements, including pedestrian gates, signage, and channelization. The four potential locations at which a pedestrian can legally cross the tracks are labeled by quadrant in Figure 3. The four potential crossing locations were not all equipped with the same safety enhancements.

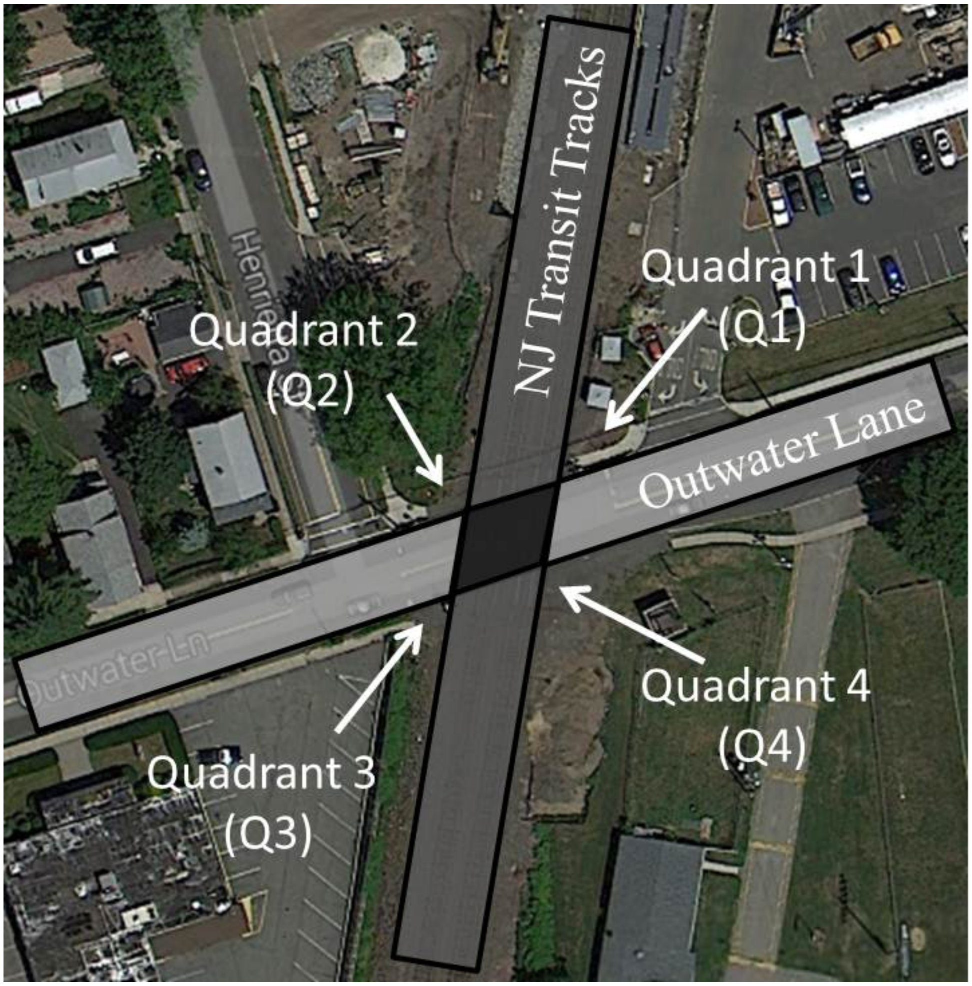

Figure 3. Outwater Lane Grade Crossing Quadrant Identification

Quadrant 1 (Q1) and Quadrant 2 (Q2) had similar safety enhancements in place at the start of the data collection. As seen in Figure 4, both Q1 and Q2 had train activated pedestrian gate signage warning pedestrians of potential train activity. Both also had fencing to prevent pedestrians from travelling to the outside of the gate.

When the pedestrian gate is in the horizontal position (fully descended), it borders a fence and blocks pedestrians from walking around the gate and outer boundary of the sidewalk. In Quadrant 3 (Q3), there were train activated pedestrian gates; however, this quadrant lacked the channelization and signage that was found in Q1 and Q2. The pedestrian gates in Q3 are depicted in Figure 5.

