

VERMONT AGENCY OF TRANSPORTATION

**Research and Development Section
Research Report**



**EVALUATION OF BLINKERSIGN®
CROSSWALK LIGHTING SYSTEM**

Report 2014 – 13

December 2014

**Evaluation of BlinkerSign®
Crosswalk Lighting System**

Final Report

Report 2014 – 13

December, 2014

Reporting on Work Plan 2005-R-3

STATE OF VERMONT
AGENCY OF TRANSPORTATION

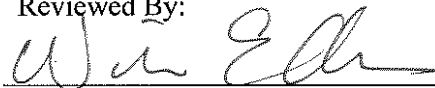
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16. Abstract Concerning pedestrian safety, the Vermont Agency of Transportation (VTTrans) is constantly searching for ways to improve areas where large volumes of people and heavy vehicular traffic may come in direct conflict with one another. In an effort to address this matter, VTTrans installed BlinkerSigns®, produced by Tapco, in November 2008 to enhance the visual delineation limits of a preexisting crosswalk adjacent to the Quechee Gorge Visitor Center in Hartford, Vermont. The signs incorporate Day-Viz™ LEDs and 3M™ VIP Diamond Grade™ sheeting giving drivers notice much further in advance than conventional signs. After analyzing the results from the speed studies, the BlinkerSigns® have proven more effective, and therefore safer, than having no system in place. Four years following installation of the BlinkerSigns®, yielding compliance has increased by 8% on average, and a 20% increase was found in the number of vehicles slowing down as they approach within 300 feet of the crosswalk. From these findings, it has been determined that the BlinkerSigns® have provided long-term benefits. The product should be considered at future crosswalks and emergency crossings on Vermont Agency of Transportation projects where increased visibility is warranted. Other recommended applications are crossings that are not well lit, locations of high pedestrian crossings and at critical crossings in urban areas where significant automotive and pedestrian traffic conflicts occur.			
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ABSTRACT

Concerning pedestrian safety, the Vermont Agency of Transportation (VTrans) is constantly searching for ways to improve areas where large volumes of people and heavy vehicular traffic may come in direct conflict with one another. In an effort to address this matter, VTrans installed BlinkerSigns[®], produced by Tapco, in November 2008 to enhance the visual delineation limits of a preexisting crosswalk adjacent to the Quechee Gorge Visitor Center in Hartford, Vermont. The signs incorporate Day-Viz[™] LEDs and 3M[™] VIP Diamond Grade[™] sheeting giving drivers notice much further in advance than conventional signs.

After analyzing the results from the speed studies, the BlinkerSigns[®] have proven more effective, and therefore safer, than having no system in place. Four years following installation of the BlinkerSigns[®], yielding compliance has increased by 8% on average, and a 20% increase was found in the number of vehicles slowing down as they approach within 300 feet of the crosswalk. From these findings, it has been determined that the BlinkerSigns[®] have provided long-term benefits. The product should be considered at future crosswalks and emergency crossings on Vermont Agency of Transportation projects where increased visibility is warranted. Other recommended applications are crossings that are not well lit, locations of high pedestrian crossings and at critical crossings in urban areas where significant automotive and pedestrian traffic conflicts occur.

INTRODUCTION

According to the National Highway Traffic Safety Administration (NHTSA), pedestrians represent a significant portion of traffic-related injuries and fatalities in the United States. In 2012, there were 4,743 pedestrian fatalities and 76,000 pedestrian injuries in traffic crashes. Relatively, a pedestrian was killed every 111 minutes and injured every 7 minutes on average (1). In an effort to reduce these alarming totals, numerous design guidelines and electronic traffic control devices have been developed.

In accordance with the Manual on Uniform Traffic Control Devices (MUTCD) Section 3B.18, P1 and P2, Crosswalk Markings, “Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops. Crosswalk markings in conjunction with signs and other measures also serve to alert road users of a pedestrian crossing point across roadways at locations that are not controlled by highway traffic signals or STOP or YIELD signs” (2). Previous studies have shown that many pedestrians feel overly secure when using a marked crosswalk often placing them in dangerous situations. Additionally, the motorist stopping response is greatly reduced due to variables such as foreshortening and distance diminishment, roadway alignment, weather, dirty windshields, glare, adverse lighting conditions, and driver inattentiveness (3).

