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13. ABSTRACT (Maximum 200 words)

The Volpe Center was tasked by FRA's Office of Research, Development and Technology with evaluating the effectiveness of the use of photo enforcement for driver education at the East Princeton Street grade crossing in Orlando, FL (Crossing ID 622173H). The goal of the photo enforcement-based driver education program is to reduce the number of vehicles that commit grade crossing warning devices violations, thus reducing the possibility of getting struck by an oncoming train. A before-and-after design was used to evaluate the effectiveness of the photo enforcement program on drivers' compliance of the grade crossing warning devices. Grade crossing warning device violations were collected for 14 continuous days before the implementation of the photo enforcement program from April 14, 2016 to April 27, 2016. The signage and photo enforcement system were installed on August 8, 2016, and the city of Orlando started issuing violation notices on August 11, 2016. Eight months after the implementation of the photo enforcement system, grade crossing warning device violations were then again collected for 14 continuous days from April 13, 2017 to April 26, 2017. The average hourly rate of violations per activation decreased from 6.0296 before to 5.1004, resulting in a 15.4 percent reduction, after the photo enforcement program was implemented.

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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)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0	1	2	3	4	5							
Centimeters	0	1	2	3	4	5	6	7	8	9	10	11	12	13

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

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Contents

Executive Summary 1

1. Introduction 3
   1.1 Background 3
   1.2 Objectives 3
   1.3 Overall Approach 3
   1.4 Organization of the Report 4

2. Test Site Location and Data Collection 5
   2.1 Test Site Location Characteristics 5
   2.2 Data Collection 8

3. Overview of Orlando Photo Enforcement-Based Driver Grade Crossing Education Program 10
   3.1 Overview of the East Princeton Street Photo Enforcement System 10

4. Analysis of Violation Notices 14
   4.1 Survey Results 21

5. Evaluation of the East Princeton Street Photo Enforcement System 24

6. Results 26
   6.1 Data Characteristics 26
   6.2 Violation Counts and Rates 28
   6.3 Violation Counts and Rates by Type of Violation 30
   6.4 Summary of Findings 38

7. Conclusion 40
   7.1 Next Steps 41

8. References 42

Appendix A. Example of a Violation Notice 43

Appendix B. Example of Educational Material 44

Appendix C. Survey Questions 45

Appendix D. Survey Responses 47

Appendix E. Comments from Survey Responses 51

Appendix F. Paired T-test Results 55

Appendix G. Two-Way ANOVA Results - Type I Violation Rate 56

Appendix H. Two-Way ANOVA Results - Type II Violation Rate 57

Abbreviations and Acronyms 58

Illustrations

Figure 1. East Princeton Street Grade Crossing Satellite Image ... 5
Figure 2. Lane Coding Scheme for East Princeton Street Grade Crossing ... 6
Figure 3. A Google Street View of the Crossing in the Westbound Direction ... 7
Figure 4. A Google Street View of the Crossing in the Eastbound Direction ... 7
Figure 5. Video Data Collection System at East Princeton Street ... 8
Figure 6. Camera Placement at East Princeton Street Grade Crossing ... 9
Figure 7. Photo Enforcement System at East Princeton Street ... 11
Figure 8. Photo Enforcement Signage at East Princeton Street ... 12
Figure 9. Violation Notices Issued by Month (8/11/2016 to 9/30/2017) ... 15
Figure 10. Distribution of Violations by Vehicle Speed ... 16
Figure 11. Normalized Crossing Violation Values by Age Group ... 18
Figure 12. Population by Age Group ... 19
Figure 13. Survey Responses about the Photo Enforcement Sign at the Crossing ... 22
Figure 14. Distribution of Missed Detections by Time of Day ... 25
Figure 15. Distribution of Activations by Day of Week ... 27
Figure 16. Distribution of Violations by Day of the Week ... 28
Figure 17. Distribution of Violations by Time of Day ... 29
Figure 18. Violation Rate by Violation Type and Direction of Traffic ... 32
Figure 19. Vehicle Actions during Flashing Lights Phase ... 33
Figure 20. Example of Type I Violations in Westbound Direction (Green Circles) ... 34
Figure 21. Vehicle Actions during Gate Descend Phase ... 35
Figure 22. Example of Type II Violation in Westbound Direction (Yellow Circle) ... 35
Figure 23. Example of Type III Violation in Eastbound Direction (Red Circle) ... 36
Figure 24. Lead Vehicle Actions during Gate Ascend Phase ... 37
Figure 25. Example of Type IV Violations (Green Circles) ... 38
Figure 26. Violation Rate by Violation Type ... 40

Tables

Table 1. Violation Notices Issued by Month (8/11/2016 to 9/30/2017) 14
Table 2. Distribution of Crossing Violation Records by Gender... 17
Table 3. Distribution of Crossing Violation Records by Age Group 17
Table 4. Grade Crossing Warning Devices Repeat Violators.. 20
Table 5. Repeat Offenders Time of the Violation... 21
Table 6. Survey Response for Why Offenders Drove through the Crossing during Activation .. 22
Table 7. Descending Gate Violations 24
Table 8. Project Schedule 26
Table 9. Distribution of Activations by Type of Train 27
Table 10. Violation Counts and Rates by Period (All Types) 30
Table 11. Distribution of Violation Counts and Rate by Type of Violation and Direction of Traffic 31

Executive Summary

The Volpe Center was tasked by the Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) with evaluating the effectiveness of the use of photo enforcement for driver education at the East Princeton Street grade crossing in Orlando, FL (Crossing ID 622173H).

To improve motorists' compliance of grade crossing warning devices, the City of Orlando initiated a driver education program centered on sending warning notices to registered owners of vehicles who violated grade crossing warning devices. The goal of the photo enforcement-based driver education program was to reduce the number of vehicles that commit grade crossing warning devices violations, thus reducing the possibility of getting struck by an oncoming train. Although using photo enforcement technology, this is ultimately a grade crossing safety driver education program.

This pilot program, using photo enforcement technology, was demonstrated at the East Princeton Street grade crossing. The automated photo enforcement system at that crossing was a turnkey portable system that consisted of a battery bank in a lower enclosure, a pole, and an upper enclosure housing all of the cameras and sensors. The system detected violations from the time gates started to descend. The crossing was also fitted with photo enforcement signage.

The Volpe Center used a before-and-after design to evaluate the effectiveness of the photo enforcement program on drivers' compliance of the grade crossing warning devices. Researchers collected grade crossing warning device violations for 14 continuous days before the implementation of the photo enforcement program, from April 14, 2016 to April 27, 2016. The City of Orlando installed the signage and the photo enforcement system on August 8, 2016 and started issuing violation notices on August 11, 2016. Eight months after the implementation of the photo enforcement system, grade crossing warning device violations were again collected for 14 continuous days from April 13, 2017 to April 26, 2017. Vehicles that violated grade crossing warning devices were coded as having committed one of four violation types: entering the crossing during flashing lights phase (Type I), entering the crossing during descending gate phase (Type II), entering the crossing during horizontal gate phase (Type III), and entering the crossing during gate ascend phase (Type IV).

Results indicated that the implementation of the photo enforcement-based education program reduced the overall violation rate by 15.4 percent from the pre- to the post-test period. Additionally, all four violation types experienced a reduction in violation rate after the implementation. The Type I violation rate was reduced by 13.9 percent, the Type II violation rate was reduced by 13.5 percent, the Type III violation rate was reduced by 100 percent, and the Type IV violation rate was reduced by 16.1 percent.

Part of this research study included analyzing information about driver behavior at the crossing (e.g., human factors contributing to the failure to yield at the crossing). The City, in collaboration with FRA and the Volpe Center, created and distributed a survey to gather this information. Out of 1,320 violation notices that were sent out, the City received 133 (10.1 percent) survey responses back. The respondents ranged in age from 16 to 88 years old and consisted of 53.4 percent male, 42.1 percent female, and 4.1 percent that did not provide gender data. The survey results show that 35 percent of the responding violators understood the photo enforcement sign at the crossing while 60 percent indicated that they did not see the sign. In response to why they drove through the crossing when the warning devices were activated, a significant number of the respondents (27 percent) indicated that they did not see the activated crossing signals. The full results of the survey responses are contained in Appendix D and Appendix E.

1. Introduction

The U.S. Department of Transportation (DOT) John A. Volpe National Transportation Systems Center (Volpe Center) provides technical support to Federal Railroad Administration's (FRA) Office of Research, Development and Technology (RD&T) in the area of railroad infrastructure research. This support includes key research associated with all aspects of highway-rail grade crossing safety and trespass prevention. One major effort is to develop a more precise understanding of the risks presented by highway-rail grade crossings and then determine how best to mitigate (i.e., decrease or eliminate) the risks. This report presents the findings of a study on the use and impact of a photo enforcement-based driver education program on driver compliance with active warning devices at highway-rail grade crossings.

1.1 Background

According to the FRA Highway-Rail Grade Crossing Inventory database, nearly 54 percent of all public at-grade crossings are equipped with active warning devices (gates and/or flashing lights). Incidents at active crossings make up a significant percentage of the overall number of grade crossing incidents, despite being protected by active warning devices which alert motorists to the presence of oncoming trains. Of the total 1,743 incidents at public grade crossing in 2016, approximately 70 percent (1,211) occurred at crossings equipped with active warning devices. [1]

In order to improve motorists' compliance of grade crossing warning devices, the city of Orlando initiated a driver education program centered on sending warning notices to registered owners of vehicles who violate grade crossing warning devices. This pilot program, using photo enforcement technology, was demonstrated at the East Princeton Street grade crossing (Crossing ID 622173H). FRA's Office of RD&T tasked the Volpe Center with evaluating the effectiveness of the photo enforcement-based program at the East Princeton Street crossing. The goal of the program was to reduce the number of vehicles that commit grade crossing warning device violations, thus reducing the possibility of getting struck by an oncoming train.

1.2 Objectives

This research study had two main objectives. The first was to determine whether the photo enforcement-based driver education program at the East Princeton Street grade crossing was successful in reducing the number of vehicles that violate grade crossing warning devices. The second was to evaluate the effectiveness of photo enforcement technologies to detect and deter highway-rail grade crossing violations along a mixed-use rail corridor.

1.3 Overall Approach

The Volpe Center performed a before-and-after study to understand the safety benefits of the installation and operation of an automated photo enforcement system and associated driver educational outreach at a highway-rail grade crossing. Since grade crossing incidents are rare events, violations of grade crossing active warning devices were used as proxy to evaluate safety benefits. Four different types of violations were coded for 14 continuous days before installation and then again approximately 8 months after the installation and operation of the photo enforcement-based program. The violations were then analyzed to measure the effectiveness of the program.

To study the effectiveness of the automated photo enforcement technologies to detect highway-rail grade crossing violations, the number of descending gate violations automatically captured by the automated photo enforcement was compared against descending gate violations manually coded by the Volpe Center research staff.

1.4 Organization of the Report

This report is organized as follows:

- Section 2 provides an overview of the test site location and data collection activities.
- Section 3 provides an overview of the Orlando Photo Enforcement-Based Driver Grade Crossing Education program.
- Section 4 presents descriptive statistics of the violation notices, including results of survey questions.
- Section 5 presents evaluation of the East Princeton Street photo enforcement system in detecting descending gate violations.
- Section 6 presents findings of the before-and-after analysis.
- Section 7 presents conclusions of the study.

2. Test Site Location and Data Collection

The site chosen by the city for this effort was the grade crossing on East Princeton Street in Orlando, FL (Crossing ID 622173H). The SunRail Florida Hospital Health Village station is adjacent to the crossing on the north side of the crossing, as shown in Figure 1.

2.1 Test Site Location Characteristics

The East Princeton Street grade crossing is located at milepost 787.99 of the Sanford subdivision. There are two active railroad tracks that intersect East Princeton Street and runs in a north/south direction. According to the DOT Grade Crossing Inventory data, the estimated annual average daily traffic (AADT) at this crossing was 7,800 in 2008, with a posted speed limit of 30 mph. The crossing is on the SunRail commuter rail line and has both passenger (SunRail and Amtrak) and freight (CSX) trains that pass through the crossing at speeds ranging from 20 to 25 mph. During the two data collection periods for this study, an average of 41 trains passed though the crossing daily on weekdays and 8 trains passed through the crossing daily on weekends. (SunRail does not operate on weekends.) The crossing is equipped with two long vehicle gates, four pedestrian gates, seven sets of mast mounted flashers and four sets of cantilever-mounted flashers.

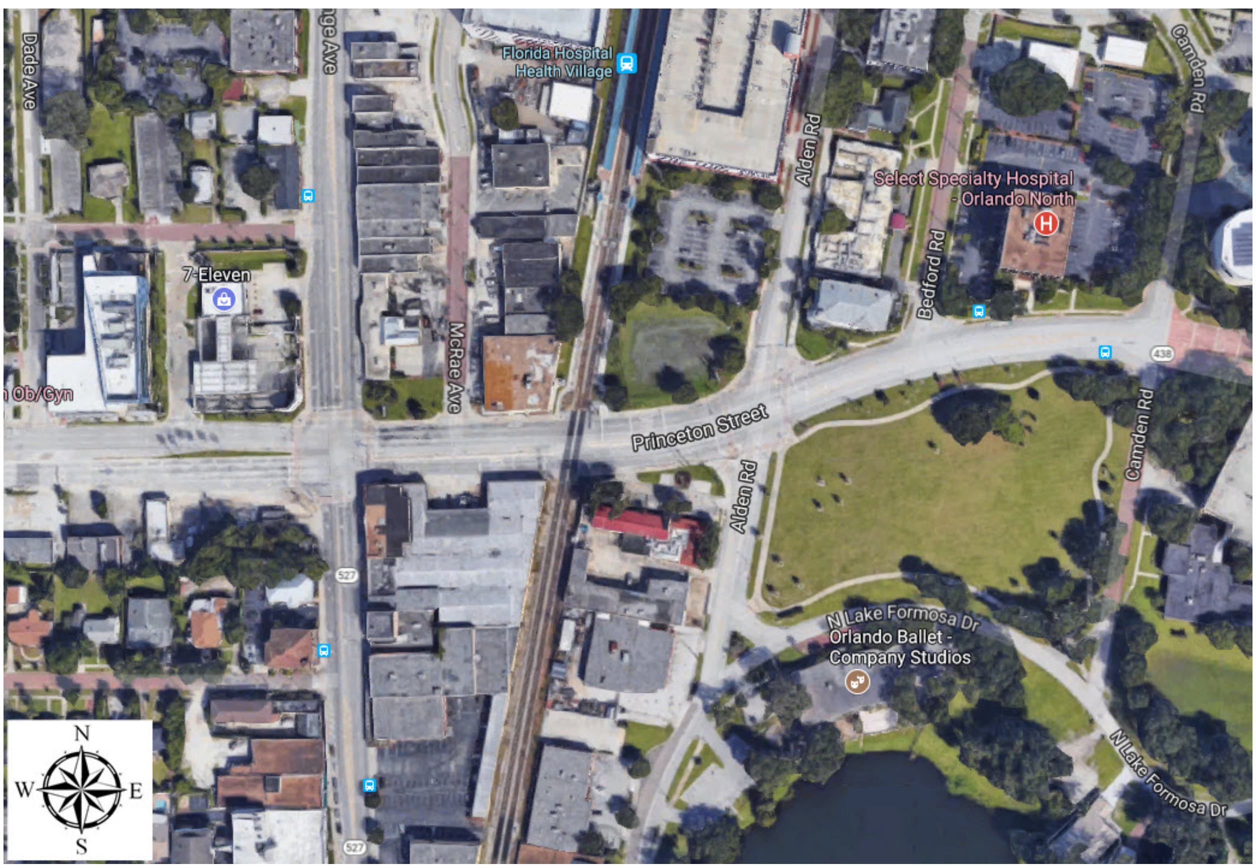


Figure 1. East Princeton Street Grade Crossing Satellite Image

2.1.1 Westbound

There are three lanes of traffic that intersect the crossing in the westbound direction. The inner most lane (lane 3) splits into two lanes immediately after the crossing with the innermost lane becoming a left-turn-only lane onto North Orange Avenue. The signalized intersection at North Orange Avenue is located approximately 260 feet west of the crossing. The traffic lights at the intersection are interconnected (advanced preemption) with the crossing signals allowing traffic to clear the crossing during an activation. Figure 2 shows the 5 lanes that intersect with the crossing and Figure 3 shows Google street view on approach to the crossing in westbound direction.