There were no safety enhancements installed in Quadrant 4 (Q4) at the start of the study, as seen in the left foreground of Figure 6.

Figure 4. Quadrant 1 (left) and Quadrant 2 (right) Safety Enhancements at the Start of the Study

Figure 5. Quadrant 3 Safety Enhancements at the Start of the Study

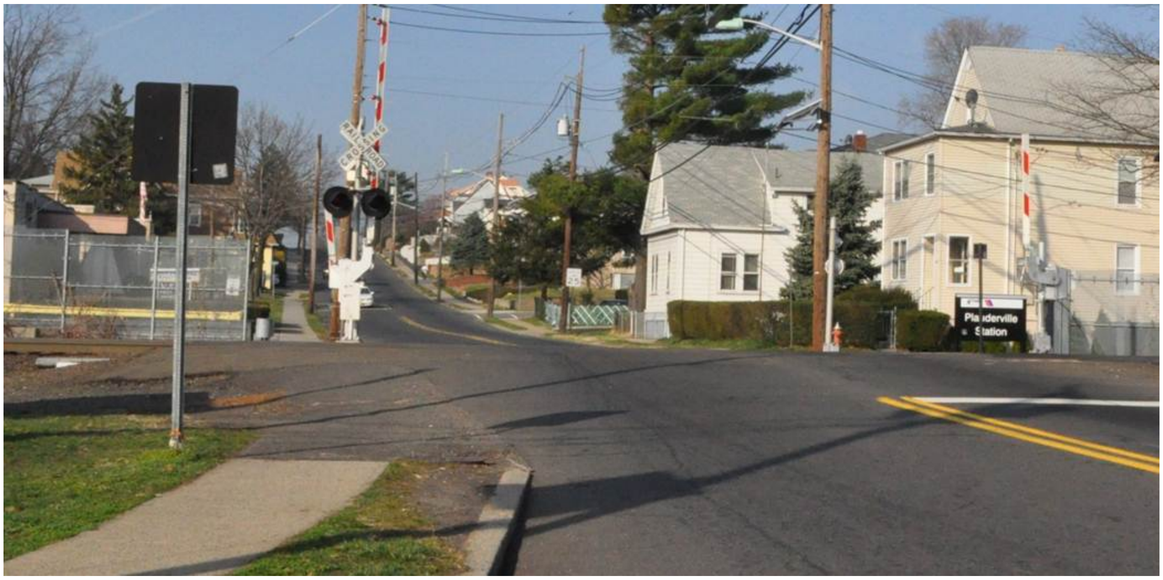

Figure 6. Quadrant 4 at the Start of the Study

Enhancements were made to both Q3 and Q4 after data collection began for this study. In August 2012, train activated pedestrian gates were added to Q4, and channelizing guard rails were added to both Q3 and Q4. These guard rails were intended to deter pedestrians from travelling around the pedestrian gates (to the outside) once the gates had descended. The extended guard rail in Q3 and the new pedestrian gate and guard rail are depicted in Figure 7.

Figure 7. Added Safety Enhancements in Quadrant 3 (left) and Quadrant 4 (right) in August 2012

Each of the safety enhancements is designed to deter pedestrians from accessing the ROW during train activations. However, it is still possible for a pedestrian to violate the crossing by bending under or going around the pedestrian gates after the gates have descended. With the Plauderville Train Station platform just north of the crossing, the amount of foot traffic was presumed to be high with pedestrians rushing to catch their train, which at times may be on the other side of the crossing. Situations in which two trains pass through the crossing during the same activation (“second train” events) may in fact be the most potentially dangerous grade crossing incident. The pedestrian safety enhancements discussed above deter pedestrians from accessing the tracks in the event of approaching trains; however, they do not provide the pedestrian with any information about the possibility that multiple trains may be approaching the crossing during the same time frame.