In an effort to increase pedestrian safety and driver awareness, VTrans, installed a series of in-pavement flashing warning LED lights, known as SmartStud™, in September of 2006 to enhance the visual delineation limits of a preexisting crosswalk in Quechee, in the town of Hartford, VT. This location is characterized by a high tourist population and large traffic volume. While the results from a before and after study found that the in-pavement lighting system was effective in increasing driver awareness and pedestrian safety, several of the lighting units malfunctioned during the two year monitoring period. According to the manufacturer, the housing was not sufficiently embedded making them susceptible to wear and cracking under the weight of vehicles. Subsequently, the markers failed possibly due to physical stress from the impact of the plows and/or vehicles running over the compromised housing. In addition, this wear also caused the lenses to become opaque reducing the visibility of the lighting and likely their overall effectiveness.

The Agency’s Highway Safety and Design Section remained committed to implementing a device that would alert motorists to the presence of a pedestrian crossing or preparing to cross the street under all ambient conditions including winter months. As opposed to embedded systems that were found to be highly susceptible to damage from winter maintenance, several upright alternatives were considered. Ultimately, two experimental flashing L.E.D. traffic signs, known as BlinkerSigns® produced by TAPCO, were hardwired into the existing SmartStud™ System.

The purpose of this final report is to examine and evaluate the overall effectiveness of the replacement BlinkerSign® system.

PROJECT LOCATION AND SUMMARY

In accordance with the Experimental Feature workplan, WP 2005-R-3, the enhanced safety features were installed along US Route 4 at approximately MM 3.4 in the town of Hartford, near the Quechee Gorge Visitors Center. This area is characterized by a heavily travelled roadway consisting of local residents and tourists. The average annual daily traffic (AADT), on this two-lane roadway, is 12,500, a moderately high AADT for the State of Vermont. Although the posted speed limit is 35 miles per hour (mph), visual observations indicate that many motorists travel above this speed.

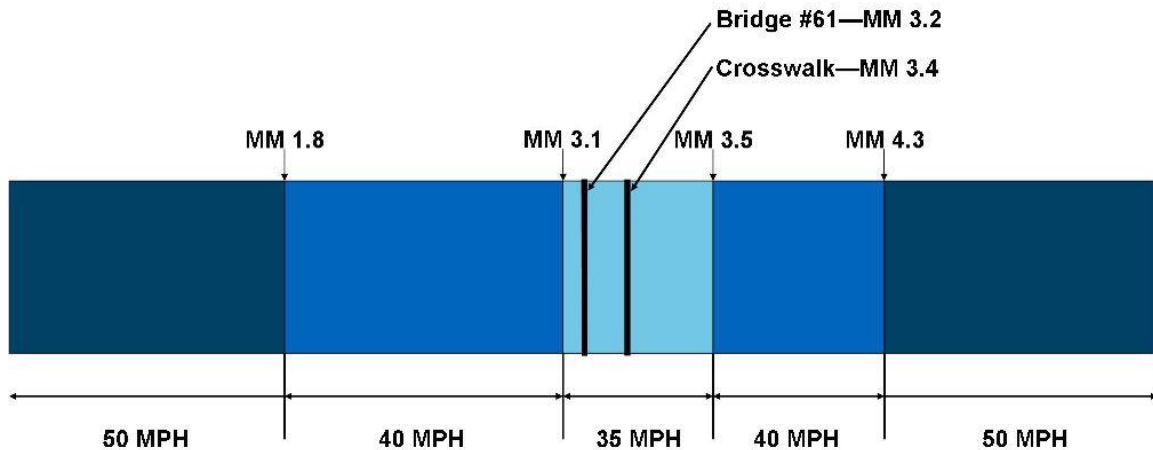


Figure 1 Speed Limit Diagram.

The roadway is relatively flat with limited horizontal curve alignments. It is suspected that the observed increase in speed may be caused by unfamiliarity with the area as much of the demographic is composed of tourists (3).

The original enhanced warning system, Smart Stud In-Pavement Crosswalk Lighting System was installed in conjunction with the Quechee Gorge Visitor Center Project, Hartford PLH QGSP (2). This enhancement project included the construction of a new Visitor's Center

and parking lot. Together, the improvements were supposed to enhance safe passage from the Visitor's Center to key vantage points of the gorge. Due to poor performance, the Smart Stud system was replaced with the BlinkerSigns[®] (see Report 2011-03).