Figure 2. Lane Coding Scheme for East Princeton Street Grade Crossing

Figure 3. A Google Street View of the Crossing in the Westbound Direction

2.1.2 Eastbound

There are two lanes of traffic that intersect the crossing in the eastbound direction. Figure 4 shows Google Street View on approach to the crossing in the eastbound direction. The innermost lane (lane 2) splits into two lanes immediately after the crossing with one lane becoming a left-turn-only lane onto Alden Road. This road is the entrance to the SunRail Florida hospital located adjacent to the crossing on the northeast corner. The signalized intersection at Alden Road is located approximately 185 feet east of the crossing. The traffic lights at the intersection are interconnected (advanced preemption) with the crossing signals allowing traffic to clear the crossing during an activation.

Figure 4. A Google Street View of the Crossing in the Eastbound Direction

2.2 Data Collection

A video-based data collection system consisting of a solar panel, a camera, and a digital video recorder along with supporting hardware contained in a utility box was used to collect video of vehicles travelling in both directions at the East Princeton Street grade crossing. Figure 5 shows pictures of the data collection system installed at the East Princeton Street grade crossing.

Figure 5. Video Data Collection System at East Princeton Street

The video data collection equipment was mounted on a street light pole along East Princeton Street on the southeast side of the crossing, as shown in Figure 6 below. As can be seen, a single data collection system monitored both directions of vehicle traffic at the crossing. The data collection system was installed on April 14, 2016 and remains operational as of the date of this report.

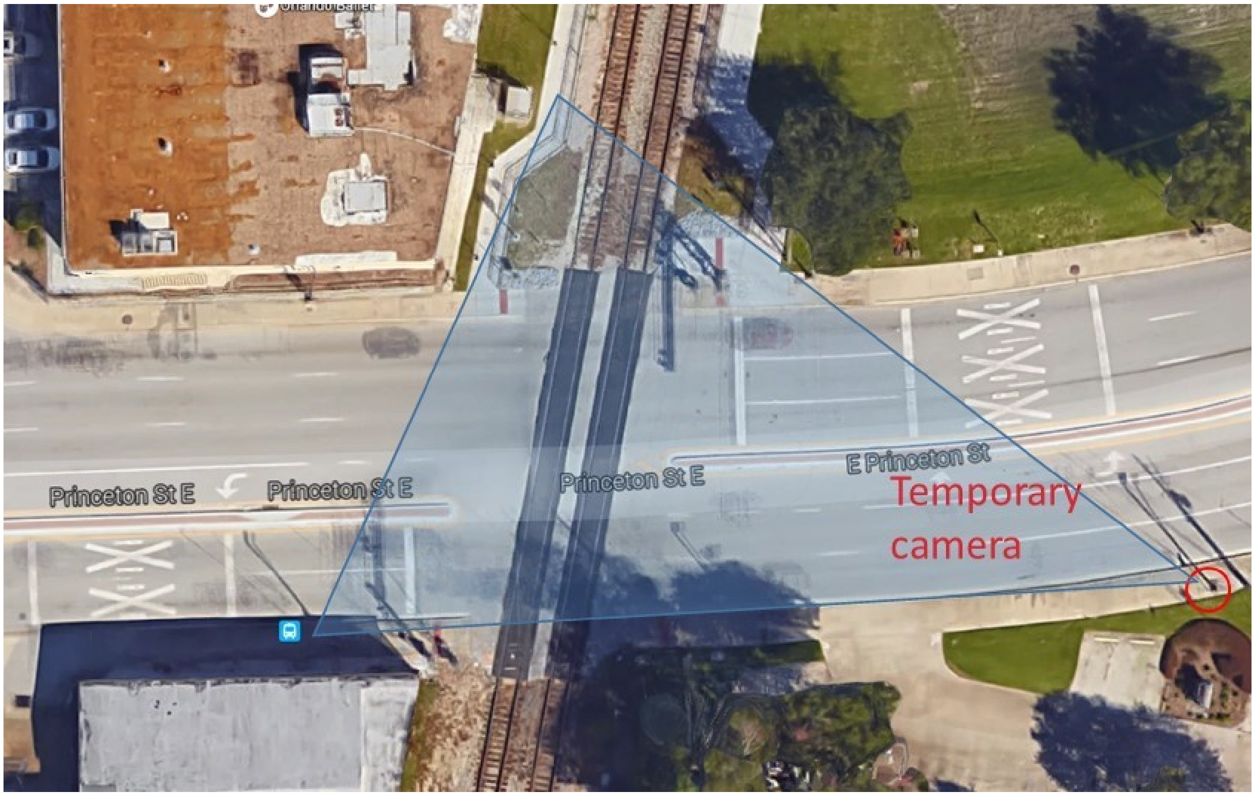


Figure 6. Camera Placement at East Princeton Street Grade Crossing

3. Overview of Orlando Photo Enforcement-Based Driver Grade Crossing Education Program

The City of Orlando has implemented the Orlando STOPS red light camera enforcement system at many of its most dangerous signalized intersections to help prevent motor vehicle collisions due to red light running violations [2]. Currently, the City has 24 intersections fitted with red light camera systems.

To improve compliance of the grade crossing warning devices, Orlando also decided to install photo enforcement systems at up to six grade crossings. The six crossings locations considered for photo enforcement are listed below:

- W. Central Blvd. between Orange Ave. and Garland Ave. – Crossing ID 622189E
- W. Colonial Dr. between Orange Ave. and Garland Ave. – Crossing ID 622181A
- W. South St. between Garland Ave. and Boon St. – Crossing ID 622192M
- E. Princeton St. between Orange Avenue and Alden Rd. – Crossing ID 622173H
- W. Michigan St. between Division Ave. and Kunze Ave. – Crossing ID 622307E
- W. Robinson St. between Orange Ave. and State Ln. – Crossing ID 622186J

Currently the City has installed photo enforcement systems at the West Central Boulevard and East Princeton Street grade crossings by two different vendors. However, the photo enforcement system is only operational at the East Princeton Street grade crossing. Unlike red light violators, who receive actual citations with fines, the City decided to send out warning notices along with education materials and survey questions to registered owners of the vehicles that violated the grade crossing warning devices. This program, although using photo enforcement technology, is ultimately a grade crossing safety driver education program.

3.1 Overview of the East Princeton Street Photo Enforcement System

The system used for automated photo enforcement at the East Princeton street grade crossing was installed and operated by Sensys America, Inc. The system sits adjacent to the East Princeton Street sidewalk before the crossing in the westbound direction approximately 130 feet from the crossing stop line. It is a turnkey portable system that consist of a battery bank in a lower enclosure, a pole, and an upper enclosure housing all of the cameras and sensors. The whole system weighs approximately 514 lbs and is approximately 44 inches tall. It was designed to be a self-contained and stand-alone system not connected to the railroad signaling system and temporarily installed off the roadway. The system was installed on August 8, 2016 and became operational on August 11, 2016.

The photo enforcement system captured violations for westbound traffic only. However, signage alerting drivers of the photo enforcement was installed for both directions of traffic. The signage for the westbound traffic was placed on an existing pole on the sidewalk located approximately 65 feet before the crossing stop line and the signage for the eastbound traffic was placed on a pole on the sidewalk located approximately 45 feet before the crossing stop line. The signage was developed in collaboration with the City, FRA, and the Volpe Center. Images of the Sensys photo enforcement system and signage installation are shown in Figure 7 and Figure 8, respectively.

Figure 7. Photo Enforcement System at East Princeton Street

Figure 8. Photo Enforcement Signage at East Princeton Street

There are four types of violations a motorist can commit at a highway-rail grade crossing equipped with gates. These include:

- Type I: Vehicle traversed a crossing while lights were flashing but before gates started descending
- Type II: Vehicle traversed a crossing while gates were descending.
- Type III: Vehicle traversed a crossing while gates were fully horizontal.
- Type IV: Vehicle traversed a crossing while gates were ascending.

Type III violations are the most risky, followed by Type II, Type I and then Type IV. In Florida, all four types of violations are illegal. However, Orlando decided to only issue warning notices to registered owners of the vehicles who committed type II violations. Type I and Type IV violations were not enforced because it would require a substantial amount of effort to include those types of violations. The project team's analysis of the East Princeton Street crossing showed that approximately 87 percent of the vehicles committed Type I violations and approximately 90 percent of the vehicles committed Type IV violations. Type III violations at this crossing are almost impossible as it would require a driver to break the horizontal gate which covers the entire roadway. The median separating the direction of traffic also makes it difficult to go around the horizontal gates.

The photo enforcement system at the East Princeton street grade crossing is activated when a vehicle fails to stop before traversing the crossing during the gate descend phase, resulting in a Type II violation. Several photos and video recordings of the violation are captured by the system and uploaded onto a secure password protected website. A city staffer then reviews the video and determines whether to issue a warning notice to the vehicle owner. The warning notice looks very similar to an actual citation sent out by the City for red light violations but states very clearly that it is just a warning notice, and the owner is not required to pay any fines or go to court. The warning notice is accompanied by education materials about safe driving tips at grade crossings and a short survey. A copy of the warning notice, education materials, and survey questions are shown in Appendix A, Appendix B, and Appendix C, respectively.

4. Analysis of Violation Notices

This section presents general statistics on 1,320 violation notices sent out by the City to the vehicle owners who committed descending gate violations at the East Princeton Street grade crossing. The City started issuing the violation notices on August 11, 2016 and is still currently issuing violation notices at the same crossing at the time of this report. The 1,320 violation notices were issued over more than a 1-year period from August 11, 2016 to September 30, 2017. The following variables are included in each violation notice:

- Date and time when the violation occurred
- Citation number of the violation
- Plate number of the vehicle that committed the violation
- Vehicle speed at the time of the violation
- ZIP code of the registered owner of the vehicle that committed the violation
- Age of the registered owner of the vehicle that committed the violation
- Gender of the registered owner of the vehicle that committed the violation
- Name of the city employee that approved the violation
- Violation approval date

The City provided non-personally identifiable information (PII) data to the research staff for this analysis.

Violation by Month: Table 1 and Figure 9 show the distribution of 1,320 violation notices by month. As mentioned earlier, the City started issuing the violation notice on August 11, 2016, therefore the violation count for August 2016 is only for part of that month starting from August 11 to August 31, 2016. As can be seen, the violation notices issued ranged from 53 in February 2017 and September 2017 to 136 in April 2017.

Table 1. Violation Notices Issued by Month (8/11/2016 to 9/30/2017)

Month	Violation Notice Count	% of Total
August, 2016[1]	122	9.2%
September, 2016	119	9.0%
October, 2016	76	5.8%
November, 2016	86	6.5%
December, 2016	84	6.4%
January, 2017	120	9.1%

[1] August 2016 is only for partial month, as the City started issuing violation notices on August 11, 2016.

Month	Violation Notice Count	% of Total
February, 2017	53	4.0%
March, 2017	58	4.4%
April, 2017	136	10.3%
May, 2017	94	7.1%
June, 2017	131	9.9%
July, 2017	77	5.8%
August, 2017	111	8.4%
September, 2017	53	4.0%
Total	1,320	

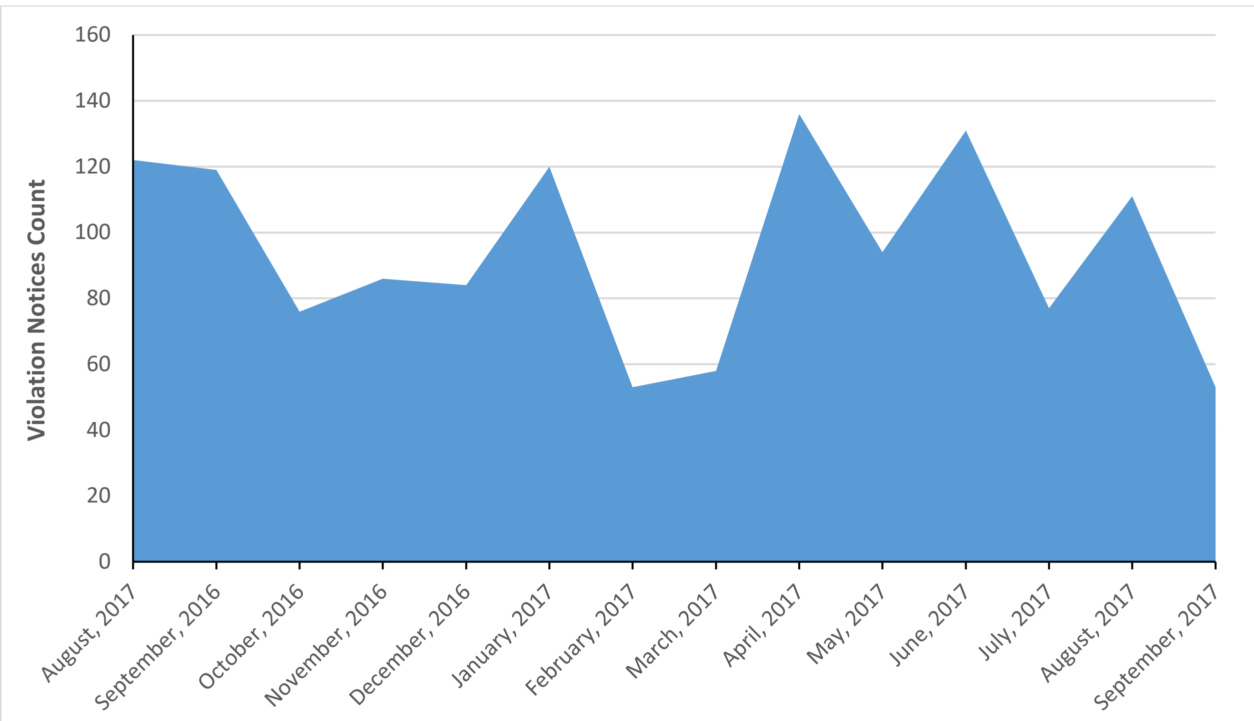


Figure 9. Violation Notices Issued by Month (8/11/2016 to 9/30/2017)

Vehicle Speed at Time of Violation: The photo enforcement system recorded the speed at the time a vehicle committed a descending gate violation. Figure 10 shows the distribution of the violation notices by the speed at the time of violation. The speed ranged from 5.1 mph to 45 mph, with an average speed 21.2 mph. Of the 1,320 total violations, 1,198 (90.8 percent) had recorded speeds less than or equal to the 30-mph posted speed limit at the crossing.