The Outwater Lane grade crossing has experienced six accidents between April 1977 and October 2011; the October 2011 accident involved a second train. Specifically, the narrative for the October 2011 incident (Incident No. 201110624) states, “trespasser was struck and fatally injured by Eastbound Train #1292 while crossing tracks at the Outwater Crossing after Westbound Train cleared” [2]. Though activations during which two trains pass through the crossing are not frequent, such events create potentially dangerous situations when they do occur.

3. Another Train Coming Warning System

To prevent unsafe pedestrian activity during second train events, an additional safety measure was chosen for evaluation that consists of a warning sign to alert pedestrians visually and aurally that multiple trains are approaching.

Second train approaching signs have been evaluated previously at different locations for effectiveness in reducing the risky behaviors of both drivers and pedestrians. Although the specific warning systems evaluated differed from those used in this particular study, the evaluations may still help researchers understand the expectations for the location in question as far as signage and warning system are concerned. In one case, an animated sign designed to inform drivers of approaching second trains was installed at a grade crossing in northern Baltimore County, MD [3]. This sign, which said "Warning – 2^{nd} Train Coming," also included a train animation. The animated sign was mounted above the roadway at the grade crossing and motorist behaviors were recorded and analyzed for 30 days before and after installation of the signage. The behavior most likely to be impacted (i.e., vehicles which cross the tracks after one train has cleared the crossing, but before a second train has arrived) was reduced by 32 percent (from 53 to 39 incidents), according to the study. However, this study focused on motorist behavior, which may be different from expected pedestrian behavior.

Researchers also examined the effects of an animated graphic sign (which depicted a person looking both left and right at a train) on pedestrian behavior at a grade crossing in Los Angeles County, CA [5]. A reduction in risky pedestrian behaviors was observed. Specifically, 14 percent fewer pedestrians (from 380 to 326) crossed the tracks within 15 seconds of an approaching train after the signage was installed. This reduction grew as more risky behaviors were examined: a 32 percent reduction (from 59 to 40) in pedestrians crossing within 6 seconds of an approaching train and a 73 percent reduction (from 15 to 4) in pedestrians crossing within 4 seconds of an approaching train.

3.1. Another Train Coming Warning System for Current Study

The sign chosen by NJ Transit Rail for the current study is the same type presently in use at near-station crossings along the Union Pacific West Line in the Chicago area [6]. The system, which is depicted in Figure 8, flashes the word "Danger" in red and displays "Another Train Coming" below it in bright, white Light Emitting Diode (LED) lights. Above the sign is mounted a speaker, which is also depicted at the top of Figure 8, which repeats the phrase "Danger, another train coming" in a male voice for the duration of the activation.

The addition of the warning sign and aural alert is intended to make pedestrians more aware of the second train and potentially more cautious around the crossing in general.

Figure 8. Another Train Coming Signage and Auditory Speaker

The systems were mounted at the crossing in one of two ways. In Q1 and Q3, the sign and speaker were mounted on an arm sticking out from the gate pole, onto which were mounted both the street and sidewalk gates. As seen in Figure 9, the signage in Q1 (left) and Q3 (right) was positioned directly above the pedestrian walkway.

Figure 9. Another Train Coming Signage Placement in Q1 and Q3

Placement of the signage in Q2 and Q4 was slightly different. In each of these quadrants, the sign and speaker were mounted directly to the gate post without any arm extending the signage away from the post. In these quadrants, the signage was not directly above the pedestrian walkway, but instead to the left of the walkway, as depicted in Figure 10.

Figure 10. Another Train Coming Signage Placement in Q2 and Q4

3.2. Data Collection Equipment

The data collection equipment consisted of two small video cameras connected to a digital video recorder and solar panel. Figure 11 shows the two systems, each consisting of a solar panel, camera, and box which housed the digital video recorder.

Figure 11. Solar Panel, Camera, and Box Housing the Digital Video Recorder

Inside each box was a digital video recorder that was able to record and store videos of the crossing. The digital video recorder was fully powered by the solar panel and is shown in Figure 12.

