U.S. Department of Transportation

**Federal Railroad Administration**

# Effectiveness of LED-Enhanced Signs in Reducing Incidents of Vehicles Stopping on Tracks

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The U.S. Department of Transportation Volpe National Transportation Systems Center conducted a study of the effectiveness of LED-enhanced R8-8 signs in reducing incidents of vehicles stopping on the tracks. The researchers captured video at the Brighton Street crossing in Belmont, MA before and after LED-enhanced signs were installed. The signs were standard R8-8 panels that read "DO NOT STOP ON TRACKS," except that they had flashing white LEDs. Signs manufactured by two different companies were tested. Results showed the signs produced a 41 percent reduction in frequency of vehicles stopping on the tracks.

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# METRIC/ENGLISH CONVERSION FACTORS

## ENGLISH TO METRIC

### LENGTH (APPROXIMATE)

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

### AREA (APPROXIMATE)

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

### MASS - WEIGHT (APPROXIMATE)

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

### VOLUME (APPROXIMATE)

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

### TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

## METRIC TO ENGLISH

### LENGTH (APPROXIMATE)

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

### AREA (APPROXIMATE)

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

### MASS - WEIGHT (APPROXIMATE)

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

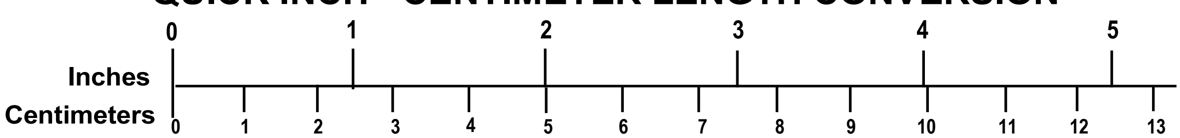
### VOLUME (APPROXIMATE)

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

### TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

## QUICK INCH - CENTIMETER LENGTH CONVERSION

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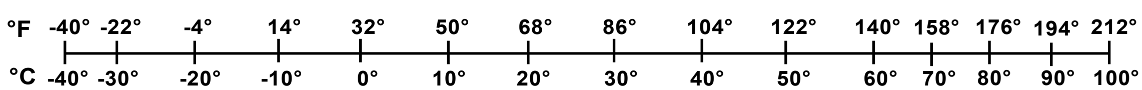


For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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The authors would like to acknowledge Ryan Brown and Tashi Ngamdung of the Systems Safety and Engineering Division, DOT John A. Volpe National Transportation Systems Center, for their support with system installation and data analyses.

The authors would also like to thank the town of Belmont, Massachusetts, the Massachusetts Bay Transportation Authority, and Keolis Commuter Services for permitting us to conduct this test at the Brighton Street crossing.

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## Executive Summary

The Federal Railroad Administration (FRA) is involved with numerous wide-ranging engineering, education, and enforcement efforts to increase highway-rail grade crossing safety by reducing the number, frequency, and severity of incidents that occur each year. In 2018 alone, there were a total of 2,211 incidents resulting in 265 fatalities and 834 injuries over 211,000 at-grade highway-rail crossings in the U.S. [1]. Although many factors were associated with these incidents, a significant number involved vehicles stopping on the tracks, usually due to heavy traffic conditions.

The objective of this research was to study the effectiveness of light-emitting-diode (LED)-enhanced signage in reducing the number of vehicles stopping on the tracks during heavy traffic conditions. The John A. Volpe National Transportation Systems Center (Volpe Center) was tasked by the FRA Office of Research, Development and Technology (RD&T) with studying the effects of LED-enhanced R8-8 signs that read “DO NOT STOP ON TRACKS.” This project was the second phase of a study conducted at the Brighton Street crossing in Belmont, MA (crossing ID 052315W), which had a history of being blocked by vehicles stuck in traffic and stopping on the tracks.

Volpe Center researchers captured baseline video data of the crossing in March, 2019, then installed LED-enhanced signs on April 1, 2019. The signs had white LEDs that flashed continuously and were solar powered. Researchers captured post-installation video data in late April 2019. The analysis showed a decrease of more than 41 percent in the frequency of vehicles stopping on the tracks after the LED-enhanced signs were installed.

While the results of this research appear promising, this safety improvement has only been studied at one crossing. Additional field testing and analysis is necessary before recommendations for wider use can be made.

# 1. Introduction

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

In 2018 alone, there were a total of 2,211 incidents resulting in 265 fatalities and 834 injuries over 211,000 at-grade highway-rail crossings in the United States [1]. Many of these incidents involved vehicles stopping on railroad tracks, often due to traffic congestion. This study examines the effectiveness of LED-enhanced signs in reducing occurrences of drivers stopping on the tracks.

## 1.1 Background

The Brighton Street grade crossing (crossing ID 052315W) has been problematic from a safety standpoint for many years. Rush hour traffic regularly backs up onto the tracks, and a crosswalk leading to an adjacent rail trail also causes vehicles to stop on the tracks.

In June, 2013, a vehicle was struck by a Massachusetts Bay Transportation Authority (MBTA) Commuter Rail train when a person driving down Brighton Street accidentally turned onto the ROW. No one was injured in that incident. On December 9, 2016, a woman was seriously injured when she stopped her vehicle on the tracks under heavy traffic conditions [2]. She got out to help her passengers exit the vehicle as a train approached. She succeeded in doing this, but when the train struck the vehicle it in turn struck her, causing serious injuries. On March 8, 2018, a suicide occurred near this crossing, and on February 8, 2019, a tow truck sustained minor damage when it was grazed by an outbound MBTA train.

The MBTA was interested in improving public safety after an unexpected spike in fatalities in 2017 [3]. While most of these were trespassing incidents, the MBTA was looking at safety improvements system-wide. FRA, supported by the Volpe Center, initiated a collaborative grade crossing research effort with the MBTA at that time.