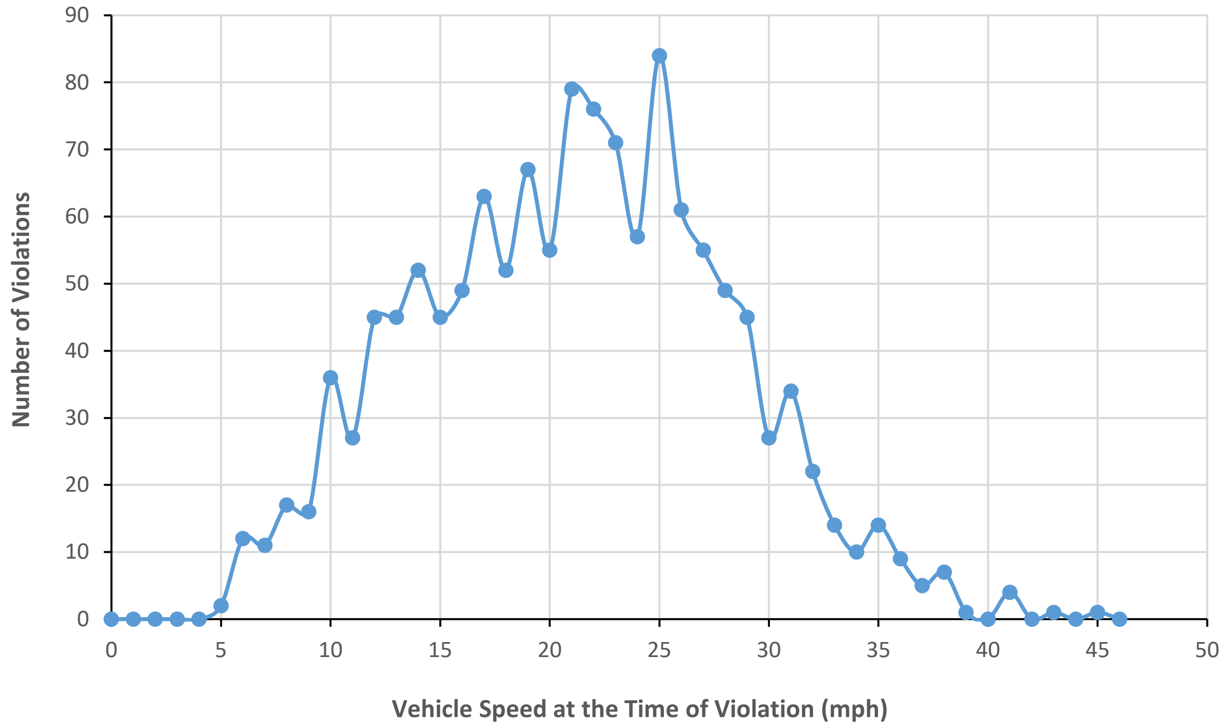


Figure 10. Distribution of Violations by Vehicle Speed

Yang and Najm [3] conducted a study of red light violation records to understand the correlation between red light violations and various driver, intersection, and environmental factors. As a part of that study, they looked at the relative ratio of red light violation percentages by licensed driver percentages and total million vehicle miles travelled (MVMT) percentages for gender and for age group of the violator, as well as repeat red light violators. The Volpe Center performed the same analysis on the East Princeton Street grade crossing violation dataset to understand the correlation between crossing violations and gender and age group.

Gender of the Violator: Table 2 shows the distribution of violation notices by gender, number of licensed drivers (LDs) in Florida by gender, total MVMT by gender, and relative ratio of crossing violation percentages by licensed drivers percentages and total MVMT percentages. Of the total 1,320 violation notices, 188 violation notices were missing gender data. As can be seen, the relative ratio of $\frac{\%\ of\ Crossing\ Violations}{\%\ of\ LD}$ shows that male drivers were more likely than female drivers to commit descending gate violations (1.09 vs. 0.91). But when analyzed by vehicle miles travelled, the relative ratio of $\frac{\%\ of\ Crossing\ Violations}{\%\ of\ MVMT}$ shows that female drivers were more likely than male drivers to commit descending gate violations (1.25 vs. 0.85). It should be noted that total MVMT data is for the entire nation. However, the proportion of licensed drivers by gender in Florida is very much similar to entire nation (Male: 49.1–FL; 49.4%–U.S. and female: 50.9%–FL; 50.6%–U.S.).

Table 2. Distribution of Crossing Violation Records by Gender

Gender	No. of Xing Vs	% of Xing Vs	No. of LDs[2]	% of LDs	% of Xing Vs / % of LDs	Total MVMT[3]	% of MVMT	% of Xing Vs % of MVMT
Male	606	53.5%	7,206,475	49.1%	1.09	1,317,941	62.80%	0.85
Female	526	46.5%	7,468,685	50.9%	0.91	780,667	37.20%	1.25
Sub-total	1132	***	***	***	***	***	***	***
Missing Data	188	***	***	***	***	***	***	***
Total	1320	100.0%	14,675,160	100.0%	***	2,098,608	100.0%	***

Age of the Violator: Table 3 shows the distribution of violation notices by age group, number of LDs in Florida by age group, total MVMT by age group, and the relative ratio of crossing violation percentages by licensed driver percentages and by total MVMT percentages. Normalized crossing violation values by age group are shown in Figure 11. As can be seen, the relative ratio of $\frac{\%\ of\ Crossing\ Violations}{\%\ of\ LD}$ shows that driver in the age group between 30 to 39 years old were most likely to commit descending gate violations (ratio of 1.43). But when analyzed by vehicle miles travelled, the relative ratio of $\frac{\%\ of\ Crossing\ Violations}{\%\ of\ MVMT}$ shows that older drivers over the age of 70 were most likely to commit descending gate violations (ratio of 1.74). As noted earlier, MVMT data is for the entire nation. Florida has a higher percentage of older population than the national average, as can be seen Figure 12. This could be one of the reasons why the relative ratio of older drivers are higher when analyzed by total MVMT.

Table 3. Distribution of Crossing Violation Records by Age Group

Age Group	No. of Xing Vs	% of Xing Vs	No. of LDs1[4]	% of LDs	% of Xing Vs / % of LDs	Total MVMT[5]	% of MVMT	% of Xing Vs / % of MVMT
<= 19	4	0.35%	470,557	3.21%	0.11	83,169	3.96%	0.09
20 to 29	146	12.90%	2,250,949	15.34%	0.84	412,282	19.65%	0.66

[2] Number of licensed drivers in Florida, 2016.

[3] Total vehicle miles of travel in the U.S., in millions, 1996.

[4] Number of licensed drivers in Florida, 2016.

[5] Total vehicle miles of travel in the U.S., in millions, 1996.

Age Group	No. of Xing Vs	% of Xing Vs	No. of LDs1[4]	% of LDs	% of Xing Vs / % of LDs	Total MVMT[5]	% of MVMT	% of Xing Vs / % of MVMT
30 to 39	253	22.35%	2,297,219	15.65%	1.43	539,014	25.68%	0.87
40 to 49	246	21.73%	2,388,332	16.27%	1.34	503,354	23.99%	0.91
50 to 59	231	20.41%	2,703,125	18.42%	1.11	288,915	13.77%	1.48
60 to 69	157	13.87%	2,351,669	16.02%	0.87	170,488	8.12%	1.71
>= 70	95	8.39%	2,213,309	15.08%	0.56	101,386	4.83%	1.74
Sub-total	1,132		***					
Missing Data	188		***					
Total	1,320		14,675,160			2,098,608		

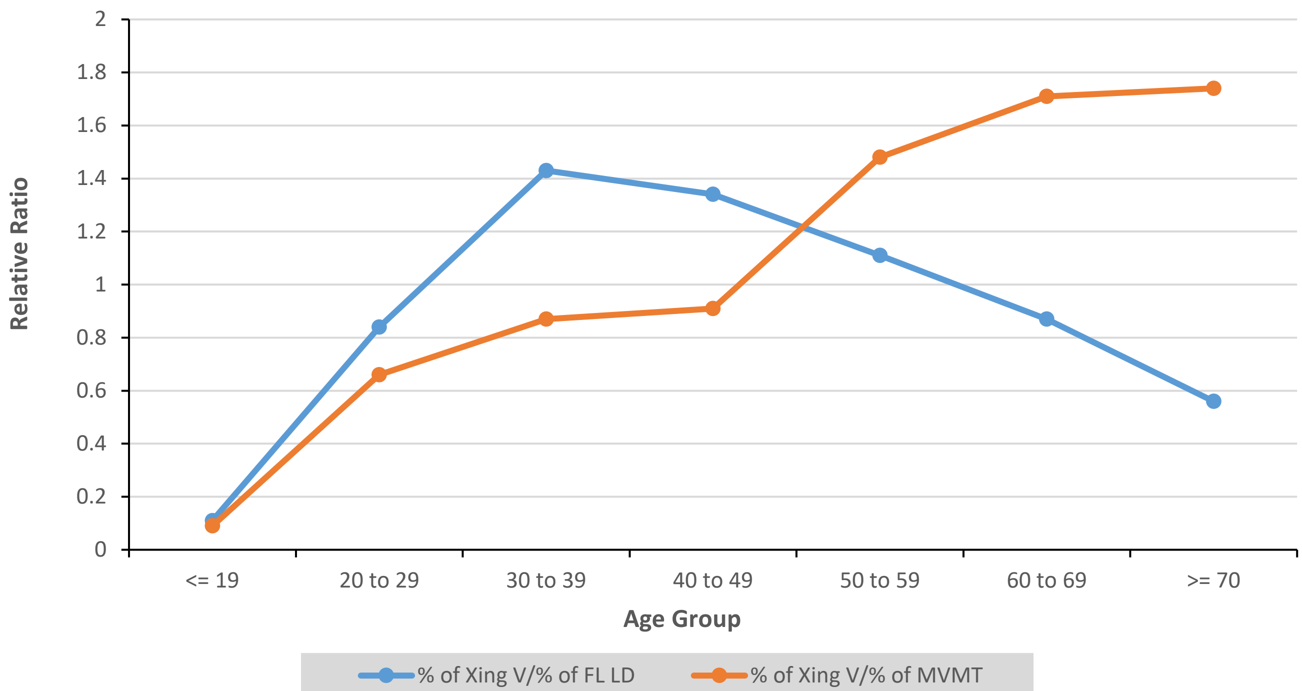


Figure 11. Normalized Crossing Violation Values by Age Group

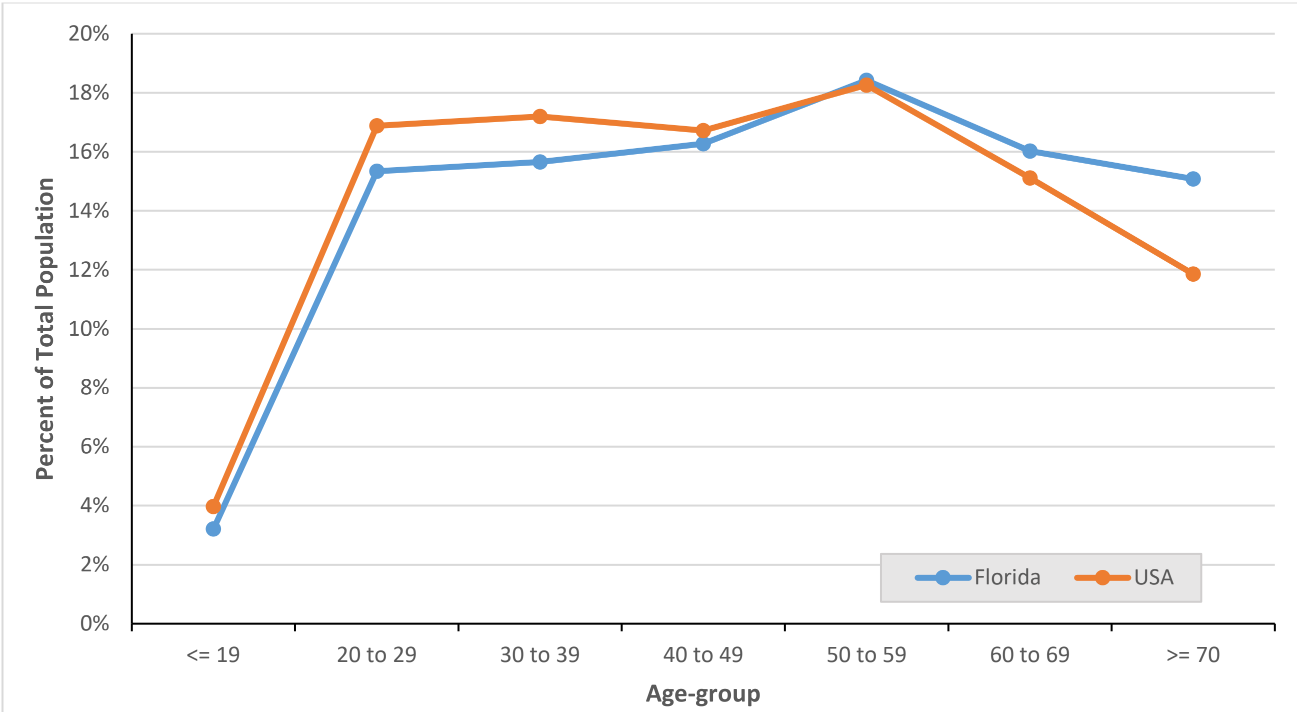


Figure 12. Population by Age Group

Repeat Crossing Warning Offenders: During the study period, 2.5 percent of the violation notices were issued to 16 repeat offenders. Fifteen repeat offenders committed two violations and one repeat offender committed three violations during the study period. Repeat violators were determined by matching vehicle license plates. Table 4 shows the distribution of the repeat grade crossing warning devices offenders. Of the 16 total repeat offenders, 11 were female and 5 were male. The repeat offender ages ranged from 27 to 77, with an average age of 57.2. That was 10 years older than the average age of all offenders, which was 47.1 years old. The average speed at the time of violation for repeat offenders was slightly higher, at 21.44 mph, compared to 21.2 mph for all offenders.

Table 4. Grade Crossing Warning Devices Repeat Violators

No. of Repeated Offenses	No. of Repeat Offenders (via vehicle plate matching)	Repeat Offenders vs. Total No. of Violators	No. of Xing Violation Records	Repeat Violation Records vs. Total Violation Records
2	15	1.15%	30	2.27%
3	1	0.08%	3	0.23%
Total	16	1.23%	33	2.50%
Total Number of Crossing Violations				1,320
Number of Violators with 1 Crossing Violation				1,287
Total Number of Violators				1,303
Percent of Violators with 1 Crossing Violation				97.50%

Table 5 shows the time of the violation for the 16 repeat offenders. All of the repeat offenders committed the violation during either morning or afternoon rush hours, except for two repeat offenders that committed violations around 12:00 p.m. and 8:00 p.m. Fourteen of the 16 repeat offenders committed violations around the same time frame but on different days. The other two repeat offenders committed their violations in the morning and afternoon rush hours.