The systems were configured to record video data for 24 hours per day, although data were only analyzed when grade crossing activations occurred. Cameras (and the digital video recorder and solar panels) were installed on April 11, 2012, and data were collected through May 2, 2013. During this time, although weather-related equipment malfunctions did occur, at least one of the two cameras was always operational.

Figure 12. Digital Video Recorder

One of the two cameras was mounted to a pole located near Q1 (the pole-mounted setup is shown in the left half of Figure 11). The view from this camera captured pedestrian movements in all four quadrants; however, pedestrians approaching Q4 could not be seen. A sample of the view from the camera is provided in Figure 13.

A second camera was mounted on the fence near Q3. This camera was connected to the same type of digital video recorder and solar panel as the pole-mounted camera. This camera was also capable of capturing pedestrian movements in all four quadrants; however, the vantage point was closer to the ground. Figure 14 provides a sample view from the fence mounted camera.

Since both of the cameras were able to capture pedestrian movements in all four quadrants, only one of the two cameras was necessary for accurate data collection.

Figure 13. View from Pole Mounted Camera in Q1

Figure 14. View from Fence Mounted Camera in Q3

4. Results

Data were collected between April 11, 2012, and May 2, 2013. The ATCWS was installed at all four quadrants and activated on August 6, 2012. Baseline (pre-installation) data were collected between April 11, 2012, and August 3, 2012, while post-installation data were collected between September 7, 2012, and May 2, 2013. On October 29, 2012, Hurricane Sandy landed on the east coast of the United States causing extensive damage to the NJ Transit Rail system. The Bergen County line of the NJ Transit Rail system was not operational until November 12, 2013, at which point it resumed limited operations with below normal levels of traffic. As a result, far fewer second train incidents occurred during this time period. To correct for this, data were collected and coded during the post-installation conditions until the number of pedestrians at the crossing during a second train event was equal for both pre- and post-installation periods. Though the number of days during which data were collected differed for before and after installation, the total number of opportunities for a pedestrian to violate was equal.

4.1. Data Characteristics

A total of 438 second train events, 193 pre-installation and 245 post-installation, were recorded during this data collection and are detailed in Table 1. The weather was clear during 93 percent (406) of these second train events and raining or snowing for the remaining 7 percent (22). The majority of second train events occurred on weekdays for both the pre- (83 percent) and post-installation (78 percent) period. See Table 1 for a breakdown of second train events by weekend and weekday. Pre-installation indicates the period of time before signage was installed at the crossing (4/11/12–7/3/12) and post-installation indicates the period of time after the installation of the signage (9/7/12–5/2/13).

Table 1. Total Number of Second Train Events by Weekend and Weekday

	Weekday 2nd Train Events	Weekend 2nd Train Events	All 2nd Train Events
Pre-installation	160	33	193
Post-installation	192	53	245
TOTAL	**352**	**86**	**438**

A larger number of second train events occurred during the post-activation period (245) than during the pre-installation period(193); however, because of reduced passenger traffic during the post-installation time period, the number of potential violators (i.e., pedestrians present at the crossing during a second train activation) was equal for both pre- and post-installation conditions. Table 2 describes the number of pedestrians (n= 235) who were present at the crossing during second train activations within the pre-installation and post-installation periods. Additionally, Table 2 provides the number of pedestrians who went on to commit a violation during that second train activation. The number of violators was higher during the post-installation time period (130 violators) than during the pre-installation time period (120 violators), though this difference was not statistically significant (Z = 0.904, P > 0.05). Examples of both pre- and post-installation violations can be found in Appendix A.

Table 2. Number of Pedestrians at the Crossing and Number of Violators during Second Train Activation Events

	Number of Pedestrians Present at Crossing during 2nd Train Activations	Number of Pedestrians who Violated during 2nd Train Activations
Pre-Installation	235	120
Post-Installation	235	130

For the purposes of this study, violations were classified into three types based on when the pedestrians traversed the crossing:

- Type 1: The pedestrian traveled under the pedestrian gate as it was descending prior to the arrival of a train
- Type 2: The pedestrian traveled under the pedestrian gate after it had fully descended.
- Type 3: The pedestrian traveled under the pedestrian gate after it had initiated ascent, but had not yet completely ascended.