### *1.1.1 Past Research*

The Volpe Center conducted a research study that evaluated the effectiveness of light-emitting diode (LED) regulatory signs at a passive highway-rail grade crossing in 2013. In that study, existing grade crossing crossbuck (R15-1) signs and advance warning signs (W10-1) were replaced with flashing LED-equipped signs at a grade crossing in Swanton, Vermont. The objective was to assess the impact of two LED-enhanced passive warning device configurations on the speed profiles of motor vehicles as they approached a passive grade crossing. [4]

While there is little additional published research that documents the effectiveness of LED-enhanced signs at grade crossings, they have already been deployed on multiple railroads [5]. As the number of installed signs continues to rise, there is an increasing need to characterize the benefit provided by this technology.

## 1.2 Objectives

The objectives of this research included:

- Test the effectiveness of adding new R8-8 signs that have flashing LEDs in reducing incidents of vehicles stopping on the tracks.
- Test the durability, ease of installation, and brightness of the LED-enhanced signs.

## 1.3 Overall Approach

To evaluate the effectiveness of the LED-enhanced signs, the Volpe Center collected pre-installation video of vehicular traffic from March 18-22, 2019 and post-installation video from April 22-26, 2019. The Volpe Center only analyzed traffic from 6:00 a.m. to 10:00 a.m. and from 3:00 p.m. to 7:00 p.m. each day, resulting in the analysis of 40 hours of pre-installation and 40 hours of post-installation traffic data.

## 1.4 Scope

This study investigated the effectiveness of LED-enhanced R8-8 signs, which read "DO NOT STOP ON TRACKS" in reducing incidents of vehicles stopping on the tracks. This study was limited to a single crossing in the Town of Belmont, MA.

## 1.5 Organization of the Report

This report is organized as follows:

- Section 2 presents an overview of the test site location and data collection activities.
- Section 3 presents a description of the LED-enhanced signs.
- Section 4 presents the results of the evaluation.
- Section 5 presents the conclusion of the study.

## 2. Test Site Location and Data Collection

The selected crossing is located on Brighton Street in the town of Belmont, MA (crossing ID 052315W). This crossing was selected by the MBTA due to recent incidents involving vehicles queuing over the tracks.

In 2017, the Volpe Center studied the effectiveness of pavement markings in affecting driver behavior at this crossing. The town of Belmont painted cross-hatching just prior to the tracks, and the Volpe Center studied driver behavior before and after they were deployed. Those markings, along with new pavement lettering that reads “DO NOT BLOCK THE BOX” remain, although they have begun to fade.

The Volpe Center applied for and received authorization from the town of Belmont to install and evaluate the LED-enhanced signage in March 2019. This approval was received after discussions with the town’s Department of Public Works, Police Department, and presentation to the Board of Selectmen in February 2019, as shown in Figure 1.


**Figure 1. Town of Belmont Board of Selectmen Meeting**

## 2.1 Test Site Location

Brighton Street in Belmont is a two-lane municipal road that is heavily trafficked at rush hour, with most traffic heading southbound in the morning and northbound in the afternoon. While the nearest traffic signals are about 2,000 feet away in each direction, left-turning traffic due to nearby schools and businesses, along with numerous crosswalks and bus stops, often cause traffic to back up onto the tracks during peak commuting times. The annual average daily traffic (AADT) for Brighton Street is 16,900 vehicles. The MBTA Commuter Rail Fitchburg line uses the tracks which cross Brighton Street, with an average of 38 trains per day [6]. Figure 2 shows the crossing used for the research study.

There is a bike path adjacent to the tracks on the east side of the crossing, whose current endpoint is at Brighton Street. A crosswalk extends from the end of the bike trail, allowing cyclists and pedestrians to cross the road. There are plans to extend the bike trail to the west side of the crossing, although to date a final decision on the exact route has not been made.

The grade crossing is protected by flashers and roadway gates on the vehicular approaches and pedestrian gates on the sidewalks in the two exit quadrants. Standard R8-8 signs are posted on both vehicle approach sides. Grade crossing advance warning signs (W10-1) and associated pavement markings, as well as pavement markings consisting of "DO NOT BLOCK THE BOX" and a crosshatch pattern between the stop line and tracks, are also installed on both approaches. The lettering and crosshatch patterns were added by the town of Belmont in November 2017.

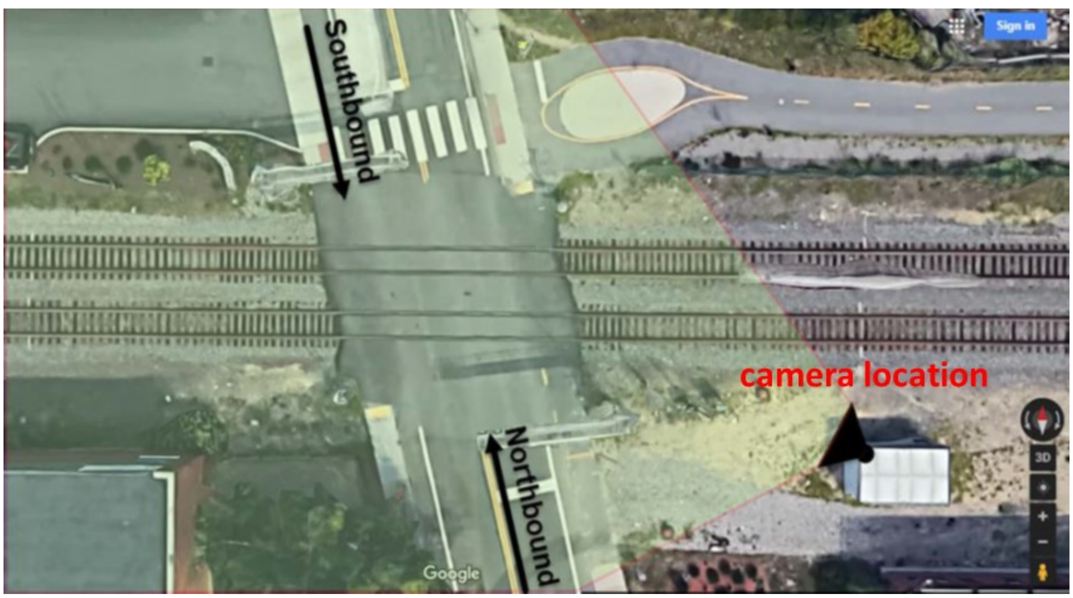


**Figure 2. Aerial View of Brighton St. Crossing**

### 2.1.1 Southbound

There is one lane of traffic in the southbound direction, which traverses a crosswalk immediately before the grade crossing, shown in Figure 3.