Table 5. Repeat Offenders Time of the Violation

ID	Time of the Violation		
	Time1	Time2	Time3
1	4:45:17 PM	4:10:42 PM	
2	8:02:17 AM	8:02:53 AM	
3	8:10:44 AM	8:03:27 AM	
4	9:01:39 AM	8:32:04 AM	
5	11:32:25 AM	11:32:42 AM	
6	7:48:07 PM	7:55:19 PM	
7	5:32:29 PM	9:05:31 AM	
8	5:57:36 PM	6:13:42 PM	
9	8:39:55 AM	8:43:14 AM	
10	4:34:04 PM	4:33:13 PM	
11	4:33:56 PM	5:40:35 PM	
12	5:12:55 PM	5:32:59 PM	
13	5:13:10 PM	9:32:56 AM	
14	8:32:52 AM	8:32:52 AM	
15	4:43:45 PM	5:43:01 PM	
16	6:14:41 PM	5:43:10 PM	6:11:26 PM

4.1 Survey Results

Part of this research study included analyzing information about driver behavior at the crossing (e.g., human factors contributing to the failure to yield at the crossing). The City, in collaboration with FRA and Volpe Center, created and distributed a survey to gather this information. A mail survey with stamped envelope was included with the violation notices sent out to the registered owners of the vehicles who committed violations at the East Princeton Street grade crossing. A link was also included with the violation notice in case the offender wanted to complete the survey on-line. The survey consisted of 10 multiple choice questions, a question about the offender's gender and age, and a free form section for general comments. Appendix C shows the survey questions included with the violation notice.

Out of 1,320 violation notices that were sent out, the City received 133 (10.1 percent) survey responses back; 130 via mail and 3 online. Of the 133 total survey respondents, 71 (53.4 percent) were male, 56 (42.1 percent) were female, and 6 (4.5 percent) did not provide gender data. The respondents ranged in age from 16 to 88, with an average age of 49.8 years.

One survey question asked respondents to indicate whether they understood the photo enforcement sign at the railroad crossing. As discussed earlier, there was only one photo enforcement sign on the sidewalk side for each direction of traffic. The options for response included "Yes," "No," and "I did not see the sign." All 133 respondents provided an answer to the question but two selected more than one option. Both of them selected "No" and "I did not see the sign." Figure 13 shows the distribution of the responses to this survey question.

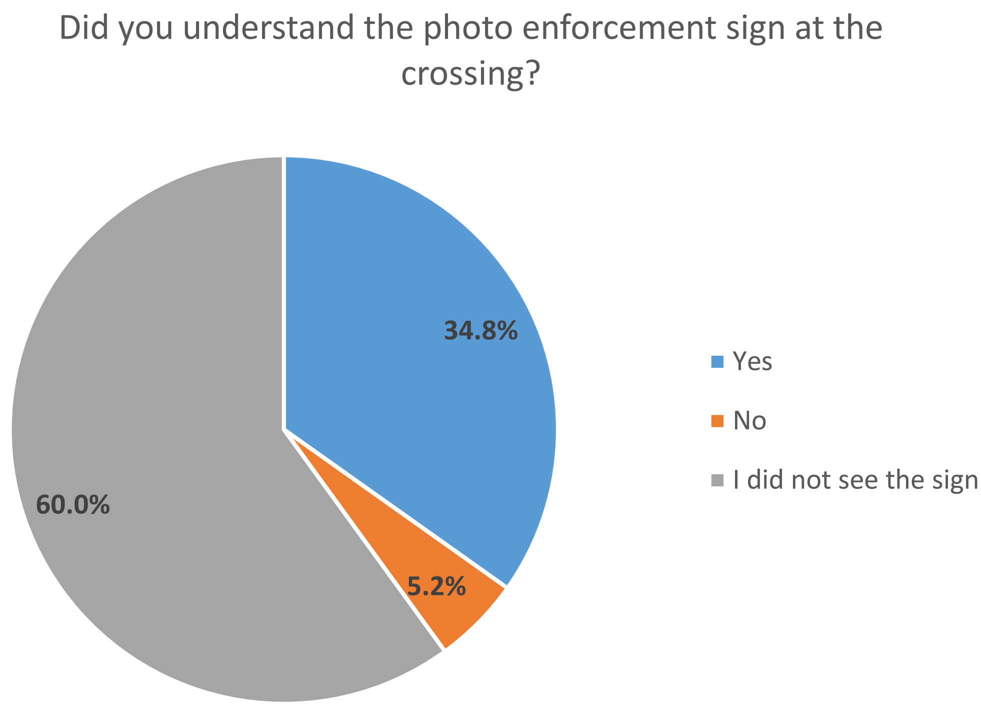


Figure 13. Survey Responses about the Photo Enforcement Sign at the Crossing

The respondents were also asked to indicate why they drove through the railroad crossing when the warning devices were activated. There were nine options for response and respondents were directed to select all options that applied. Of the 133 respondents, 5 did not provide any data and 29 selected at least 2 options. Table 6 shows the distribution of responses to this question.

Table 6. Survey Response for Why Offenders Drove through the Crossing during Activation

Response	Count	Percent of Total
I did not see the train	19	11%
I did not see the activated crossing signals (e.g., lights flashing, gate lowering)	48	27%
I felt I had enough time to get through	29	17%
I followed the car in front of me	10	6%

Response	Count	Percent of Total
I felt the wait would be too long	4	2%
I was in a rush (e.g., late for an appointment)	10	6%
I was unfamiliar with the rules	13	7%
Other	29	17%
I don't know	8	5%
No Answer	5	3%
Total	**175**	**100%**

The respondents were also asked to share any questions or comments about the East Princeton Street grade crossing or the survey. This was a free form question where respondents could write anything. Of the 133 total surveys received, 67 people provided comments. Most respondents expanded on a previous question about why they drove through the crossing during an activation. Responses were generally positive. Appendix D provides results of the remaining survey questions and Appendix E lists all 67 comments.

5. Evaluation of the East Princeton Street Photo Enforcement System

The Volpe Center sought to evaluate the effectiveness of the East Princeton Street photo enforcement system to detect motor vehicles that violate highway-rail grade crossing warning devices. To evaluate the accuracy in detecting grade crossing violations, descending gate violations captured by the system over a five-day weekday period from April 17 to April 21, 2017 was compared with the descending gate violations manually coded by research staff over the same time period.

From April 17 to April 21, 2017, Volpe Center staff manually coded a total of 67 descending gate violations in the westbound direction recorded from their own video data collection system. During the same time period and in the same direction of traffic, the photo enforcement system generated 164 violation records, and of that total, the City issued 32 violation notices. The majority of the 164 violation records were ascending gate violations, and some were generated due to a false radar trigger.

Of the 67 manually coded descending gate violations, 37 violations were also captured by the system, but 29 violations were not. Table 7 shows the distribution of 67 manually coded violations and 37 violations captured by the system by lane. As can be seen, the system was most accurate for lane 3, (the median lane) with 13 of 17 (76.5 percent) violations detected, followed by lane 5, (the outermost lane) with 16 of 31 (51.6 percent) violations detected, and least accurate for lane 4, (the middle lane) with 8 of 19 (42.2 percent) violations detected. See Figure 2 for the East Princeton Street crossing lane-coding scheme.

Table 7. Descending Gate Violations

	Lane 5 (outermost lane)		Lane 4 (middle lane)		Lane 3 (median lane)		Total	
	Volpe	System	Volpe	System	Volpe	System	Volpe	System
4/17/2017	6	4	3	2	4	2	13	8
4/18/2017	8	4	4	1	6	6	18	11
4/19/2017	9	6	5	2	2	2	16	10
4/20/2017	3	1	2	0	3	2	8	3
4/21/2017	5	1	5	3	2	1	12	5
Total	31	16	19	8	17	13	67	37

The 29 missing violations occurred over all 5 days and at all times of the day. Figure 14 shows the distribution of the 29 missing violations by time of the day. As can be seen, the majority of the missed detections occurred during the afternoon rush hour, from 4:00 p.m. to 6:00 p.m. Of the 29 missing violations, 5 were coded at the same time as when the gate started to descend and 13 were coded within 1 second of gate descend time. Some of the missing violations could have been because a large vehicle was stopped in the outermost lane (lane 5), causing the sensor line-of-sight to be blocked, resulting in missed detections. As mentioned earlier in the report, the photo enforcement system is approximately only 44 inches tall.

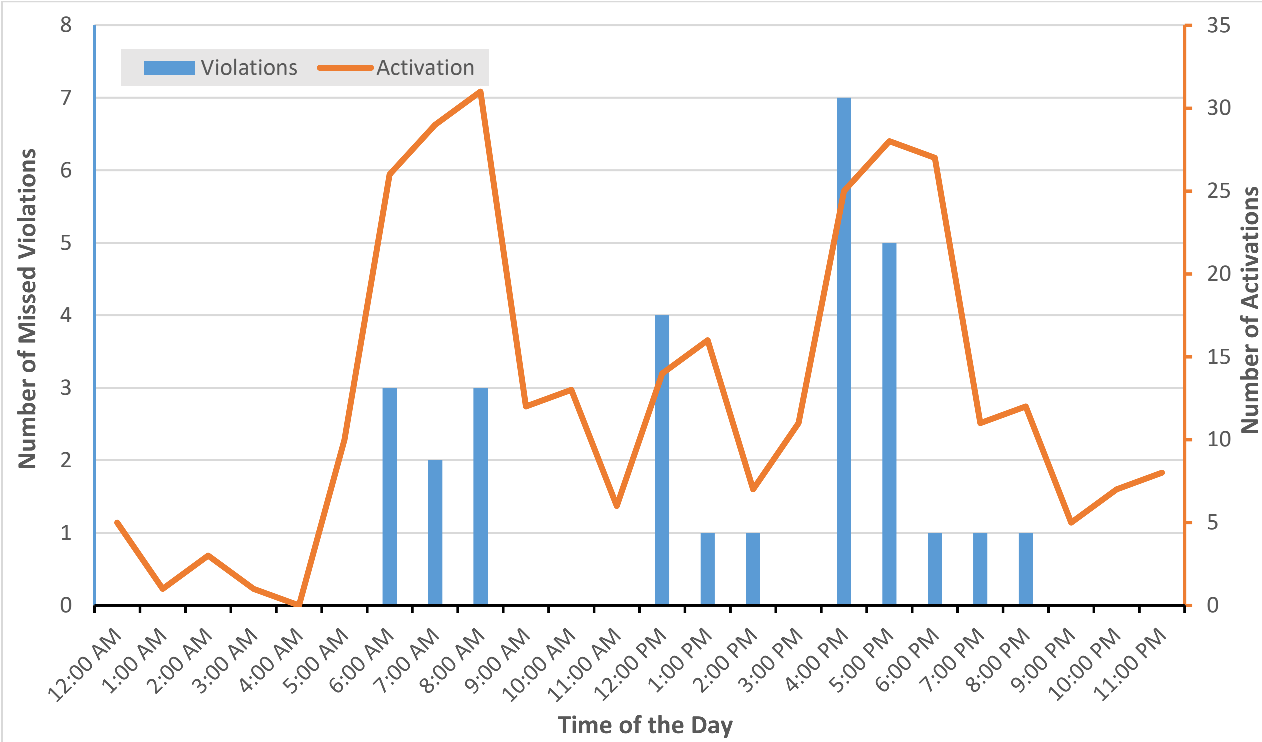


Figure 14. Distribution of Missed Detections by Time of Day

6. Results

A before-and-after design was used to evaluate the effectiveness of the photo enforcement program on drivers' compliance with the grade crossing warning devices. Violations were collected for 14 continuous days before the implementation of the photo enforcement program, from April 14, 2016 to April 27, 2016. The signage and the photo enforcement system were installed on August 8, 2016 and the City of Orlando started issuing violation notices on August 11, 2016. Eight months after the implementation of the photo enforcement system, violations were then again collected for 14 continuous days from April 13, 2017 to April 26, 2017. Since Orlando is a vacation destination and there is an influx of tourists during different times of the year, post-installation data was collected exactly a year apart to make sure that two data collection periods had exposure to a similar population set. Table 8 shows the data collection, photo enforcement system installation, and photo enforcement program schedule for the East Princeton Street grade crossing.

Table 8. Project Schedule

Description	Start Date	End Date	Total Days
Pre-installation data collection	4/14/2016	4/27/2016	14 days
Photo enforcement signage installation	8/8/2016	8/8/2016	1 day
Photo enforcement system installation (westbound)	8/8/2016	8/8/2016	1 day
Photo enforcement system operational (westbound)	8/11/2016	To date	
Post-installation data collection (8 months after installation)	4/13/2017	4/26/2017	14 days

A grade crossing warning device violation occurs when a motorist disregards an active warning device (flashing lights and gates) and traverses a grade crossing during an activation period. An activation period starts when the lights begin to flash and ends when the gates finish their ascent to a vertical position and the lights stop flashing. Violations were classified into four types: Type I, Type II, Type III, and Type IV. Descriptions of each violation are presented in section 3.1.

Each activation was recorded as a unique event regardless of whether or not there was violation. The time and lane of travel during a violation were recorded for Type I, II, and III violations. Almost all vehicles that were stopped behind the fully deployed gate committed a Type IV violation. It would have been very time-consuming to record all Type IV violation details (time, lane). Therefore, only the total number of vehicles that committed Type IV violations and the total number of lead vehicles that stopped during this phase were recorded.

6.1 Data Characteristics

A total of 1,310 activations (584 pre-installation and 726 post-installation) were recorded over the 4-week data collection period. Figure 15 shows the distribution of activations by day of the week. As can be seen, the majority of the activations occurred during weekdays as opposed to weekends for both pre- and post-installation periods (96 percent for pre-installation and 94 percent for post-installation). The SunRail commuter rail system, which accounted for majority of the activations, does not operates on weekends.