We predicted that a Type 1 (descending) and Type 2 (horizontal) violation were most likely to be mitigated by the addition of a second train warning sign. Type 3 (ascending) violations were less likely to be affected based on the pedestrians' knowledge that two trains had already passed through. Although the number of second train events with at least one Type 2 violator did not change from before to after activation (n =21 for both), the number of Type 1 violators went from five to zero and Type 3 violators increased marginally. See Table 3 for a breakdown of type of pre- and post-installation violation. A chi square analysis confirms that a significant change occurred in type of violation between pre- and post-installation conditions, χ^2 (2, N = 250) = 6.06, P < .05. However, the significance is mainly the result of a reduction, from five to zero, in descending violators.

Table 3. Type of Violation before and after Installation

	Descending	Horizontal	Ascending	TOTAL
Pre-installation	5	21	94	120
Post-installation	0	21	109	130
TOTAL	**5**	**42**	**203**	**250**

Although the number of Type 2 violators did not change with the activation of the second train signage, this does not necessarily indicate that the signage was ineffective at changing pedestrian behavior. The gates may be in a horizontal position for an extended period of time; thus, horizontal violations may not always take place at the same time relative to the train movements. It is possible that although the number of horizontal violators was not impacted by the signage, the time when the horizontal violation occurred may have been. One way to investigate this is to track when each violator chose to violate, in terms of the location of the two trains involved in the event. The locations of the trains were categorized into three potential train arrangements:

- The violation occurred before Train 1 had arrived at the crossing,
- The violation occurred between Train 1 and Train 2, or
- The violation occurred after Train 2 had completely passed through the crossing.

Despite an overall increase in the number of violators who violated following the activation of the second train signage, the number of violators who violated between two trains was reduced by 50 percent (22 violators before installation to 11 after installation). Table 4 shows when the pedestrians violated the crossing in relation to the location of the two trains.

Table 4. Location of Trains when the Violator Crossed before and after Installation

	Before Train 1	Between Trains	After Train 2	TOTAL
Pre-installation	4	22	94	120
Post-installation	9	11	110	130
TOTAL	**13**	**33**	**204**	**250**

Looking at Type 2 violation events, the number of violators who crossed before Train 1 jumped from zero before installation to nine after installation. Additionally, a complimentary drop of nine violations was found between Train 1 and Train 2 with 20 violations occurring before installation and 11 occurring after installation, as seen in Figure 15.