**Figure 3. Southbound Approach to the Brighton St. Grade Crossing**

### 2.1.2 Northbound

There is one lane of traffic in the northbound direction. The crosswalk is immediately after the grade crossing in this direction. A picture of the northbound approach is shown in Figure 4.


**Figure 4. Northbound Approach to the Brighton St. Grade Crossing**

## 2.2 Data Collection System

The MBTA and its operator, Keolis Commuter Services, authorized the Volpe Center to attach a video camera and weatherproof enclosure containing a digital video recorder along with supporting hardware to the outside of their Brighton Street bungalow, as shown in Figure 5, to collect the necessary research data. The MBTA also provided AC power to the system from the bungalow.

Video data was collected using a Speco Technologies 3 Megapixel IP camera, model number O3VFBM. It was recorded on a SunEyes Super Mini Network Video Recorder (NVR), model number N6200-8E, using a Western Digital My Passport 4TB USB external hard drive. The system was used to collect video of vehicles travelling in both directions at the Brighton Street grade crossing.

**Figure 5. Video Data Capture Equipment at the Brighton St. Crossing**

Video data was collected using the high-definition video camera with a varifocal lens set to its widest angle, which provided a view of all five zones in both directions. It should be noted that only about 8 feet of Zone 1 in the northbound direction was visible in the pre-installation video dataset. The camera was adjusted at the time the LED-enhanced signs were installed to show the full 12 feet of that zone.

The 4 TB hard drive was capable of capturing approximately 7 weeks of video at 30 frames per second. However, due to the frequent stopping of vehicles on or near the tracks, only one week of video was required before and after the LED-enhanced signs were installed.

During its review of the video, researchers discovered the NVR stopped recording for a few minutes two times during the post-installation phase: once on Wednesday, April 24 at 17:51:45 for 4 minutes, 21 seconds; and once on Friday, April 26 at 8:54:03 for 3 minutes, 54 seconds. In the first instance, traffic was heavy, so likely some stopping events were not captured. In the second instance, traffic was relatively light, so probably few if any events were missed. Fortunately, the loss of data only accounted for 1.7 percent of the post-installation dataset, and it had no significant impact on the percentages of vehicles stopping in particular zones. Since there were over 1,900 stopping events captured in the post-installation dataset, in spite of the loss of this small amount of data, there was no impact on the validity of this study.

## 2.3 Data Analysis Method

The goal of this research study was to gain an understanding of how effectively the LED-enhanced R8-8 signs could influence driver behavior at grade crossings. The addition of the LED-enhanced signage was intended to improve the visibility of the regulatory signage, resulting in fewer motorists entering this area if unable to exit the other side. To understand the effect of the added signage, driver stopping behavior was coded both before and after the installation.

Researchers collected pre-installation video of vehicular traffic from March 18-22, 2019. The LED-enhanced signs were installed on April 1, 2019. To allow the novelty effect of the signs to dissipate, the Volpe Center did not begin collection of post-installation video data until April 22-26, 2019. This was also the week that followed April school vacation in Belmont.

Researchers only analyzed video during heavy traffic periods from 6:00 a.m. to 10:00 a.m. and from 3:00 p.m. to 7:00 p.m. each weekday, resulting in the analysis of 40 hours of pre-installation and 40 hours of post-installation traffic data.

Driver stopping behavior was coded based on five possible zones in each direction in which a motorist could come to a complete stop. These zones are shown in Figure 6.

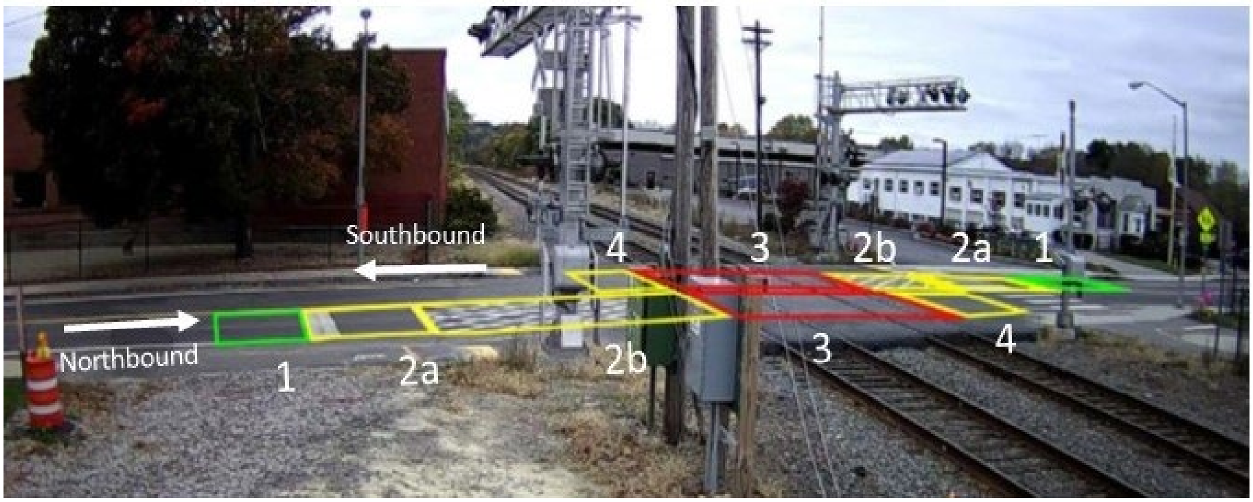


**Figure 6. Definition of Grade Crossing Zones**

The five zones over the crossing represent different levels of danger if the motorist comes to a full stop in that zone:

- Zone 1 (not dangerous): A motorist who stops in Zone 1 has stopped before the stop line where the gate descends during an activation. Motorists stopping in this zone are behaving safely.
- Zone 2a (not dangerous): A motorist who stops in Zone 2a has stopped after the stop line, but before the crosshatch pavement markings and gate.
- Zone 2b (moderately dangerous): A motorist who stops in Zone 2b has stopped on the crosshatch pavement markings, but before the tracks. Vehicles stopping in Zone 2b could be struck by a descending gate, but most likely not struck by a train unless very close to the outer rail, where they could be struck by the train's overhang.

- Zone 3 (very dangerous): A motorist who stops in Zone 3 has stopped in the most dangerous part of the crossing—the track area. In this zone, a train and vehicle could collide.
- Zone 4 (moderately dangerous): A motorist who stops in Zone 4 has stopped past but adjacent to the track area. Motorists stopping in Zone 4 would not be struck by a train, but may not be aware that they have cleared the tracks.

Only vehicles that stopped in one of these five zones were coded, and vehicles that passed through the crossing without stopping were not included in the analysis. In Zone 1, a vehicle was coded if the driver stopped in Zone 1 without any vehicles immediately in front of it in Zone 2a. This coding scheme ensured that the driver stopping in Zone 1 was conducting a safe action and not simply stopping because of traffic. Vehicles stopping in other zones had already chosen to perform an unsafe action, so a similar caveat was unnecessary. For example, if a driver came to a stop in Zone 3 with vehicles directly in front, the driver had already chosen to enter the grade crossing during an unsafe time (i.e., when traffic was backed up into the grade crossing).

Generally, the zone recorded was where the front bumper of the vehicle was located when it came to a complete stop. However, if any part of the vehicle was in Zone 3, it was recorded as Zone 3. If the rear bumper stopped in Zone 4, it was recorded as Zone 4.

The same process for data collection and processing was used in the post-installation process. Vehicles that made a complete stop in any one of the zones was recorded. Vehicles that stopped in more than one zone were recorded as having stopped in the zone of highest hazard, which rank as follows:

- Zone 3
- Zone 2b
- Zone 4
- Zone 2a
- Zone 1

This ranking is consistent with that used in a prior Volpe Center study investigating the effect of pavement markings on driver behavior at grade crossings [7]. This study makes use of video data that captures driver behavior before and after implementation of a safety enhancement. This methodology was used in Volpe's study of the effectiveness of in-pavement lights [8].

The direction of travel, time of day, and day of the week were recorded for each stopped vehicle. Other factors such as type of vehicle, weather, and the presence of pedestrians or cyclists in the crosswalk were also recorded. It was also noted if the grade crossing safety signals were activated while the vehicle was stopped and what action the vehicle took (if any). Vehicles that stopped at the crossing, not due to congestion but due to regulatory compliance, were not included in this study. MBTA buses, school buses, fuel trucks and others carrying hazmat cargo are examples of vehicles required to stop at all railroad crossings to check for trains.

## 3. LED-Enhanced Signs

For several years, vendors have been offering standard Manual on Uniform Traffic Control Devices (MUTCD)-compliant signs enhanced with flashing LEDs which are intended to capture drivers' attention in particularly dangerous conditions. Stops signs, speed limit signs, and crosswalk signs are among those popular with municipalities trying to improve safe driving behavior.

The signs used in this study were standard R8-8 signs that read "DO NOT STOP ON TRACKS." The Volpe Center decided to use LED-enhanced signs manufactured by two different companies to compare ease of installation, LED brightness, and durability. One sign was manufactured by Traffic and Parking Control Company (TAPCO), and the other by Traffic Safety Corporation (TSC). The signs look identical, and are both 24 inches by 30 inches. The MUTCD guidance states that the sign "should be located on the right-hand side of the highway on either the near or far side of the grade crossing, depending upon which position provides better visibility to approaching drivers" [9]. The Belmont Street crossing had existing R8-8 signs on the near side of the crossing in each direction, as previously shown in Figure 3 and Figure 4. The signs were larger, 36 inches by 48 inches, a size typically used on highways. The northbound sign has a second sign below it reading "STOP HERE FOR CROSSWALK AHEAD." The Volpe Center installed the LED-enhanced signs on the exit side of the crossing in each direction, mounted high enough to provide good visibility on both sides of the crossing, as shown in Figure 7. The existing signs on the approach sides were left in place.