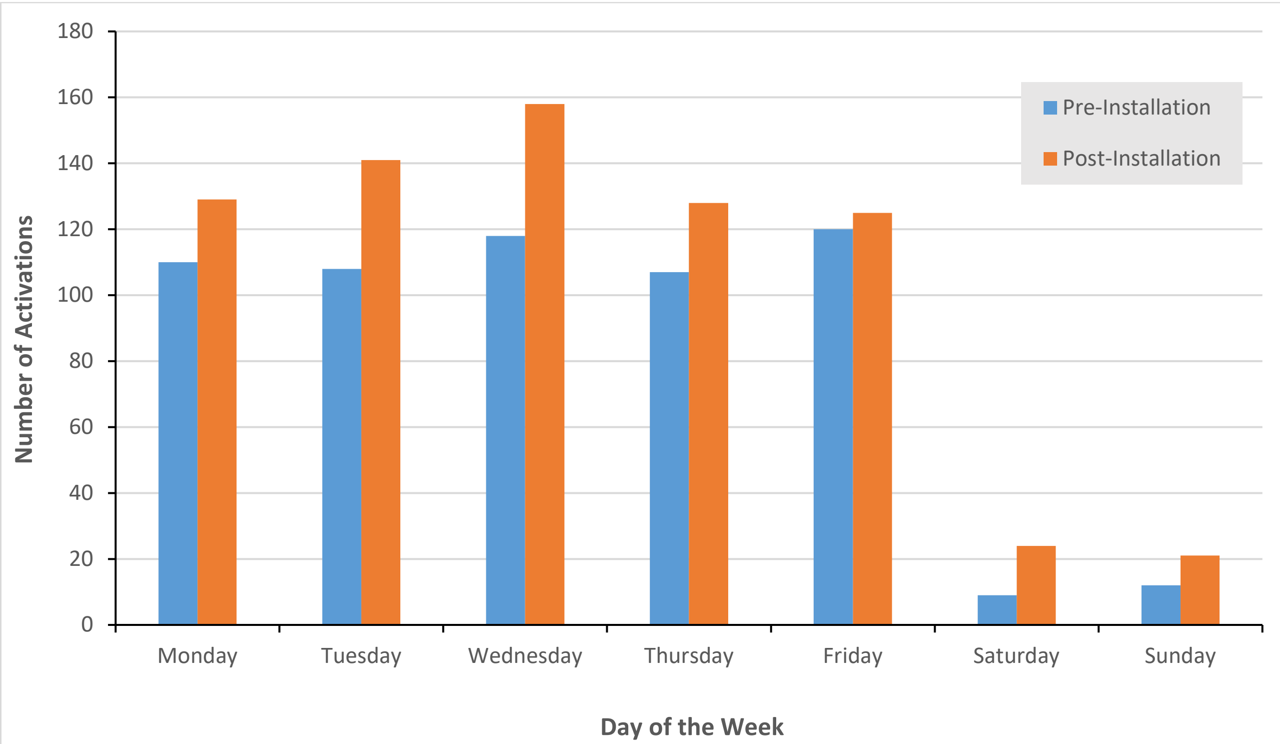


Figure 15. Distribution of Activations by Day of Week

Table 9 shows the distribution of activations by type of train for the pre-installation and post-installation periods, and for overall activations. Activations involving SunRail made up the majority of activations for both pre-installation (57.4 percent) and post-installation (47.1 percent) periods, followed by activations with no train. A "no train" activation was defined as when the crossing warning devices are activated without train presence at the crossing. No train activations occurred most frequently immediately preceding activations for southbound SunRail trains. Southbound SunRail trains arriving at the nearby station (the Florida Hospital Health Village station) before traversing the crossing triggered a gate activation; however, this activation would "time out" after about 60 seconds if the train did not move.

Table 9. Distribution of Activations by Type of Train

	Pre-Installation	Post-Installation	Total
SunRail	335 (57.4%)	342 (47.1%)	677 (51.7%)
Amtrak	52 (8.9%)	52 (7.2%)	104 (7.9%)

	Pre-Installation	Post-Installation	Total
CSX	28 (4.8%)	60 (8.3%)	88 (6.7%)
No Train	169 (28.9%)	255 (35.1%)	424 (32.4%)
Maintenance	0 (0.0%)	17 (2.3%)	17 (1.3%)
Total	584	726	1,310

6.2 Violation Counts and Rates

From the 1,310 activations, a total of 8,060 violations (all 4 types) were coded. A total of 3,941 were coded prior to the implementation, and 4,119 were coded after the implementation of the photo enforcement-based education program. Figure 16 shows the distribution of the 8,060 violations by day of the week for both pre- and post-installation periods. As can be seen, there were more violation counts during the post-installation period than during the pre-installation period for all days of the week except Fridays and Sundays. However, when analyzed by violation rate, there were less violations per activation during the post-installation period for all days of the week. The violation rates will be discussed later in this section.

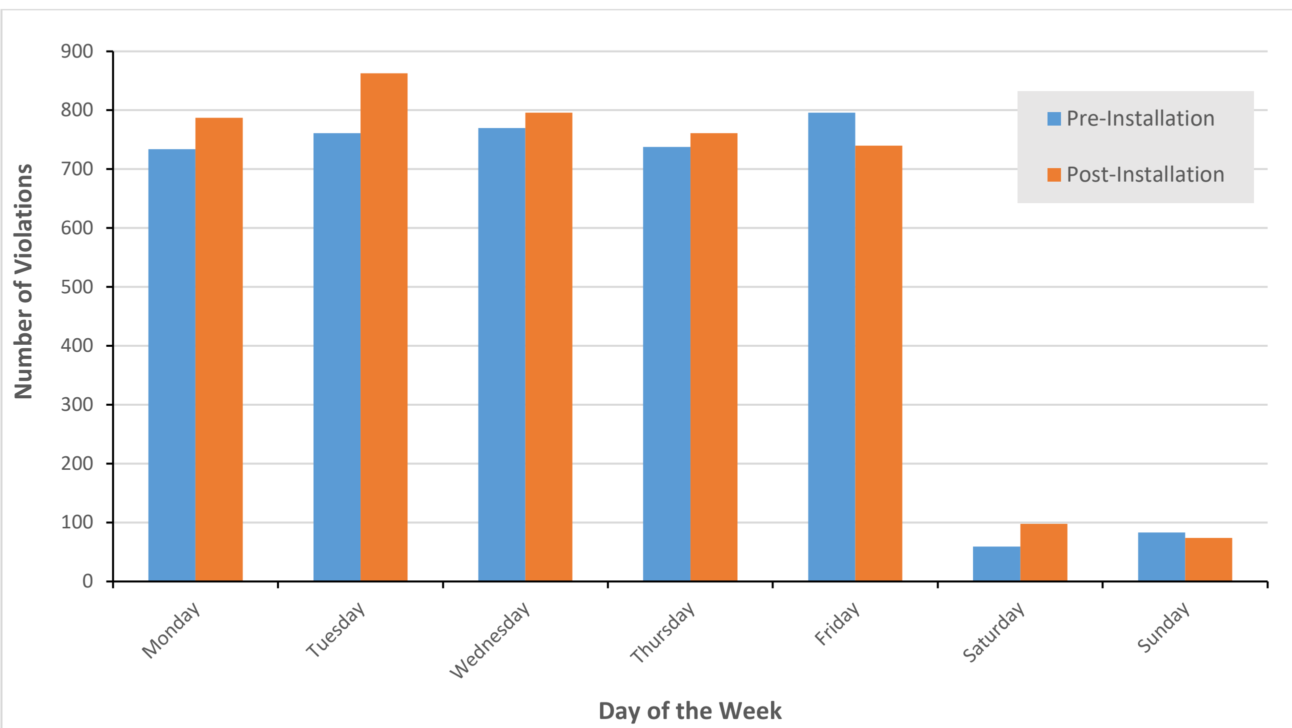


Figure 16. Distribution of Violations by Day of the Week

Figure 17 shows the distribution of the 8,060 violations by time of the day for the pre- and post-installation period. As expected, the trend shows that the violations occurred most during morning rush hours from 7:00 a.m. to 9:00 a.m. and during afternoon rush hours from 4:00 p.m. to 7:00 p.m.

To evaluate the effectiveness of the photo enforcement program on driver compliance of grade crossing warning devices, violation counts were normalized on an hour-by-hour basis over each data collection period. Activations and violations counts were summed for each 1-hour period for both the pre- and post-installation period. This means the initial sample was 336 hours for each data collection period (14 days multiplied by 24 hours). Hours of the day with zero activations were treated as missing data. After removing hours with zero activations, the sample was 206 hours for the pre-installation period and 237 hours for the post-installation period.

The average hourly rate of violations per activation was calculated by dividing the violation counts for each 1-hour period by the associated number of activations. Table 10 shows violation counts and rates before and after the implementation of the photo enforcement program along with the percent reduction for each category. As shown in Table 10, the average hourly rate of violations per activation decreased 15.41 percent, from 6.0296 before to 5.1004 after the installation. Based on a pair t-test, this decrease in rate of violations per activation was statistically significant ($t(205) = 4.18$, $p<0.05$). Appendix F provides the results of paired t-test.

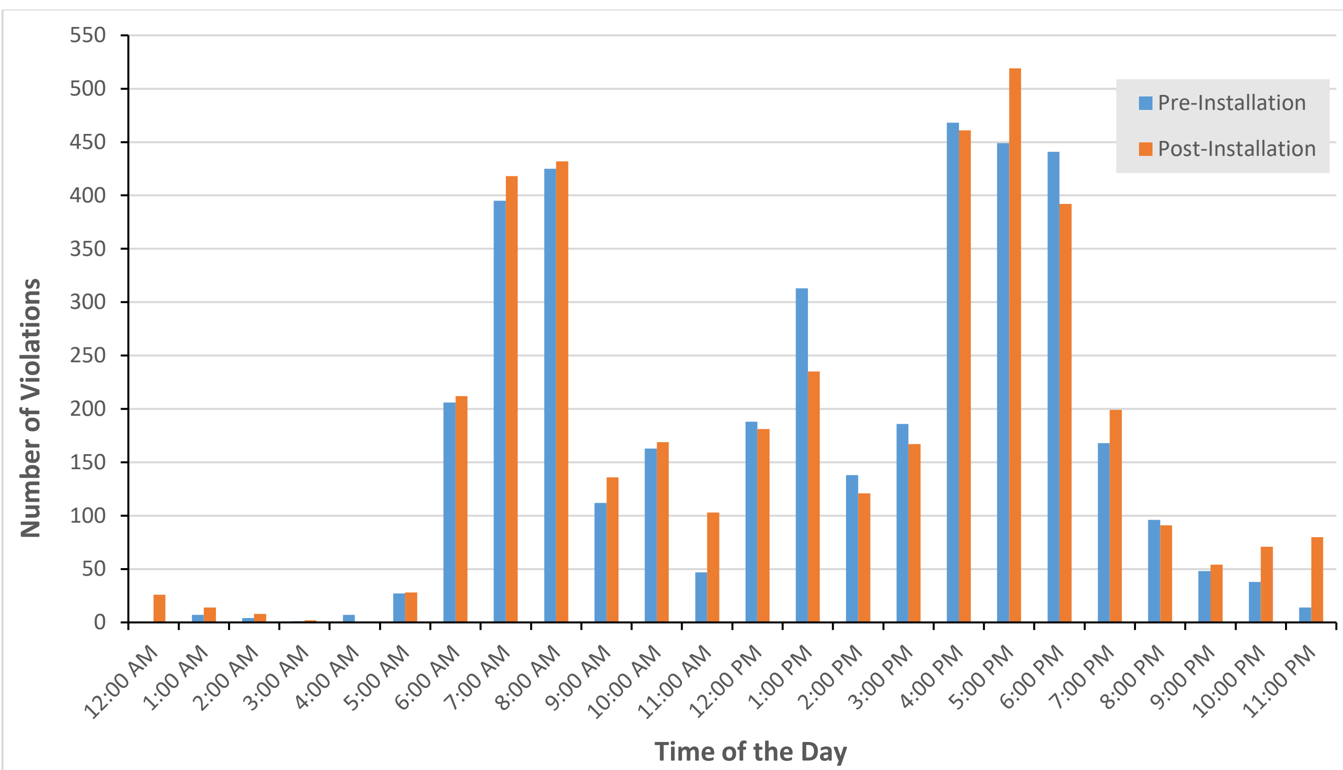


Figure 17. Distribution of Violations by Time of Day

Table 10. Violation Counts and Rates by Period (All Types)

	Before	After	Percent Reduction
Violation Count	3,941	4,120	-4.54%
Activations	584	726	-24.32%
Average Hourly Rate of Violation per Activation	6.0296	5.1004	15.41%

6.3 Violation Counts and Rates by Type of Violation

The violations observed were classified into four different types: Type I, Type II, Type III, and Type IV. As discussed earlier, Type III violations are the riskiest, followed by Type II, Type I, and Type IV.

Table 11 and Figure 18 show the distribution of violation rate by the type of violation and direction of traffic along with the percent reduction for each category.

Table 11. Distribution of Violation Counts and Rate by Type of Violation and Direction of Traffic

Violation Type	Period	Westbound		Eastbound		Both Directions	
		Number of Violations	Average Hourly Rate of Violation per Activation	Number of Violations	Average Hourly Rate of Violation per Activation	Number of Violations	Average Hourly Rate of Violation per Activation
Type I	Pre	480	0.7442	498	0.7291	978	1.4733
	Post	467	0.5977	532	0.6710	999	1.2687
	Percent Reduction		19.69%		7.97%		13.89%
Type II	Pre	162	0.2264	102	0.1563	264	0.3827
	Post	156	0.1913	111	0.1397	267	0.3310
	Percent Reduction		15.50%		10.62%		13.51%
Type III	Pre	1	0.0010	0	0	1	0.0010
	Post	1	0	0	0	1	0
	Percent Reduction		100%				100%
Type IV	Pre	***	***	***	***	2,698	4.1727
	Post	***	***	***	***	2,852	3.5007
	Percent Reduction	***	***	***	***		16.10%
Overall	Pre	***	***	***	***	3,941	6.0296
	Post	***	***	***	***	4,119	5.1004
	Percent Reduction	***	***	***	***		15.41%

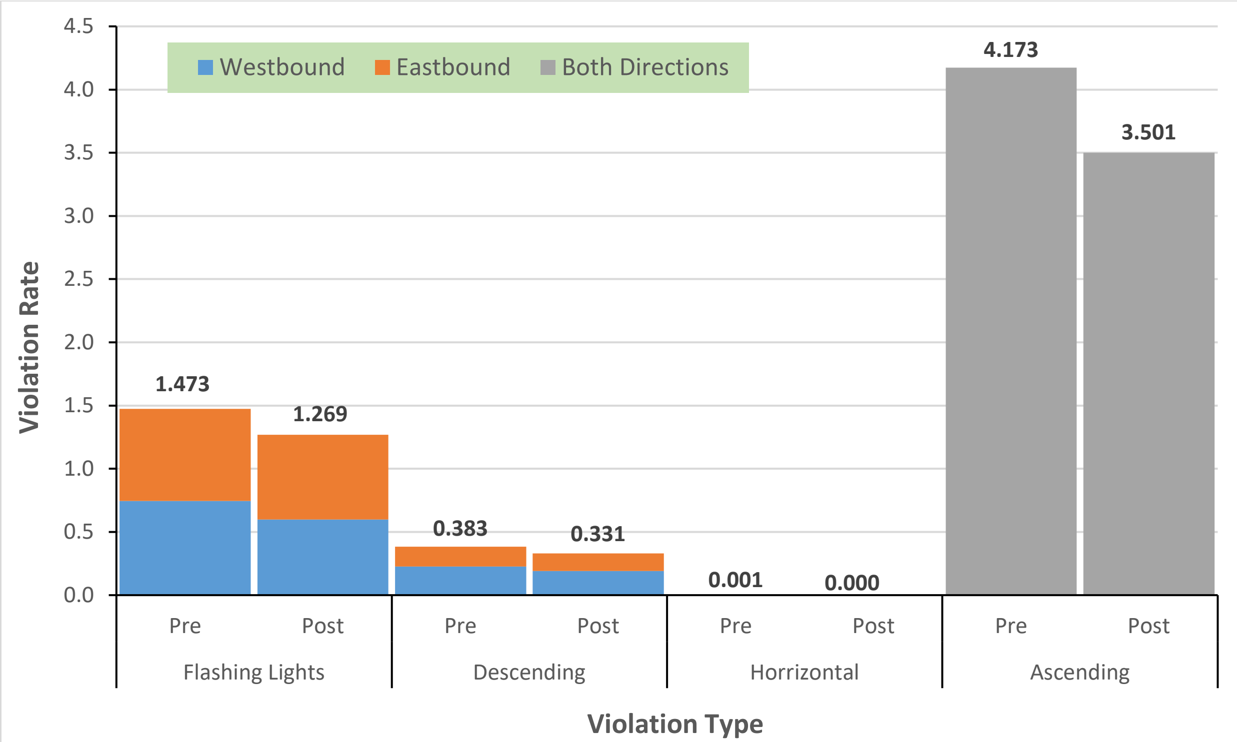


Figure 18. Violation Rate by Violation Type and Direction of Traffic

Type I Violations: Type I violations occur when vehicles traverse the crossing while the lights are flashing but before the gates start to descend. The average time of this phase at this crossing was 5 seconds. A paired t-test showed a statistically significant change in the Type I violation rate from before to after the installation of the photo enforcement system ($t(205) = 2.12$, $p<0.05$). The Type I violation rate decreased 13.9 percent, from 1.473 violations per activation per hour to 1.269 violations per activation per hour.