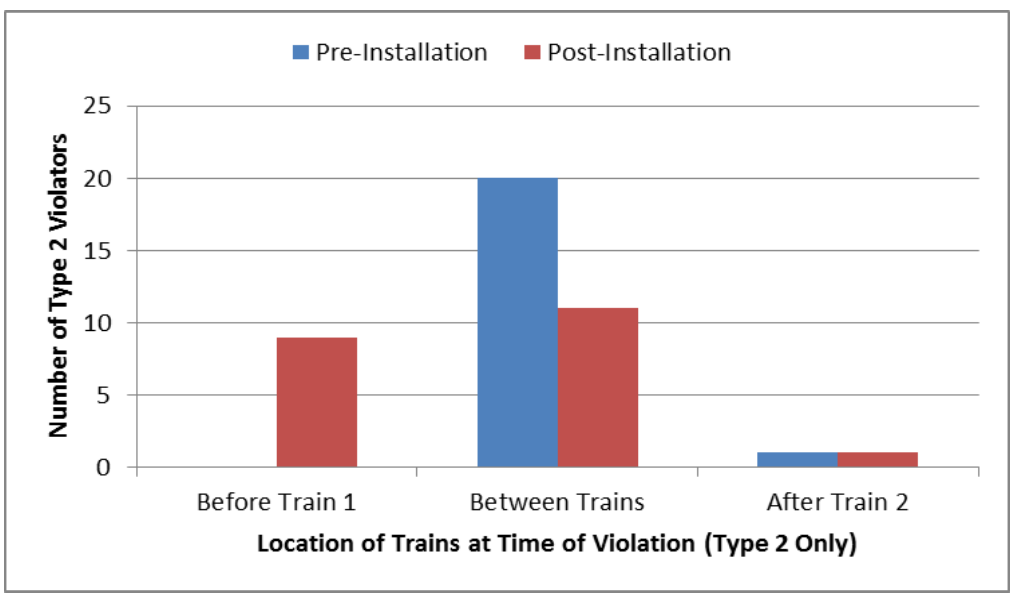

Figure 15. Number of Type 2 Violators by Location of Trains

The number of Type 2 violators who crossed after Train 2 did not change; both pre- and post-installation events had only one violator. The number of Type 2 violators who crossed before Train 1 and between Train 1 and Train 2 is almost identical, but the number of violators before Train 1 increased after the signage was installed, while violators between Train 1 and Train 2 decreased after the signage was installed. This may indicate that the signage is changing the pedestrians' decisionmaking about *when* to violate but not *if* they should violate.

To further investigate that possibility, we looked at when each violating pedestrian arrived at the crossing and when the violator crossed. If a pedestrian were to arrive at the crossing after Train 1 had already arrived at the crossing, the pedestrian would have no chance to violate prior to Train 1 (thus biasing the data). Table 5 shows the times of arrival at the crossing for only pedestrians who committed a Type 2 (horizontal) violation *between trains*.

Table 5. Time of Arrival at the Crossing Prior to Committing a Type 2 Violation between Trains

	Before Arrival of Train 1	After the Arrival of Train 1, but Before Train 1 Exited	Between Train 1 and Train 2	After the Arrival of Train 2, but Before Train 2 Exited	After Train 2 Exited
Pre-installation	8	1	12	0	0
Post-installation	11	3	7	0	0
TOTAL	**19**	**4**	**19**	**0**	**0**

Almost half (45 percent) of the individuals who violated between trains had arrived at the crossing prior to the arrival of the first train. Pedestrian arrivals prior to Train 1 were slightly higher in the post-installation condition (11 [52 percent] after installation compared with 8 [38 percent] before installation). Pedestrians, both before and after installation of the signage, may have had the opportunity to violate prior to the arrival of the first train, but many (and *all* of those in the pre-signage condition) waited until after the first train to violate. Figure 16 provides a more detailed look at the arrival patterns for *only the post-installation* condition by grouping the pedestrians into those who violated before Train 1 and those who violated between Train 1 and Train 2 (Note that arrival times after "Between Train 1 and Train 2" have been removed because no Type 2 violations occurred during these times.).

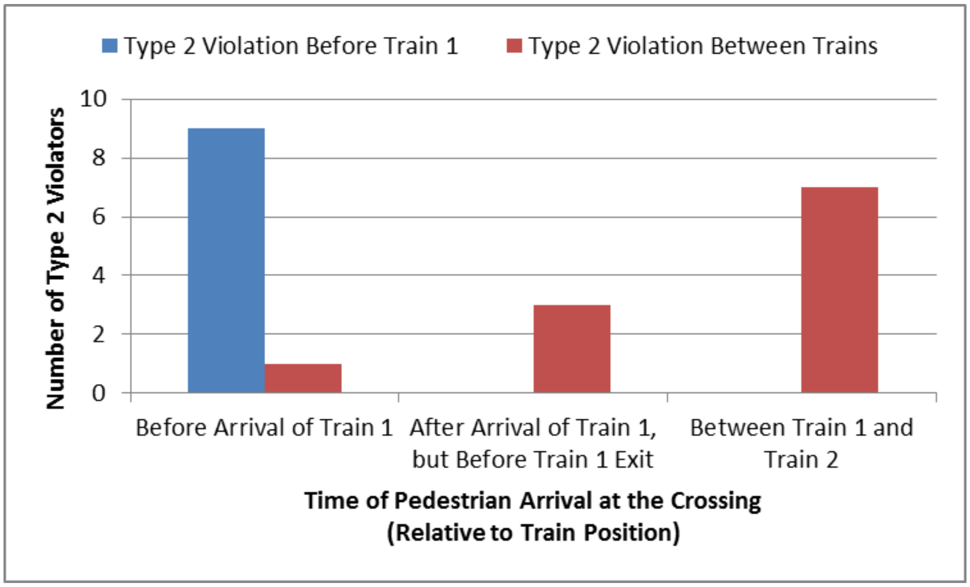

Figure 16. Number of Post-Installation Type 2 Violators by Arrival Time of the Pedestrian at the Crossing