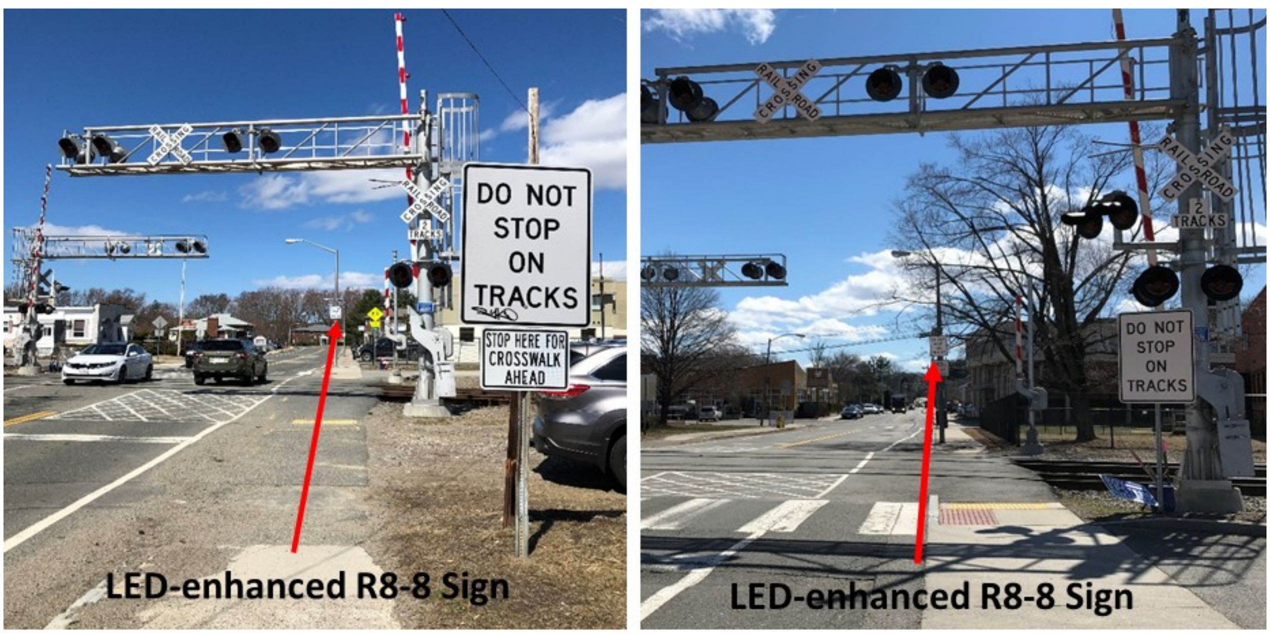


**Figure 7. Brighton St. Crossing Northbound Approach (left) and Southbound Approach (right)**

## 3.1 Features and Differences of the LED-Enhanced Signs

The LED-enhanced signs were solar powered, and each came with a small 6 volt solar panel. They were both set to flash constantly. The TAPCO sign used a battery enclosed inside a separate aluminum tube. The battery of the TSC sign was encapsulated within the sign itself. The TSC sign had a security key that could be used to turn the LEDs on or off. The TAPCO sign had to be unplugged inside the battery tube.

The LEDs of the TAPCO sign were significantly brighter than those used in the TSC sign. This mattered little after dark, when both signs appeared to flash brightly. However, in bright sunshine, the TAPCO sign was substantially more noticeable due to the brighter LEDs. Both signs had their LEDs aimed toward the roadway, so they appeared brighter from a distance than they did directly beneath the sign. The difference in luminosity can be seen in the two distance shots in Figure 8 and from directly beneath the signs in Figure 9, below. The photos were taken within a few minutes of each other, near dusk. However, differences in the way the camera adjusted for ambient light, as well as the way each sign's LEDs were focused, affected the way the LEDs appear in photographs.


**Figure 8. TAPCO (left) and TSC (right) Signs from Approximately 90 Feet**


**Figure 9. TAPCO (left) and TSC (right) Signs from Approximately 10 Feet**

The TAPCO sign came with brackets intended to fit the pole that it came with, which was much smaller in diameter than the light pole the Volpe Center mounted it to. However, the TAPCO sign was constructed with tamper-resistant screws which offered good mounting points for an Allied Moulded Products 16-inch pole mount (part no. AMPOLEMNT16) which provided excellent stability. The TSC came with two pole brackets attached to the sign at just one point each. This left the sign somewhat wobbly after installation, and there were no other holes or screws for using an alternate bracket.

## 3.2 System Cost

The Volpe Center purchased the TSC sign directly from TSC for $1,740. There were no shipping costs. The TAPCO sign was purchased via a reseller, Consolidated Traffic Controls, for $3,300. The sign came with a 14-foot aluminum pole and breakaway base, which the installation team ended up not needing. The Volpe Center contacted TAPCO to obtain the price for only the sign and brackets, direct from the manufacturer. They provided a quote for the equipment as it was installed in Belmont for $1,600 plus $65 in shipping.

## 4. Results

From the 80 hours of data collection, over 2,600 vehicles were coded as stopping in one of the four violation zones (2a, 2b, 3, and 4). Zone 1 was not considered a violation zone because it was entirely behind the stop line. Also, part of Zone 1 in the northbound lane was not visible to the camera during the pre-installation phase. It was likely that more vehicles stopped in this zone than were recorded, so northbound Zone 1 data is not included in this analysis.

### 4.1 Pre-Installation

In the pre-installation phase, a total of 1,065 vehicles stopped in one of the four violation zones during the week of March 18, 2019, with 753 in the northbound lane and 312 in the southbound lane. In short, approximately 70 percent of the vehicles stopping in one of the violation zones in the pre-installation phase were heading northbound. Table 1 reports this stopping behavior, along with the number and percentages of vehicles that stopped in each of the four zones in each direction.

**Table 1. Pre-Installation Driver Stopping Behavior by Zone**

Northbound

| | | |
|---|---|---|
| Zone 2a | 167 | 22.2% |
| Zone 2b | 279 | 37.1% |
| Zone 3 | 223 | 29.6% |
| Zone 4 | 84 | 11.2% |
| TOTAL | 753 | 100% |

Southbound

| | | |
|---|---|---|
| Zone 2a | 133 | 42.6% |
| Zone 2b | 55 | 17.6% |
| Zone 3 | 94 | 30.1% |
| Zone 4 | 30 | 9.6% |
| TOTAL | 312 | 100% |

Clearly, far more northbound vehicles stopped in one of the violation zones than in the southbound direction. This was the case with those stopping in Zone 3 (directly on the tracks) as well, which was the area of primary concern. However, regardless of direction, roughly 30 percent of all vehicles that stopped in one of the violation zones stopped in Zone 3. An example of how the traffic often stopped during times of high congestion is shown in Figure 10, clearly showing the blue vehicle stopped in Zone 3.