As discussed earlier in the report, only westbound traffic was monitored by the system. For the westbound direction, the Type I violation rate decreased by 19.69 percent, from 0.744 violation per activation per hour to 0.598 violation per activation per hour. In comparison, the eastbound direction experienced a 7.97 percent decrease in the Type I violation rate, from 0.729 violation per activation per hour to 0.671 violation per activation per hour.

The research team conducted a two-way analysis of variance (ANOVA) to test whether the factors time (pre/post) and direction (eastbound/westbound) had significant effect on the Type I violation rate. Consistent with the above analysis, hours of the day with zero activations were treated as missing data. There was a statistically significant difference in the Type I violation rate between pre and post ($F(1,882) = 7.41$, $p<0.05$)), but there was no statistically significant difference between the direction of traffic ($F(1,882) = 0.01$, $p>0.05$). The interaction between time and direction was also not statistically significant ($F(1,882) = 0.17$, $p>0.05$). Appendix G provides the results of two-way ANOVA test for Type I violations.

Additionally, the research team also collected vehicles' action (violation or stop) during each of the four violation phases. A driver approaching an active grade crossing with warning devices activated could decide to either ignore the warning of an approaching train and traverse the crossing, or stop at the crossing until the lights stopped flashing and the gates were all the way up. For this analysis, only lead vehicles that stopped were considered because the other following vehicles had no choice but to stop once the lead vehicle stopped.

Figure 19 shows the distribution of vehicle actions during the flashing lights phase for pre- and post-installation periods. Occurrences of lead vehicles stopped during this phase increased from 124 (11 percent) to 161 (14 percent) from pre- to post-installation.

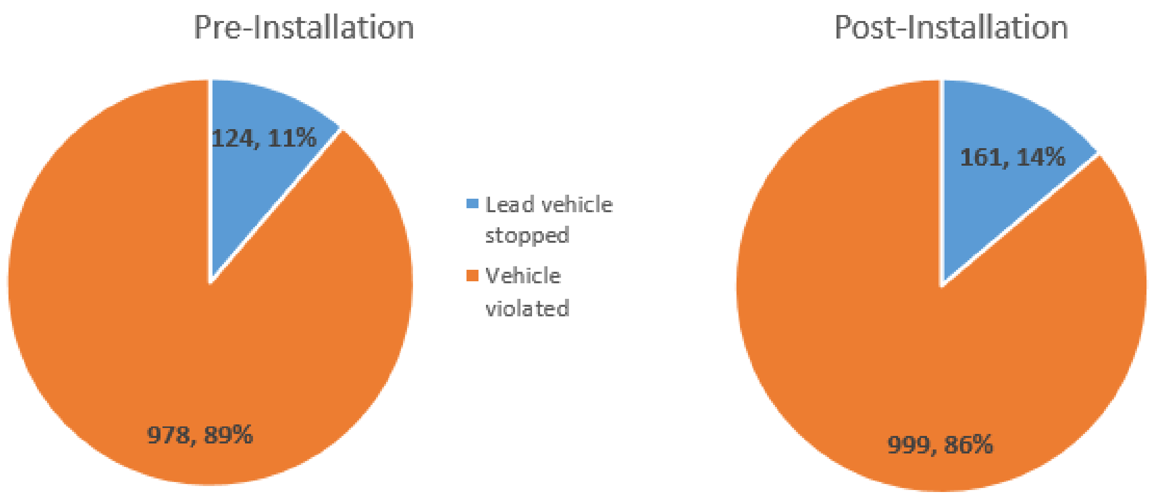


Figure 19. Vehicle Actions during Flashing Lights Phase

An example of Type I violations is shown in Figure 20. In Figure 20, the two vehicles (circled in green) committed a Type I violation by traversing the crossing during the flashing lights phase at 06:41:10. The crossing activation occurred at 06:41:08.

Figure 20. Example of Type I Violations in Westbound Direction (Green Circles)

Type II Violations: Type II violations occur when vehicles traverse the crossing while the lights are flashing and gates are descending. The average time of this phase at this crossing was about 11.6 seconds. No statistically significant change in the Type II violation rate was observed from before to after the installation of the photo enforcement system ($t(205) = 1.21$, $p>0.05$). The overall Type II violation rate decreased 13.5 percent, from 0.383 violation per activation per hour to 0.331 violation per activation per hour.

For the westbound direction, the Type II violation rate decreased by 15.50 percent, from 0.226 violation per activation per hour to 0.215 violation per activation per hour. In comparison, the eastbound direction experienced a 10.62 percent decrease in the Type II violation rate, from 0.156 violation per activation per hour to 0.140 violation per activation per hour.

The results of two-way ANOVA showed that there was no statistically significant difference in Type II violation rate between pre and post ($F(1, 882) = 2.97$, $p>0.05$) and between the direction of traffic ($F(1, 882) = 0.24$, $p>0.05$). However, the interaction between time and direction was significant ($F(1, 882) = 13.87$, $p<0.05$), such that there was a greater decrease in the Type II violation rate in the westbound direction than there was eastbound. Appendix H provides the results of two-way ANOVA test for Type II violations.

Figure 21 shows the distribution of vehicle actions during the gate descend phase. Occurrences of lead vehicles stopped during this phase increased from 1,058 (80 percent) to 1,181 (82 percent) from pre- to post-installation.

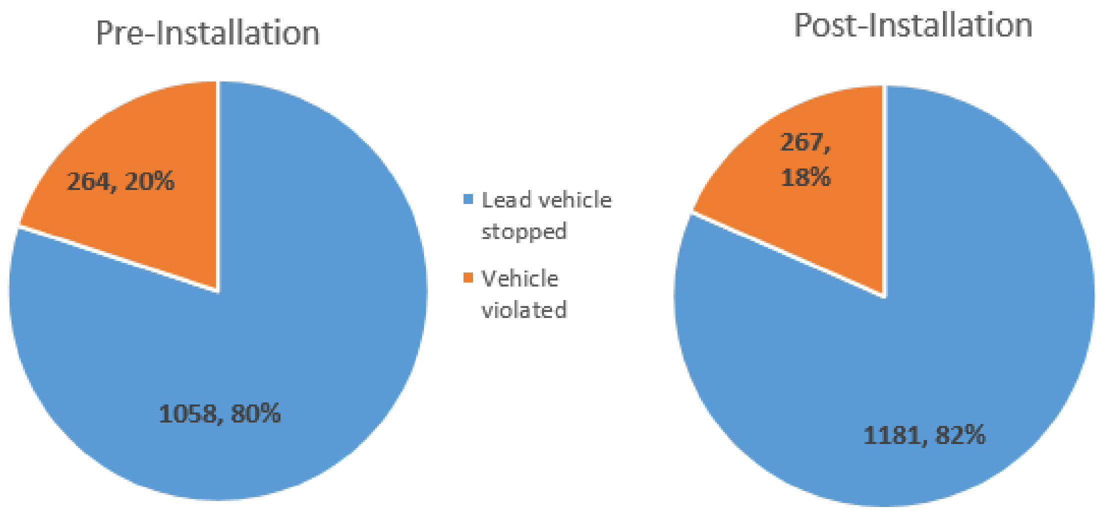


Figure 21. Vehicle Actions during Gate Descend Phase

An example of a Type II violation is shown in Figure 22. In Figure 22, the vehicle (circled in yellow) committed a Type II violation by traversing the crossing during the gate descent phase at 07:13:23. The crossing activation occurred a full 8 seconds prior at 07:13:15.

Figure 22. Example of Type II Violation in Westbound Direction (Yellow Circle)

Type III Violations: Type III violations occur when vehicles traverse the crossing while the gates are in the horizontal position. There were total of two Type III violations, one during the pre-installation period and another during post-installation period.

The one violation recorded during the pre-installation period consisted of a vehicle *attempting* to stop before the gate descended but actually coming to a stop under the gate. The driver then decided to drive across the tracks 3.2 seconds after the gates were down. A southbound SunRail train entered the crossing 16.2 seconds after the vehicle crossed the tracks.

The one violation recorded during the post-installation period consisted of a vehicle driving in the opposite direction of traffic and entering the parking lot just past the crossing in the eastbound direction. The vehicle entered the crossing 69 seconds after the gates were down. This was "no train" activation event. Figure 23 shows this vehicle (circled in red) traversing the crossing with the gates in a horizontal position.

Except for the two unique violations discussed above, all vehicles that arrived at the crossing during the pre and post periods stopped at the crossing. A total of 716 lead vehicles stopped during the pre-installation period, and 834 lead vehicles stopped during the post-installation period.

Figure 23. Example of Type III Violation in Eastbound Direction (Red Circle)

Type IV Violations: Type IV violations occur when vehicles traverse the crossing while the gates are ascending and lights are still flashing. The average time of this phase at this crossing was about 8.4 seconds. A significant change in the Type IV violation rate was observed from before to after the installation of the photo enforcement system ($t(205) = 4.12$, $p<0.05$). The overall Type IV violation rate decreased 16.10 percent, from 4.173 violations per activation per hour to 3.501 violations per activation per hour. As discussed earlier, no detail information (lane, time) was collected for Type IV violations. Therefore, an analysis of Type IV violations by direction of traffic was not performed.

Lead vehicles that had stopped in one of the three previous violation phases totaled 1,898 vehicles during the pre-installation period and 2,176 post-installation. Figure 24 shows the distribution of lead vehicle actions during the gate ascending phase. As can be seen, occurrences of lead vehicles stopped during this phase increased from 166 (9 percent) to 229 (11 percent) from pre- to post-installation.

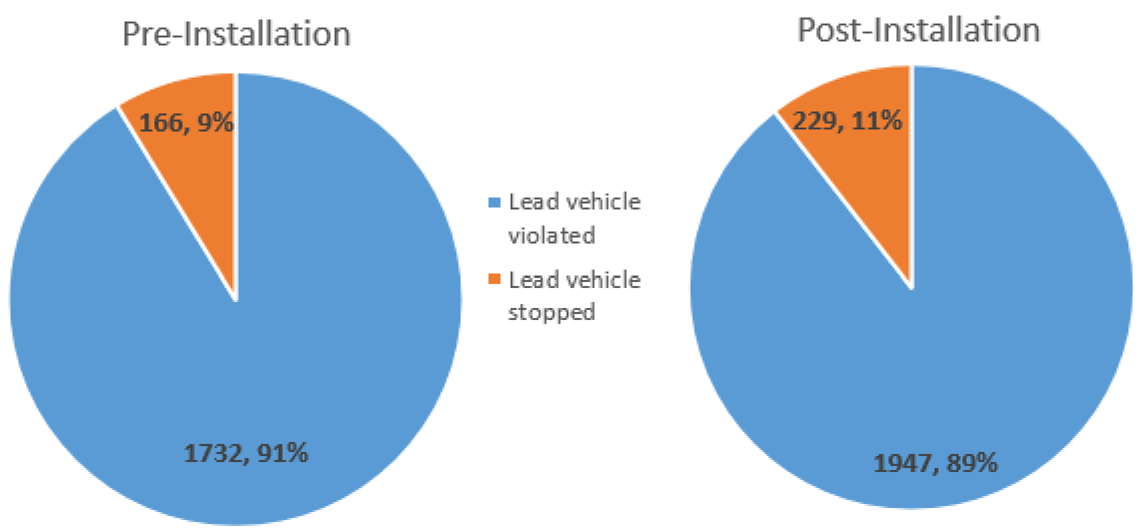


Figure 24. Lead Vehicle Actions during Gate Ascend Phase

In addition to lead vehicles that committed this violation, following vehicles did as well. There were additional 966 following vehicles that committed this violation during the pre-installation period, bringing the total ascending gate violations to 2,698 (1,732 + 966). During the post-installation period, an additional 905 following vehicles committed ascending gate violations, totaling 2,852 (1,947 + 905) ascending gate violations.

An example of Type IV violations is shown in Figure 25, where the two vehicles (circled in green) committed a Type IV violation by traversing the crossing during the gates ascent phase at 06:34:38. The crossing activation ended about 1 second later at 06:34:39.

Figure 25. Example of Type IV Violations (Green Circles)

6.4 Summary of Findings

To evaluate the effectiveness of operating a photo enforcement-based driver education program at the East Princeton Street grade crossing, the Volpe Center sought answers to the following questions:

- Does operating a photo enforcement-based driver education program significantly reduce the number of vehicles that violate grade crossing warning devices?

  Findings: Yes, the research team observed a 15.4 percent reduction in the overall violation rate after the implementation of the photo enforcement-based driver education program at the East Princeton Street crossing. The overall violation rate dropped from 6.0296 violations per activation per hour to 5.1004 violations per activation per hour. A pair t-test confirms that this reduction is significant ($t(205) = 4.18$, $p<0.05$).

- Does the photo enforcement-based driver education program significantly reduce all types of violations (flashing light phase, descending gate phase, horizontal gate phase, and ascending gate phase)?

  Findings: A significant reduction in violation rate was observed after the implementation of the photo enforcement-based driver education program during the flashing light phase ($t(205) = 2.12$, $p<0.05$) and during the ascending gate phase ($t(205) = 4.12$, $p<0.05$). Violations during the flashing lights phase decreased 13.9 percent, from 1.473 to 1.269 violations per activation per hour, and violations during the ascending gate phase decreased 16.1 percent, from 4.173 to 3.501 violations per activation per hour.

No significant reduction in violation rate was observed after the implementation of the photo enforcement-based driver education program during the descending gate phase (t(205)=1.21, p>0.05) and during the horizontal gate phase (t(205)=1.0, p>0.05). The violation rate during the descending gate phase decreased 13.5 percent, from 0.0.383 to 0.331 violation per activation per hour, and the violation rate during the horizontal gate phase decreased 100 percent, from 0.0001 to 0.0 violations per activation per hour.

- Is the automated photo enforcement system effective in detecting vehicles that commit descending gate violations?