In Figure 16, those pedestrians in the post-installation period who arrived at the crossing prior to the arrival of Train 1 and went on to violate by going under the gates were most likely to violate before the first train arrived (as opposed to waiting to violate between or after both trains). This was not the case for the pre-installation condition where none of the eight violators who arrived prior to the arrival of Train 1 decided to violate before the first train had arrived.

4.2. Summary of Findings

To evaluate the effectiveness of the addition of second train signage and auditory alerts at the crossing at Outwater Lane, answers were sought to the following questions:

- Does the second train signage and auditory warning significantly reduce the number of times when at least one pedestrian violates the crossing during second train events?

  No. Prior to the installation of the signage, 71 of the 193 second train activations (36.8 percent) had at least one violation. After the second train signage and accompanying auditory warning were installed, 78 of the 245 second train activations (31.8 percent) had at least one violation. A Z-test confirms that this reduction is not significant ($Z = 1.09$, $p < 0.05$).

- Does the second train signage and auditory warning reduce the overall number of pedestrians who violate the crossing during second train events?

  No. Prior to the installation of the signage, 120 of the 245 pedestrians at the crossing during a second train event (51.1 percent) committed a violation. Twenty-six of those 120 violators acted while the gates were descending or horizontal. After the installation of the signage, 130 of the 235 pedestrians at the crossing during a second train event (55.3 percent) committed a violation. Twenty-one of those 130 violators acted while the gates were descending or horizontal.

- Does second train signage and auditory warnings systematically lower all types of violation (ascending, descending, and horizontal)?

  No. The number of descending violators dropped from five violators before installation to zero violators after installation. However, descending violations depend greatly on the time when the pedestrian arrives at the crossing. A pedestrian can only violate while the gate is descending if he or she arrives during the limited 4-second window in which the gates initially descend; earlier arrival at the crossing would not result in a violation at all and a later arrival would miss the descent of the gate. As such, this change from five to zero may reflect our limited sample size and not a real change. No other types of violation showed a decrease; the number of horizontal violators remained the same at 21 and the number of ascending violators increased from 94 to 109 (a 16 percent change).

- Do second train signage and auditory warnings lower the number of horizontal violations to the same degree regardless of the location of the trains while the violation occurs?

  No. While the total number of horizontal violators did not change from before to after installation, the number of horizontal violations during which the violator crossed the tracks between the two trains did change. In fact, this number was reduced by 50 percent from 22 before installation to 11 after installation. However, this reduction in horizontal violators between trains showed a corresponding increase in horizontal violators (from zero before installation to nine after installation) before the arrival of the first train. The reason for this increase is not known and is obscured by a small sample size. One potential interpretation may be that the sign informs pedestrians that they will be delayed the length of two trains, instead of just one, which may incentivize some pedestrians to violate sooner to avoid this longer delay. Much more information is necessary before such a claim can be verified.

5. Conclusion

The Volpe Center was tasked with evaluating the effectiveness of an ATCWS composed of a second train warning sign and accompanying auditory warnings to mitigate pedestrian violations at a double track highway-rail grade crossing. This warning system is intended to alert pedestrians to the presence of multiple approaching trains at a grade crossing. If multiple trains are approaching a crossing during a single activation, the signage will activate and deliver the following message to alert pedestrians, both visually through a sign and aurally through a spoken message: "Danger, another train coming." If effective, the signage will reduce the frequency with which pedestrians choose to violate after the first train has passed through the crossing during a second train event. To determine if changes in pedestrian behaviors had occurred, behaviors were recorded and coded both before and after the installation of the ATCWS.