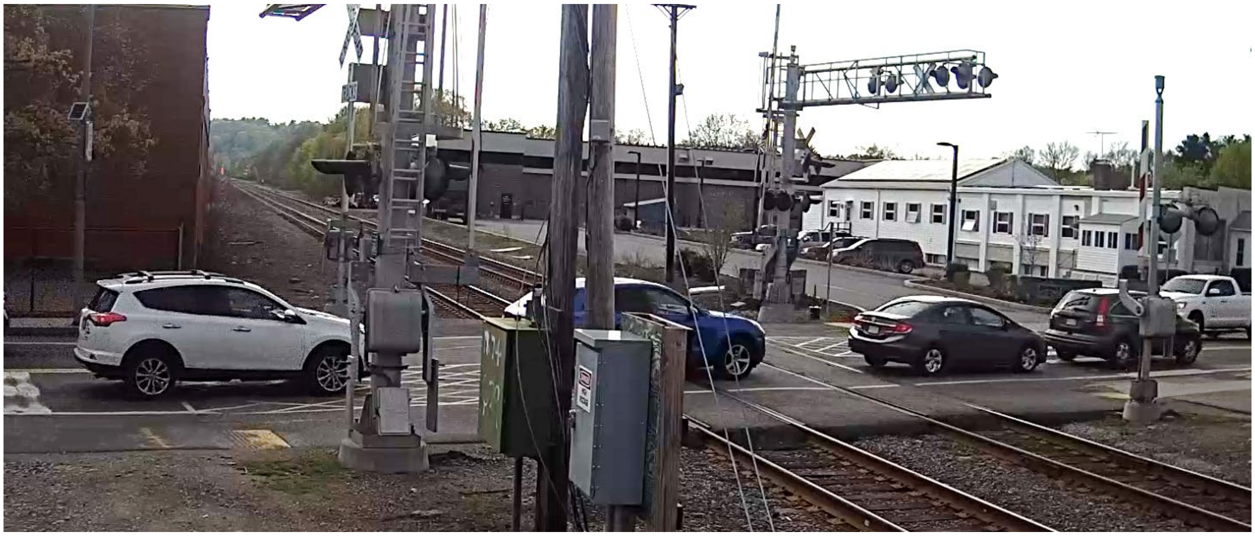

**Figure 10. Northbound Vehicles Stopping on Tracks Due to Congestion**

As noted previously, the camera view of Zone 1 in the northbound direction was limited, with only about 8 of the 12 feet defined being visible on the camera. Project researchers believe that some vehicles stopped in Zone 1 off-camera, so that zone in the northbound direction was not used in this part of the analysis. However, the entirety of Zone 1 was visible in the southbound direction. For this reason, the analysis of traffic stopping in Zone 1 was only conducted for southbound traffic. Table 2 shows a breakdown of where southbound vehicles stopped with Zone 1 included.

**Table 2. Pre-Installation Driver Stopping Behavior by Zone (southbound, incl. Zone 1)**

| | | |
|---|---|---|
| Zone 1 | 141 | 31.1% |
| Zone 2a | 133 | 29.4% |
| Zone 2b | 55 | 12.1% |
| Zone 3 | 94 | 20.8% |
| Zone 4 | 30 | 6.6% |
| TOTAL | 453 | 100% |

This shows that of all the vehicles that stopped at the crossing in the southbound direction, 31.1 percent stopped appropriately behind the stop line in Zone 1.

It should be noted that Zone 2b is slightly larger in the northbound direction (19.5 feet) than it is in the southbound direction (17.2 feet), which may partly explain the higher percentage of northbound vehicles stopping in that zone. The southbound crosshatching section was compressed due to the proximity of the crosswalk on that side of the tracks. Interestingly, even though Zone 2a in the southbound direction is comprised entirely of crosswalk, it did not seem to cause drivers to avoid stopping in it.

## 4.2 Post-Installation

In the post-installation phase, a total of 1,545 vehicles stopped in one of the four violation zones during the week of April 22, 2019, with 1,079 in the northbound lane and 466 in the southbound lane. As was the case in the pre-installation phase, approximately 70 percent of the vehicles stopping in one of the violation zones was heading northbound. Table 3 shows the stopping behavior per violation zone in both directions.

**Table 3. Post-Installation Driver Stopping Behavior by Zone**

Northbound

| | | |
|---|---|---|
| Zone 2a | 284 | 26.3% |
| Zone 2b | 444 | 41.1% |
| Zone 3 | 225 | 20.9% |
| Zone 4 | 126 | 11.7% |
| TOTAL | 1,079 | 100% |

Southbound

| | | |
|---|---|---|
| Zone 2a | 251 | 53.9% |
| Zone 2b | 81 | 17.4% |
| Zone 3 | 95 | 20.4% |
| Zone 4 | 39 | 8.4% |
| TOTAL | 466 | 100% |

As was the case in the pre-installation phase, it mattered little which direction vehicles were headed, because about the same percentage of the vehicles stopped directly on the tracks (Zone 3). However, with the LED signs present, the percentage of vehicles stopping on the tracks in Zone 3 was reduced to just over 20 percent.

The breakdown of southbound stopping zones in the post-installation phases with Zone 1 included is shown in Table 4.