  Findings: Over a 5-day period, the Volpe staff manually coded 67 descending gate violations in the westbound direction at the East Princeton Street crossing. During that same period and in the same traffic direction, the automated photo enforcement system detected 37 of those 67 descending gate violations (55.2 percent). However, it is important to point out that of the 29 missed detections, 5 were coded at the same time as when the gate started to descend, and an additional 13 were coded within 1 second of the gate descend time.

7. Conclusion

The photo enforcement-based driver education program was effective at changing driver behavior around the East Princeton Street grade crossing. The average hourly rate of violations per activation decreased from 6.0297 before to 5.1004 after the photo enforcement program was implemented. This added up to a 15.4 percent reduction in the grade crossing violation rate over the evaluation period. Additionally, all four violation types experienced a reduction in violation rate after the implementation of the photo enforcement-based driver education program. The average hourly rate of violations per activation during the flashing lights phase decreased 13.9 percent, from 1.473 to 1.269; the average hourly rate of violations per activation during the descending gate phase decreased 13.5 percent, from 0.383 to 0.0.331; the average hourly rate of violations per activation during the horizontal gate phase decreased 100 percent, from 0.001 to 0; and the average hourly rate of violations per activation during the ascending gate phase decreased 16.1 percent, from 4.173 to 3.501. These changes in average hourly rate of violations per activation can be seen graphically in Figure 26.

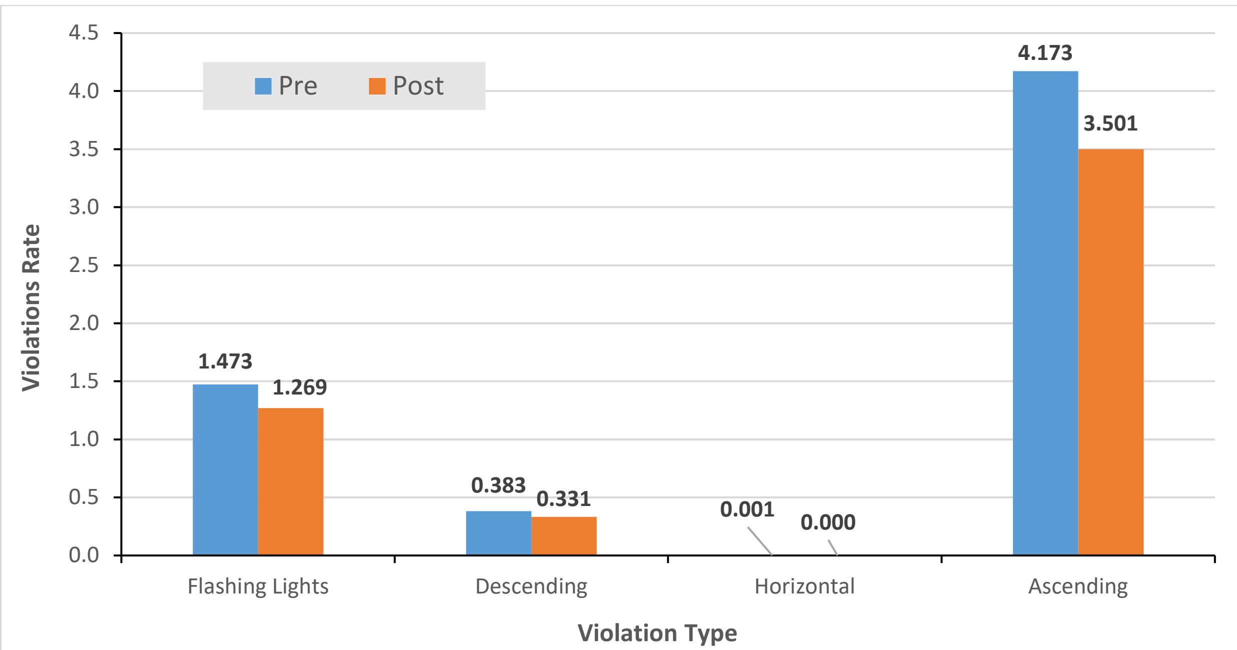


Figure 26. Violation Rate by Violation Type

Survey results revealed that about 35 percent of the respondent violators understood the photo enforcement signage at the crossing while 60 percent noted that they did not saw the sign. When asked why they drove through the crossing when the warning devices were activated, 27 percent noted that they did not see the activated signals, 17 percent noted they felt they had enough time to get through, and 11 percent noted that they did not see the train. Feedback on the overall program was generally positive.

7.1 Next Steps

The results presented in this report are from a before-and-after comparative analysis of driver actions at the East Princeton Street grade crossing 1 year apart (April 2016 vs. April 2017), where the "after" period was 8 months after the start of the photo enforcement-based driver education program. The following are potential next steps for this study:

- A 2-year analysis, where data from April 2018 would be compared to the initial analysis (April 2016 vs. April 2017). The City of Orlando continues to run the program at the East Princeton Street crossing, and analyzing the April 2018 driver data at the crossing would provide information on the long-term effect of the program at this specific location. The program would have run for about 20 months as of April 2018.
- Install and evaluate another highway-rail grade crossing with different characteristics, and compare results. A comparison with another highway-rail grade crossing may explain how much crossing geometry and vehicular traffic patterns affect results. Each of these characteristics may affect the way vehicles react to the active warning devices and signage. Testing similar implementations at other grade crossings may help to better understand if certain crossing characteristics are better suited to this type of program.
- Evaluate photo enforcement signage only at a highway-rail grade crossing and compare the results with the results of this study. The City had initially planned to install photo enforcement systems at up to six highway-rail grade crossings. Currently, only one crossing is equipped with the photo enforcement system but Orlando had installed photo enforcement signage on at least two additional highway-rail crossings (West Central Boulevard and West South Street). The Volpe Center had installed data collection equipment and collected video data before and after the installation of signage at both crossings in support of this program.

8. References

[1] FRA Office of Safety Analysis Web site: http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx accessed on February 22, 2018.

[2] Orlando STOPS Red Light Enforcement Program: http://www.cityoforlando.net/transportation/orlando-stops/ accessed on February 22, 2018.

[3] Yang, C. Y. D, and Najm, W. G. (2006). Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras. Report No. DOT-VNTSC-NHTSA-05-01. Washington, DC: National Highway Traffic Safety Administration.

[4] Fitzpatrick, K., Carlson, P. J., Bean, J. A., and Bartoskewitz, R. T. (1997). Traffic Violations at Gated Highway-Railroad Grade Crossings. Austin, TX: Texas Department of Transportation.

[5] Hallmark, S., Oneyear, N., and McDonald, T. (November 2011). Evaluating the Effectiveness of Red Light Running Camera Enforcement in Cedar Rapids and Developing Guidelines for Selection and Use of Red Light Running Countermeasures. Ames, IA: Iowa Department of Transportation and Midwest Transportation Consortium.

[6] Sposato, S., Bien-Aime, P., and Chaudhary, M. (2006). Public Education and Enforcement Research Study. Report No. DOT-VNTSC-FRA-06-03. Washington, DC: Federal Railroad Administration.

Appendix A.
Example of a Violation Notice

This program has been initiated to increase roadway safety and to reduce accidents, injuries and fatalities.

WARNING NOTICE OF RAILROAD CROSSING VIOLATION

Orlando STOPS Program
400 S. Orange Ave.
Orlando, Florida 32801-4990

[redacted]

Plate Number: [redacted]
Password:
View your violation at
www.ZeroFatality.com

ORLANDO STOPS
RAILROAD CROSSING SAFETY INITIATIVE

THIS IS <u>NOT</u> A NOTICE OF VIOLATION. YOU ARE NOT REQUIRED TO PAY A PENALTY, GO TO COURT OR RESPOND IN ANY WAY. In the future, please exercise caution when approaching an active railroad crossing. The City of Orlando cares about your safety.

Your vehicle was recorded traveling through the active rail crossing at:

Location: Princeton St WB @ Alden Rd
Date: 05/26/2017 Time: 15:43:02
Plate Number: [redacted] Vehicle Make: [redacted]
Red Time:

This warning letter is part of an educational effort led by the City of Orlando and the Federal Railroad Administration along with SunRail to advise you of a serious potential safety issue. The pictures on this notice taken by our railroad crossing security camera show a vehicle registered to you that appears to have violated F.S. 316.1575 and/or 316.1576.

According to national statistics, 96% of all rail-related fatalities and injuries occur at highway rail-grade crossings or while trespassing on railroad property, and most of these collisions can be prevented. According to Florida Statutes, a vehicle must:

- Stop at least 15 feet from a rail crossing when signal lights are activated;
- Not proceed through, around, or under any crossing gate or barrier while the gate or barrier is closed or is being opened or closed; and
- Not enter the crossing without sufficient space or undercarriage clearance to drive completely through the crossing without stopping.

As motorists, we need to always be prepared to stop at the railroad crossing; slow down, look both ways, listen; obey warning devices; and check that you have enough room on the other side of the tracks for your vehicle to cross safely. Finally, you should never race a train, and never stop on tracks. Through the City of Orlando, Orlando STOPS Railroad Crossing Safety Initiative campaign, in collaboration with the U.S. Department of Transportation Federal Railroad Administration, SunRail and Sensys America, Inc, we are working to increase awareness of this serious potential safety hazard.

At your earliest convenience, we would appreciate your assistance by participating in a brief survey, which we will use to further evaluate the effectiveness of this pilot program and improve safety at railroad crossings. Please take a moment to complete the survey that is available on line at:

https://www.surveymonkey.com/r/orlandostopsrailroad

Thank you for your attention to this matter.

Sincerely,

ORLANDO STOPS
407-246-2060
The City of Orlando cares about your safety.

VIEW YOUR VIOLATION ONLINE:
You may view your images and video online at:
www.ZeroFatality.com
Please enter Plate Number and Password provided below to enter the secure web site.

Plate Number: [redacted]
Password:

sensys america

Sensys America, Inc. is proud to provide our **RailRoad-Safe** system to improve the safety of our citizens. www.ZeroFatality.com is powered by Sensys America, Inc. www.sensysamerica.net

Appendix B.
Example of Educational Material

To Promote, Protect and Improve the Health, Safety and Welfare of our Citizens

FRA
Federal Railroad Administration

www.ZeroFatality.com

SunRail

Railroad Crossing Warnings

LOOK FOR and OBEY all railroad crossing signs and signals

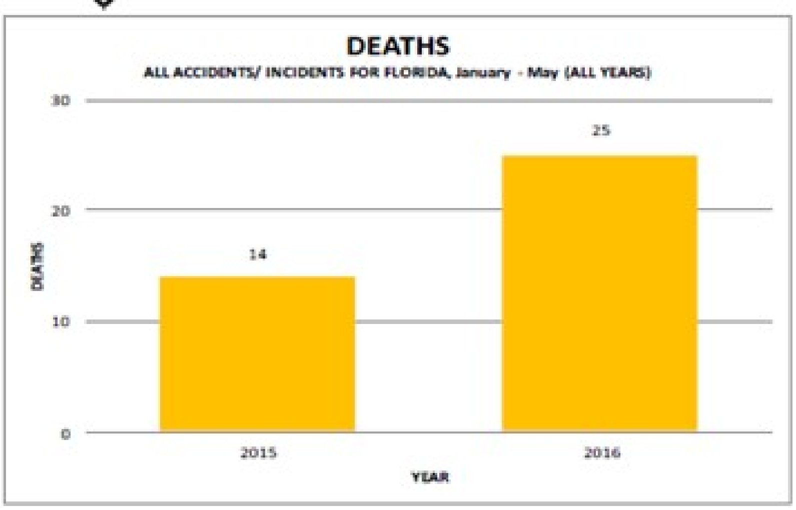
Advance warning signs—a round, yellow sign with black "**RR**" tells you that a highway-rail crossing is ahead-be prepared to stop

Pavement markings—when you see the "**RR**" painted on the pavement, be prepared to stop

STOP signs at railroad crossings—the same laws apply here as for any other intersection regulated by a **STOP** sign. You must come to a complete stop. If no trains are coming, you may proceed.

Crossbuck signs are like yield signs—*You must YIELD to trains.*

- Slow down and be prepared to stop when you see the crossbuck sign.
- A sign below the crossbuck indicates the number of tracks.



Appendix C.
Survey Questions

1. How often do you encounter <u>this particular</u> railroad crossing while driving a vehicle?
   - ☐ Every day
   - ☐ A few time a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ First time

2. How often do you see a train at this crossing?
   - ☐ Always
   - ☐ Often
   - ☐ Sometimes
   - ☐ Rarely
   - ☐ Never

3. How often do you encounter <u>other</u> railroad crossings while driving a vehicle?
   - ☐ Every day
   - ☐ A few time a week
   - ☐ A few times a month
   - ☐ A few times a year
   - ☐ First time

4. Did you understand the photo enforcement sign at the railroad crossing?
   - ☐ Yes
   - ☐ No
   - ☐ I did not see the sign

7. Why did you drive through the railroad crossing when the warning devices were activated (e.g., lights flashing, crossing gates moving)? (check all that apply)
   - ☐ I did not see the train
   - ☐ I did not see the activated crossing signals (e.g., lights flashing, gate lowering)
   - ☐ I felt I had enough time to get through
   - ☐ I followed the car in front of me
   - ☐ I felt the wait would be too long
   - ☐ I was in a rush (e.g., late for an appointment)
   - ☐ I was unfamiliar with the rules
   - ☐ Other
   - ☐ I don't know

8. Were you using a mobile device?
   - ☐ Yes, texting
   - ☐ Yes, talking hands free
   - ☐ Yes, using a map
   - ☐ Yes, for another purpose
   - ☐ No

9. What time of day did you drive through the railroad crossing?
   - ☐ Morning (5am-12pm)
   - ☐ Afternoon (12pm-4pm)
   - ☐ Evening (4pm-8pm)
   - ☐ Night (8pm-12am)
   - ☐ Late Night (12am-5am)

5. Were there other passengers in your vehicle?
   - ☐ Yes – adults only
   - ☐ Yes – children and/or adults
   - ☐ No

6. What were the weather conditions?
   - ☐ Sunny
   - ☐ Cloudy
   - ☐ Raining

10. What day of the week did this happen?
   - ☐ Weekday (Sunday – Thursday)
   - ☐ Weekend (Friday night – Saturday night)

11. About you

    Age: ____________

    Gender:___________

12. Please share any questions or comments you have about this railroad crossing or this survey.

____
____
____
____

Appendix D.
Survey Responses

Note: Of the total 12 survey questions, only one question's response is "check all that apply" (#7). The rest were all one-answer questions. However, the total for some survey questions (besides #7) add up to more than 133 because some respondents selected more than one option for answer responses.