Overall, the percent of pedestrians who chose to violate the crossing (either while the gates were descending, horizontal, or ascending) did not change after the installation of the ATCWS. In fact, the total number of violators increased from 120 prior to the installation of the signage to 130 after the signage had been installed, though this change was not statistically significant ($Z = 0.904$, $P>0.05$). The one specific situation that did show a change was the number of pedestrians who violated while the gates were horizontal and crossed the tracks between the two trains. These incidents were reduced by 50 percent from 22 prior to the signage to 11 after the signage. However, equally noteworthy is the number of pedestrians who violated while the gates were horizontal and crossed the tracks prior to the arrival of Train 1. That number increased from zero prior to the installation of the signage to nine after. Although the sample size is too small to offer definite conclusions, the increase in violations before the arrival of the first train may indicate that the ATCWS may have driven pedestrians who were intent on violating to violate the crossing sooner.

This study does not provide any conclusive evidence that the system implemented at Outwater Lane was effective in increasing cautious pedestrian behavior.

Limitations

There are several limitations that make it difficult to conclusively determine the effectiveness of this type of warning system from the data provided in this report. First, Hurricane Sandy caused very significant changes in the schedules of the NJ Transit system in the fall of 2012. The typical timing and number of trains was altered significantly making it very difficult to compare the pre- and post-installation time periods. Second train events were much rarer in the post-hurricane (and post-installation) time periods and even when second train events did occur, ridership was down and fewer pedestrians were at the crossing to witness these events. For these reasons, the number of pedestrians at the crossing during second train events was held constant (for pre- and post-installation conditions) in an effort to control for the number of pedestrians who had the opportunity to violate. Still, significant changes in ridership and train schedules make it difficult to compare these two time periods.

Secondly, the small sample size and reductions in ridership due to hurricane Sandy in this data collection make it difficult to assess any differential effects that the signage has on groups. It is possible that pedestrians in large groups will act differently from those at the crossing alone. As such, to truly assess the impacts of the new warning system, one must investigate groups of all sizes before and after installation. However, the limited data collection period and variation in the number of pedestrians at the crossing (from zero to nine) made assessments of the impacts of groups difficult. Any follow-up studies should ensure that the potential effects of multiple pedestrians at the crossing during a second train activation are considered.

Lastly, in addition to the installation of the signage and speakers, other large changes were made to the crossing during the study timeframe. A pedestrian gate and channelizing guard rails were installed in Q4 and the existing guard rails in Q3 were lengthened to improve effectiveness. Though intended to improve pedestrian safety, the actual impact of these modifications is unknown and cannot be dissociated from the installation of the signage. These modifications make it difficult to assess the true impact of the second train warning system alone, as any changes in behavior may be attributable to the combination of signage *and* other safety enhancements installed during the study timeframe.

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Appendix A. Examples of Violations

The following are examples of pedestrians violating the crossing both before (Figure 17) and after (Figure 18) the installation of the second train warning system.

The first image below depicts a pedestrian violating the crossing in the road as a train approaches. This violation occurred prior to the installation of the second train warning system.

Figure 17. Pedestrian Violation Prior to Second Train Warning System Installation

The next image depicts a pedestrian, circled in yellow, violating the crossing by traveling under the horizontal gate. Shortly after the first violation occurs, the two women depicted at the bottom of the image also violate the crossing by going underneath the horizontal gates. The bright light in the image is the glow from the second train warning sign that has been activated by the approaching trains.

Figure 18. Pedestrian Violation after Second Train Warning System Installation

Abbreviations and Acronyms

ATCWS	Another Train Coming Warning System
FRA	Federal Railroad Administration
HRI	Highway-Rail Intersection
LED	Light Emitting Diode
NJDOT	New Jersey Department of Transportation
NJ Transit Rail	New Jersey Transit Rail
Q	Quadrant
ROW	Right-Of-Way
U.S. DOT	U.S. Department of Transportation
Volpe Center	John A. Volpe National Transportation Systems