**Table 4. Post-Installation Driver Stopping Behavior by Zone (southbound, incl. Zone 1)**

| | | |
|---|---|---|
| Zone 1 | 313 | 40.2% |
| Zone 2a | 251 | 32.2% |
| Zone 2b | 81 | 10.4% |
| Zone 3 | 95 | 12.2% |
| Zone 4 | 39 | 5.0% |
| TOTAL | 779 | 100% |

## 4.3 Overall Results

In comparing the zones in which vehicles tended to stop, the Volpe Center focused on the southbound traffic because it had more certain Zone 1 data. Figure 11 below shows graphically how the tendency for vehicles to stop in Zone 3 decreased, and that frequency of vehicles stopping in Zone 1 increased after the LED-enhanced signs were installed. In fact, the frequency of vehicles stopping in Zone 3 was reduced by 41.2 percent after the signs were installed.

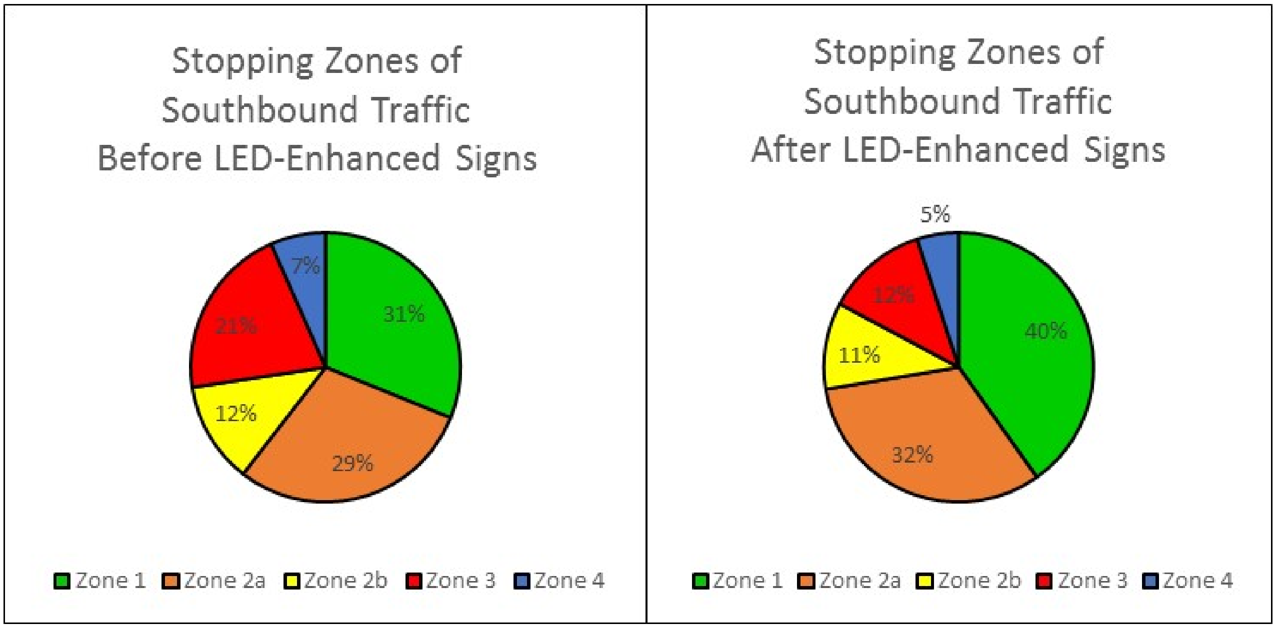


**Figure 11. Comparison of Driver Stopping Behavior by Zone Before and After Installation of the LED Signs**

The Volpe Center tried to select study periods with comparable traffic volumes, being sure to avoid school vacation weeks and holidays. However, there was clearly more congestion in the post-installation period (week of 4/22/19) than in the pre-installation period (week of 3/18/19). Using only the southbound traffic numbers, 453 vehicles stopped in one of the zones (1, 2a, 2b, 3, or 4) during the pre-installation period, while 779 stopped in one of the zones during the post-installation period. To create a more straightforward comparison, Table 5 below shows the breakdown of southbound stopping activity when only the first 453 post-installation stopping events are used.

**Table 5. Comparison of the First 453 Southbound Stopping Events**

Pre-Installation

| | | |
|---|---|---|
| Zone 1 | 141 | 31.1% |
| Zone 2a | 133 | 29.4% |
| Zone 2b | 55 | 12.1% |
| Zone 3 | 94 | 20.8% |
| Zone 4 | 30 | 6.6% |
| TOTAL | 453 | 100% |

Post-Installation

| | | |
|---|---|---|
| Zone 1 | 188 | 41.5% |
| Zone 2a | 151 | 33.3% |
| Zone 2b | 40 | 8.8% |
| Zone 3 | 55 | 12.1% |
| Zone 4 | 19 | 4.2% |
| TOTAL | 453 | 100% |

For southbound traffic, the installation of the LED-enhanced signage had a profound impact in reducing the number of vehicles that came to stop on the tracks. A chi-square test of independence showed a significant difference between the pre- and post-installation conditions ($\chi 2 = 22.9001$, df = 4, $p < 0.01$). These changes included a 41.5 percent reduction in motorists stopping in Zone 3 (from 94/453 to 55/453), a 36.7 percent reduction in motorists stopping in Zone 4 (from 30/453 to 19/453), and a 33.3 percent increase in motorists stopping appropriately in Zone 1 (from 141/453 to 188/453). Figure 12 shows the frequency of vehicles stopped per zone in the southbound direction before and after the installation of the LED-enhanced signs. This comparison shows that the LED-enhanced signs had a profound impact in reducing the number of vehicles that stopped on the tracks.