PRODUCT DESCRIPTION AND INSTALLATION

BlinkerSigns[®], manufactured by TAPCO of Elm Grove, Wisconsin, are enhanced traffic signs with Light Emitting Diodes (LED) around portions of the sign border meeting the requirements of the MUTCD Section 2A.07, "Retroreflectivity and Illumination." According to TAPCO, a feature entitled "Day-Viz[™]" features an array of incredibly bright LEDs that flash in unison, once per second. BlinkerSigns[®] may be programmed to operate continuously or on solar time clocks, push-buttons, and/or motion detectors. The signs may be integrated into an intelligent transportation system (ITS) and programmed to flash simultaneously. In addition, the BlinkerSigns[®] can operate on either solar power or hard wired into an electrical system. TAPCO utilizes 3M[™] Diamond Grade[™] sheeting, a highly reflective sheeting and asserts that the signs can be seen up to two miles away (4).

Prior to installation, Rich Lolli from TAPCO, Russ Velandar, the VTrans' Traffic Shop Supervisor, and Research personnel conducted an equipment evaluation site visit to ensure that the existing 110-volt hard wired power supply and buried cable system that was in place for the existing SmartStud[™] system could be utilized to operate the BlinkerSigns[®]. TAPCO was able to customize the control board on each BlinkerSign[®] to work with the existing SmartStud[™] controller box and existing onsite equipment including the SmartPed[™], SmartCabinet[™] and SmartButton[™].

Due to the configuration of the power supply loop, the signs were installed on the same side of the crosswalk by VTrans' Traffic Shop personnel. The first attempt to install the signs was on Wednesday, October 29, 2008. However due to an incorrect control board configuration, new signs needed to be shipped out. The new signs were installed on Monday, November 3, 2008. Traffic Shop personnel commented that the system was relatively easy to install with minimal setbacks due to the existing hard-wired system. On Tuesday, November 4, 2008, District 4 and Research personnel removed the SmartStud[™] LEDs from the ground and the holes were filled with cold patch.

PERFORMANCE AND OBSERVATIONS

Two site visits were conducted soon after installation, on Tuesday January 6, 2009 and Monday, August 2, 2010 to evaluate the condition of the BlinkerSign[®] system and visually assess the brightness of the LEDs. During the first site visit, the BlinkerSigns[®] were examined during daylight, dusk, and nighttime hours whereas the second visit was conducted solely during daylight hours. The signs appeared to be extremely visible under all light conditions especially during evening hours as shown in Figures 2 and 3, and were in excellent condition during both visits with no visible wear to the sign face or LED border. According to the District 4 maintenance crew and Traffic Shop personnel, no maintenance was performed in the first 18-month period after installation. Subsequently, the traffic shop has been onsite twice to fix electrical issues that presented themselves, rendering one of the signs non-functioning. One issue was a broken wire that was found and fixed and the second was a water (from rain) leak in one of the units that was repaired. Upkeep on winter maintenance around the signs has also been an issue during a few winter seasons since their installation. During winter storms, the stepping pads that can activate the system (in addition to the push button) can become covered with snow and ice. This causes the system to become disabled as the pads are constantly pushed by the applied weight. This has since been remedied with continued and targeted clearing during winter months.



Figure 2 BlinkerSign[®] during daylight hours.



Figure 3 BlinkerSign® during nighttime hours.

Pedestrian Study Overview

This pedestrian crossing study was modeled after an evaluation completed by the City of San Rafael, CA. The study assessed changes in driver behavior attributed to a crosswalk enhancement system. “Before” and “after” studies evaluated differences in vehicle behavior pre- and post-installation of the BlinkerSign® System. Each study incorporated a Vermont Agency of Transportation member dressed in typical pedestrian clothing with two crossing scenarios. In scenario 1, the decoy pedestrian provided the impression that they were about to step in the crosswalk by looking in both directions. In scenario 2, the decoy pedestrian looked in both directions and placed one foot into the crosswalk, as shown in Figure 4. Oncoming traffic was visually monitored during these events in order to assess driver behavior. Each scenario was completed 200 times (100 times per lane direction).