1. How often do you encounter this particular railroad crossing while driving a vehicle?

Response	Count	Percentage
Every day	24	18%
A few times a week	30	23%
A few times a month	27	20%
A few times a year	28	21%
First time	24	18%
No Answer	0	0%
Total	133	100%

2. How often do you see a train at this crossing?

Response	Count	Percentage
Always	1	1%
Often	8	6%
Sometimes	35	26%
Rarely	55	41%
Never	33	25%
No Answer	2	1%
Total	134	100%

3. How often do you encounter other railroad crossings while driving a vehicle?

Response	Count	Percentage
Every day	26	20%
A few times a week	26	20%
A few times a month	30	23%
A few times a year	43	32%
First time	7	5%
No Answer	1	1%

Response	Count	Percentage
Total	133	100%

4. Did you understand the photo enforcement sign at the railroad crossing?

Response	Count	Percentage
Yes	47	35%
No	7	5%
I did not see the sign	81	60%
No Answer	0	0%
Total	135	100%

5. Were there other passengers in your vehicle?

Response	Count	Percentage
Yes - adults only	29	22%
Yes - children and/or adults	8	6%
No	94	71%
No Answer	2	2%
Total	133	100%

6. What were the weather conditions?

Response	Count	Percentage
Sunny	100	75%
Cloudy	25	19%
Raining	3	2%
No Answer	5	4%
Total	133	100%

7. Why did you drive through the railroad crossing when the warning devices were activated (e.g., lights flashing, crossing gates moving)? (check all that apply)

Response	Count	Percentage
I did not see the train	19	11%
I did not see the activated crossing signals (e.g., lights flashing, gate lowering)	48	27%

Response	Count	Percentage
I felt I had enough time to get through	29	17%
I followed the car in front of me	10	6%
I felt the wait would be too long	4	2%
I was in a rush (e.g., late for an appointment)	10	6%
I was unfamiliar with the rules	13	7%
Other	29	17%
I don't know	8	5%
No Answer	5	3%
Total	175	100%

8. Were you using a mobile device?

Response	Count	Percentage
Yes, texting	0	0%
Yes, talking hands free	1	1%
Yes, using a map	3	2%
Yes, for another purpose	0	0%
No	129	97%
No Answer	0	0%
Total	133	100%

9. What time of day did you drive through the railroad crossing?

Response	Count	Percentage
Morning (5am-12pm)	40	30%
Afternoon (12pm-4pm)	47	35%
Evening (4pm-8pm)	43	32%
Night (8pm-12am)	2	1%
Late Night (12am-5am)	0	0%
No Answer	3	2%
Total	135	100%

10. What day of the week did this happen?

Response	Count	Percentage
Weekday (Sunday-Thursday)	100	75%

Response	Count	Percentage
Weekend (Friday night - Saturday night)	18	14%
No Answer	15	11%
Total	133	100%

11. Age of survey respondent.

Age	Count	Percentage
<= 19	3	2%
20 to 29	20	15%
30 to 39	11	8%
40 to 49	29	22%
50 to 59	22	17%
60 to 69	28	21%
>= 70	14	11%
No Answer	6	5%
Total	133	100%

12. Gender of survey respondent.

Response	Count	Percentage
Male	71	53%
Female	56	42%
No Answer	6	5%
Total	133	100%

Appendix E.
Comments from Survey Responses

#	Comment
1	I was driving the speed limit. The lights and crossing arms began as I was approximately 30 ft. from the tracks. It was safer to avoid slamming the brakes and continue through since I did not see a train. I appreciate the warning instead of a ticket! Thank you!
2	I am past the while line when lights flashing was activated, no crossing gates lowering at the time. Not familiar with the railroad crossing.
3	Will not happen again I will keep my distance and be more aware
4	Thank you for notice. My grandson was operated on for over 8 hours - No excuse - I left hospital happy because of being successful - did not notice sign (RR) or arms starting to drop - again thank you for making me aware
5	I don't recall running this.
6	I did not feel I was far enough in back of rail crossing gate and that gate would come down on my vehicle.
7	I am sure that this is not a good procedure, but it would be nice to have more sign specifically at night. To know not to make a right turn.
8	My vehicle was directly under the railroad crossing lights when the lights became active. The traffic photo clearly shows that. I will be more careful in the future. Thank you
9	Would never knowingly cross against the flashing lights. Believe they started as I was just at or on the tracks.
10	It was a stupid, foolish choice! Thank you for not fining me - which I deserve! It won't happen again
11	I was waiting for a train and it never came.
12	This particular railroad crossing equipment has malfunctioned before! When I approached the crossing, I looked both ways to see if a train was coming. There was no train so I proceeded through. Other cars did the same but that is not why I went through the crossing. I did not hear a train warning either.
13	Signal started as I was approaching. I did not have enough time to break. When I went back the following week I made sure to watch for train signals. In fact, I was actually at the stopped signal arm when the train went by last week.
14	I appreciate the warning notice as it has caused me to take extra care.
15	The reason I did not stop was because the speed I was traveling had placed me too close to the train tracks by the time the crossing gate were coming down.
16	I was already going across when the gates lowered
17	I was behind several cars behind the STOP line. The light at the intersection turned green, I began to follow the vehicles in front of me. As I approached the tracks an ambulance with lights and sirens came rapidly down Orlando Ave causing the line of cars I was in to stop suddenly. I found myself under the gate when the lights and alarm started. I felt my safest route was to get off the track area as the cars in front of me started up as the ambulance passed.
18	Thanks for the education and awareness
19	I think it's an excellent idea to remind us that we were not completely aware of our surroundings especially after a long day at work. This warning will definitely make me more aware of railroad crossings in general. Thanks for the reminder.

#	**Comment**
20	Not from Orlando. Traffic was heavy. Thought I had enough space to get across the track before the rails came down. Sorry my mistake!
21	I will be more careful! Thanks!
22	The crossing lights & bars had come down with no train and then came back up. I started through and the lights and bars started to move. I kept going to avoid the bars hitting my car.
23	The signal changed just as I got to the crossing
24	I was already at a point where crossing through safely (I could see no train and I know I had time to make it across before bars lowered) was a better option than screeching to a halt and stopping on the tracks, then trying to back up off of them. I didn't have enough forewarning to stop in time once the system activated. I wasn't speeding either.
25	I did not do this on purpose. The only thing I can think is that I had spent the night at the hospital where my son was seriously ill, and I was not thinking straight.
26	Thank you for the warning and the education. :)
27	I went to check the signs, and they are on the right side by the pavement, none on the island where I always stayas I make a left into the ramp to join I-4. And going back to my place in the evening, there is none on the island. And I position myself on the left-most to make a left into alden going to the hospital. So unless I am on the right-most lane, I won't see the sign. I had to go and check on these signs, I had to take the right-most lane to be able to see them. And the top yellow light, if I am far enough, I would see it. But coming from alden road making a right into Princeton heading west and staying to the left to get to I-4, it is not low enough for me to see clearly well. And there's no sign at all on the island that says so like the one on the right side by the pavement.
28	Thank you for this survey, it makes thing about what I did.
29	I was taking this route to work because of traffic on John Young parkway. I have no drive this way before. I do not think the safety gates were moving in this photo. Thank you
30	I was accelerating after waiting at a red light. The lights just began to flash as I started to cross the tracks.
31	The crossing signals came down and no train cross in front of me. Then the crossing signals went up and the cars behind me follow
32	The signals began after I crossed the painted roadway warning. Before crossing the marks, it was all clear. Thanks, Keep the train. Give transportation dedicated funding!
33	I have space and time to cross
34	Two trains came back to back, the rails went up and almost immediately went back down and I was caught in the middle and had to make quick decision.
35	The lights did not start flashing until I was too close to stop and the bar did not come down until after I was over the tracks. I had just made right turn onto Princeton and did not see the lights due to the …..
36	When I cross the railroad the train had already pass.
37	The gate comes down rather quickly possibly because of the sunrail station nearby at Florida Hospital. Had traffic behind me and didn't want to slam on my brakes.
38	Heavy traffic caused me to stop near to the tracks, but me car was under the gate, when the crossing lights/arm went off. I moved forward to the other side of the tracks.
39	The signal came on, activated, late. I was crossing the tracks when it initiated.
40	The trees block the lights hard to see

#	Comment
41	The train had already passed and the bats were going up. I started driving across the tracks before the bats were completely up.
42	I honestly did not see the lights/hear any sounds. Brighter lights and maybe an alarm would be helpful.
43	It's dangerous if a train hits a car or a person. I try to follow railroad working (?) instruction
44	My guess is I didn't see the lights due to the sun, and red/green lights are the best colors to use
45	Sorry, the lights came on as I was driving through - I didn't see them. I know to stop and always do when lights flashing and bells sound.
46	I was not avoiding the warning. I was already near the crossing when lights came on. If I would have stopped I would have been on the tracks. I didn't have time to stop. I will make sure though that I will follow all safety precautions at all railroad crossings in the future.
47	This particular crossing at Princeton/Alden is in need of "smoothing". It hurts to drive over it. Otherwise, I am very sympathetic to the goals of this survey, feel properly chagrinned, and my loved one that takes SunRail yelled at me and told me not to make her train the one that kills me! Great Job FRA - Please keep up the great work.
48	Thank you for only giving a warning. I saw the picture of this incident and do not think I am at fault. I was far beyond the tracks when the ams came down. It was very similar to driving through a yellow light. It would have been more dangerous to break hard and risk getting hit by the car behind me. I had momentum and cleared the tracks when the lights first started. Thank you for what you do though. I have seen other cars run tracks much later than me.
49	Signal started just as I was entering zone. There was no way to stop other than on the tracks. The vehicle in the second 2 pictures is not of my vehicle. He on the other hand had plenty of time to stop but I can see how you would mistake a black mini cooper for a black SUV.
50	I apologize what I did. I will be more careful when crossing a railroad interception.
51	Thank you for a warning as opposed to a ticket. This educational effort works, because I will be a lot more aware at railroad crossings and will never drive through a lowering gate again. Again, thank you for not ticketing me.
52	My husband (64 yrs) and I never observed light signal before we cross. I'll never put my family in danger - Thanks for the warning letter and your concern!!!
53	I was already passing through when the crossing activated and I proceeded as I was in the crossing. I am not from Orlando and not familiar with area. Was taking my husband home from Florida Hospital. The will never happen again
54	I think this survey is an excellent idea. I was following the U-hal truck in front of me and never saw the signal. Should have allowed more space between. A good wakeup call
55	Thank you
56	Didn't see it, Maybe more lights and a siren!
57	The crossing signal were not activated and not train around in sight. That could be a malfunction of the system. I always follow signs on the road. But thanks anyway for the taking care of the situation. I hope that you can correct the malfunction of this crossing.
58	Cars in front of me blocked my path to move forward, had no choice but to try to get through the crossing
59	This particular railroad crossing constantly malfunctioning for some reason, it activates itself even when no train is approaching. Thanks for your attention
60	The first time, I had a mistake. I am sorry. I try , I never make again. Thanks
61	All cars and trucks going through-no train see photo

#	Comment
62	went through and the warning signs got activated
63	Thanks for this notice.
64	Your records are incorrect. I did not cross the railroad with warning activated. It appears that I was on the other side when the warning was activated. There was traffic ahead of me and slowed down once I crossed the railroad tracks. I would not cross an activated crossing. I was driving the car, my name is Pedro J Acosta. Track maintenance crew was operating the sign and it came one for the second time once we crossed.*
65	I HAD ALREADY BEGUN CROSSING THE TRACKS WHEN THE ARM CAME DOWN AND LIGHTS BEGAN FLASHING. I WASN'T GOING TO STOP ON THE TRACKS
66	Lights did not begin or bars lowering until after I went through. Clearly the lights should flash some and bars lower at a quicker rate of speed if the train is coming that quickly.
67	I realized what I had done after it was too late to stop!

Appendix F.
Paired T-test Results

Violation Rate Descriptive Statistics

		Mean (per Hour)	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Total Violations/Activation	6.0296	206	3.35613	.23383
	Post Total Violations/Activation	5.1004	206	3.08601	.21501
Pair 2	Pre Type 1/Activation	1.4733	206	1.23210	.08584
	Post Type 1/Activation	1.2687	206	1.08563	.07564
Pair 3	Pre Type 2/Activation	.3827	206	.53466	.03725
	Post Type 2/Activation	.3310	206	.45814	.03192
Pair 4	Pre Type 3/Activation	.0010	206	.01393	.00097
	Post Type 3/Activation	.0000	206	.00000	.00000
Pair 5	Pre Type 4 All/Activation	4.1727	206	2.26185	.15759
	Post Type 4 All/Activation	3.5007	206	2.11771	.14755

Violation Rate Paired Sample T-Tests

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Post Total Violations/Activation	.92927	3.18741	.22208	.49142	1.36712	4.184	205	.000
Pair 2	Pre-Post Type 1/Activation	.20465	1.38615	.09658	.01423	.39506	2.119	205	.035
Pair 3	Pre-Post Type 2/Activation	.05166	.61056	.04254	-.03221	.13553	1.214	205	.226
Pair 4	Pre-Post Type 3/Activation	.00097	.01393	.00097	-.00094	.00289	1.000	205	.318
Pair 5	Pre-Post Type 4 All/Activation	.67200	2.34235	.16320	.35023	.99376	4.118	205	.000

Appendix G.
Two-Way ANOVA Results - Type I Violation Rate

Summary Statistics for Type 1 Violations per Activation by Direction of Travel

Post	Direction	Mean	Std. Deviation	N
0 Pre	1 EB	.7291	.82154	206
	2 WB	.7442	.80017	206
	Total	.7367	.80997	412
1 Post	1 EB	.6128	.73289	237
	2 WB	.5863	.64136	237
	Total	.5996	.68805	474
Total	1 EB	.6669	.77666	443
	2 WB	.6598	.72305	443
	Total	.6633	.74992	886

ANOVA Results for Type 1 Violations per Activation by Direction of Travel

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4.250a	3	1.417	2.532	.056
Intercept	393.554	1	393.554	703.439	.000
Post	4.143	1	4.143	7.406	.007
Direction	.007	1	.007	.013	.911
Post * Direction	.095	1	.095	.170	.680
Error	493.455	882	.559		
Total	887.537	886			
Corrected Total	497.704	885			

a. R Squared = .009 (Adjusted R Squared = .005)

Appendix H.
Two-Way ANOVA Results - Type II Violation Rate

Summary Statistics for Type 2 Violations per Activation by Direction of Travel

Post	Direction	Mean	Std. Deviation	N
0 Pre	1 EB	.1563	.31890	206
	2 WB	.2264	.39482	206
	Total	.1913	.36015	412
1 Post	1 EB	.1996	.32801	237
	2 WB	.1085	.23380	237
	Total	.1540	.28816	474
Total	1 EB	.1795	.32416	443
	2 WB	.1633	.32396	443
	Total	.1714	.32398	886

ANOVA Results for Type 2 Violations per Activation by Direction of Travel

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.796[a]	3	.599	5.798	.001
Intercept	26.292	1	26.292	254.558	.000
Post	.306	1	.306	2.966	.085
Direction	.024	1	.024	.236	.627
Post * Direction	1.432	1	1.432	13.867	.000
Error	91.096	882	.103		
Total	118.915	886			
Corrected Total	92.892	885			

a. R Squared = .019 (Adjusted R Squared = .016)

Abbreviations and Acronyms

Abbreviation or Acronym	Name
ANOVA	Analysis of Variance
AADT	Average Annual Daily Traffic
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
LD	Licensed Drivers
MUTCD	Manual on Uniform Traffic Control Devices
MVMT	Million Vehicle Miles Travelled
NHTSA	National Highway Transportation Safety Administration
PII	Personally Identifiable Information
RD&T	Research, Development and Technology
ROW	Right-of-Way
U.S. DOT	U.S. Department of Transportation
Volpe Center	John A. Volpe National Transportation Systems Center