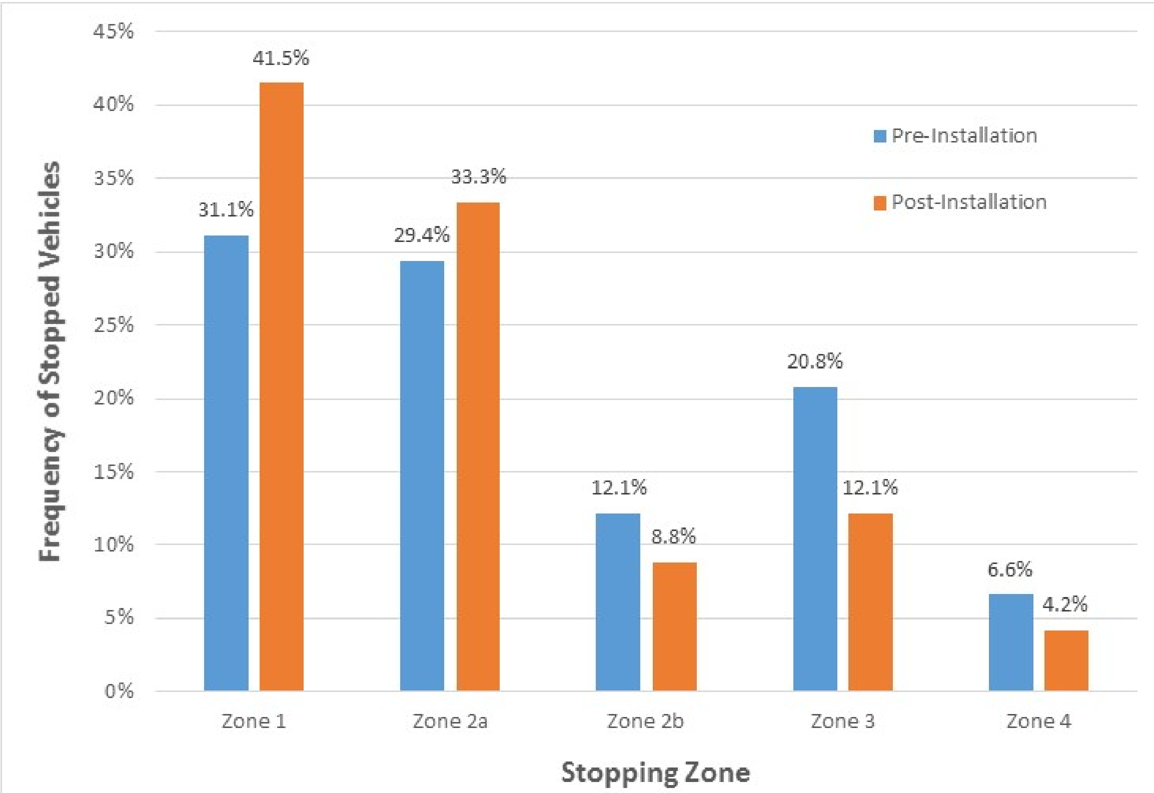


**Figure 12. Frequency of Southbound Vehicles Stopping by Zone**

The statistics also showed that at this crossing, far more vehicles stopped on the tracks in the northbound direction than in the southbound direction. In reviewing the video, one reason for this was clear: Many drivers did not see pedestrians or bicyclists attempting to cross at the crosswalk until they were already within one of the violation zones, so they stopped near or on the tracks to allow them to cross. In fact, 81 of the 223 (36.3 percent) of the vehicles that stopped in Zone 3 (directly on the tracks) in the northbound direction in the pre-installation phase did so to allow a bicyclist or pedestrian to cross the roadway. This number was relatively unaffected by the presence of the LED-enhanced signs. In the post-installation phase, this number was a very similar 89 out of 225, or 39.6 percent. However, this condition rarely trapped these vehicles on the tracks. The pedestrians and bicyclists tended to pass quickly and vehicles could proceed without significant delay. On the other hand, those that stopped on the tracks due to traffic congestion were sometimes trapped there for significant amounts of time, and had limited options for getting off the tracks when trains approached. An example of northbound vehicles stopping for bicyclists in the crosswalk is shown in Figure 13.

**Figure 13. Example of Northbound Vehicles Stopping on Tracks Due to Bicyclists**

## 4.4 Reliability

Although only 10 weeks passed between the installation of the signs and the writing of this report, the Volpe Center was not aware of any malfunctions of the flashing LEDs or even any perceptible decrease in intensity. Both the TSC sign and the TAPCO sign were functioning as intended as of the writing of this report.

## 5. Conclusions

The LED-enhanced "DO NOT STOP ON TRACKS" signs were clearly effective in reducing the number of vehicles that stopped on the tracks. The research team analyzed the numbers in many different ways, and each time results showed a reduction of more than 41 percent in the frequency of vehicles that stopped on the railroad tracks after the installation of the signs.

The LED-enhanced sign manufactured by TAPCO clearly flashed more brightly than the sign manufactured by TSC. However, this difference seemed to have little effect on the improvements in safety, with the northbound and southbound statistical improvements effectively mirroring one another.

It should be noted that the Brighton Street grade crossing is only one crossing in one community, and it is possible that the LED-enhanced signs installed at another location with different conditions such as traffic patterns, grade crossing layout, etc., may produce different results. FRA should consider conducting similar before-and-after studies in other locations.

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[9] Federal Highway Administration. (2009). Manual on Uniform Traffic Control Devices for Streets and Highways.

## Abbreviations and Acronyms

| Abbreviation or Acronym | Name |
|---|---|
| AADT | Average Annual Daily Traffic |
| FRA | Federal Railroad Administration |
| IP | Internet Protocol |
| LED | Light-Emitting Diode |
| MBTA | Massachusetts Bay Transportation Authority |
| MUTCD | Manual on Uniform Traffic Control Devices |
| NVR | Network Video Recorder |
| RD&T | Railroad Development and Technology |
| ROW | Right-of-Way |
| TAPCO | Traffic and Parking Control Company |
| TB | Terabytes |
| TSC | Traffic Safety Corporation |
| U.S. DOT | U.S. Department of Transportation |
| Volpe Center | John A. Volpe National Transportation Systems |