The “before” study took place two months prior to the SmartStud™ System installation on Monday, July 18, 2005. The first BlinkerSign® System “after” evaluation was carried out about 7 ½ months after installation on Wednesday, June 24, 2009 by Jon Kaplan, the Agency’s Bicycle and Pedestrian Program Manager, and Research personnel, and the final study on August 6, 2012, 45 months after installation. Although efforts were made to minimize as many variables

as possible, the decoy pedestrian used in the “before” and “after” SmartStud™ evaluations was not available so a different Agency member was chosen. Weather conditions during all studies were comparable.



Figure 4 Looking and stepping crossing scenario, pre HAWK installation.

Methodology was parallel in both studies. The first task was to delineate observation stations. This was done with painted stakes, marked out within a 500-foot stretch from the crosswalk in both the east and westbound directions. Observation stations are shown in Figure 5, which details the test area. After stations were set, the decoy pedestrian carried out the two crossing scenarios for both traffic directions. During this time, agency workers were taking observations 500 and 300 feet back from the crosswalk. All non-crossing Agency personnel were inconspicuously stationed along the side of the roadway to avoid drawing attention from the passersby.

Numerical data was collected using a stopwatch. The time in seconds for the leading car to travel from the 500'- 300' from the crosswalk was recorded. This data was used to calculate the leading car's approach speed, in mph. The deceleration speed was calculated similarly, using the time to travel from the stakes marked off at 300 and 100 feet. Additional observations included the vehicle's first braking distance, its compliance to the crosswalk system, and state of licensure.

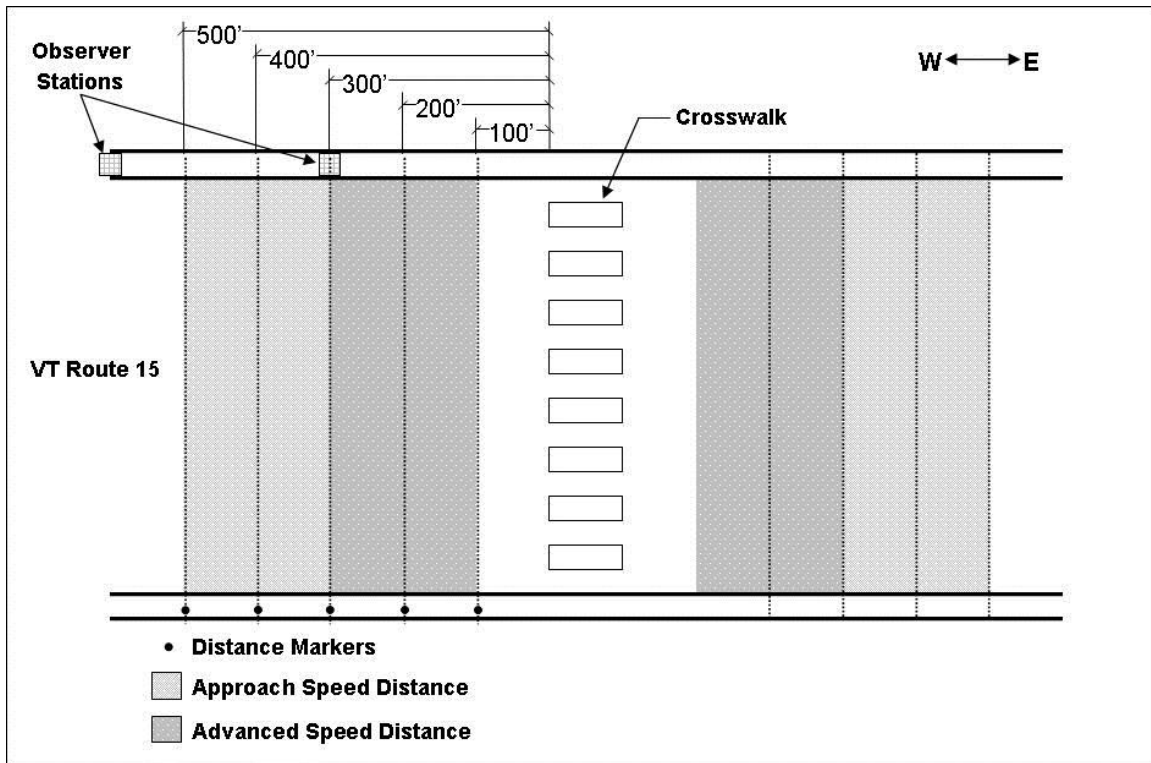


Figure 5 PHB study test area, for both pre- and post-installation experiments.

Data Analysis

Average speeds (miles per hour) were calculated by dividing the travel distance (feet) by travel time (seconds). All values were subsequently converted into miles per hour. Pre- and post-installation data was pooled together to develop a final summary, composed of roughly 800 data points. Results compared the test site before and after installation of the High-Intensity Activated Crosswalk. Data analysis yielded the system's performance success through percent increase/decrease of vehicles yielding, and percent increase/decrease of approach and deceleration speeds. All definitions and data analysis are summarized below. Please note that all raw data is available upon request.

Approach Speed

The approach speed is the speed of the vehicle while approaching the crosswalk within a range of 300 to 500 feet. This value represents the travel speed of the vehicle prior to and/or as the driver is first able to see the pedestrian. At this point, the driver should recognize the need to start slowing down in preparation to stop at the crosswalk. It is calculated by dividing the

distance travelled, (300 to 500 feet = 200 feet) by the time in seconds, it took the vehicle to travel the distance.

A graphical representation for the system exhibiting the average approach speeds for both east and westbound travel directions are showing below in

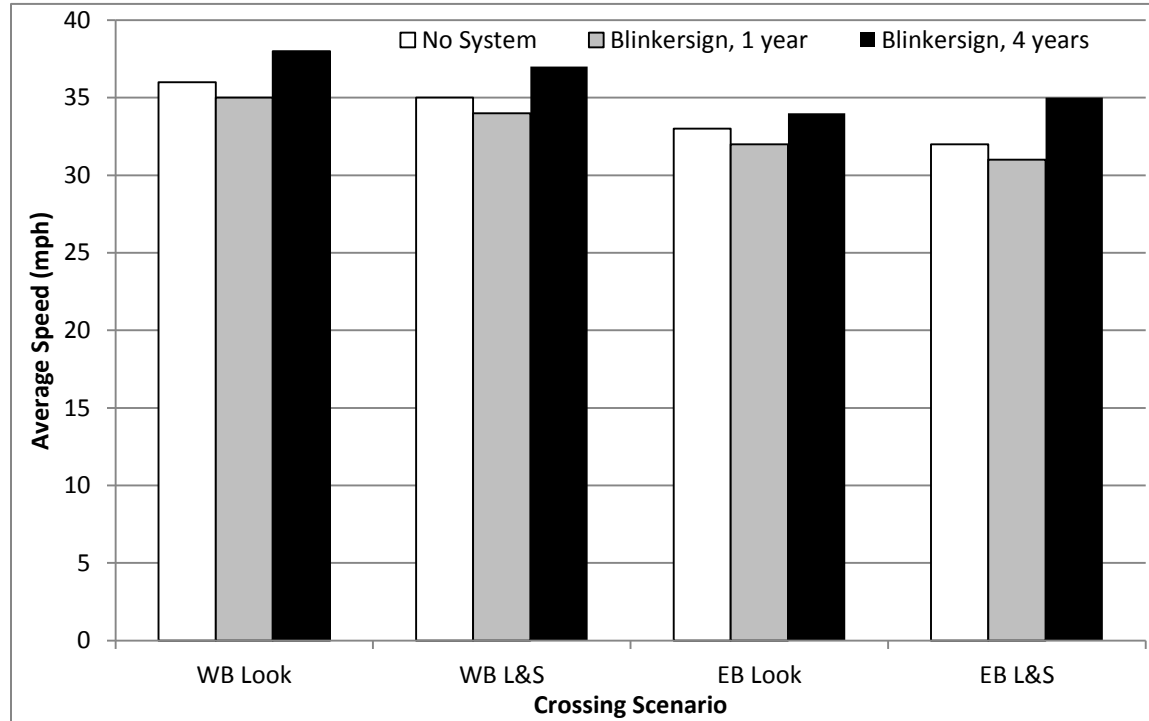


Figure 6. It should be noted that this figure includes speeds of all vehicles whether they yielded to the decoy pedestrian or not. A breakdown of each scenario for the two directions is provided later in the report. The data shows that, on average, vehicles approach the crosswalk at a faster speed from the west than they do from the east, regardless of what system is in place. Approach speeds decreased by one mile per hour with the addition of the BlinkerSigns[®], however after an additional three years approach speeds actually increased by 2 mph over no system at all, indicating that drivers may now be driving faster in general through this tourist area.

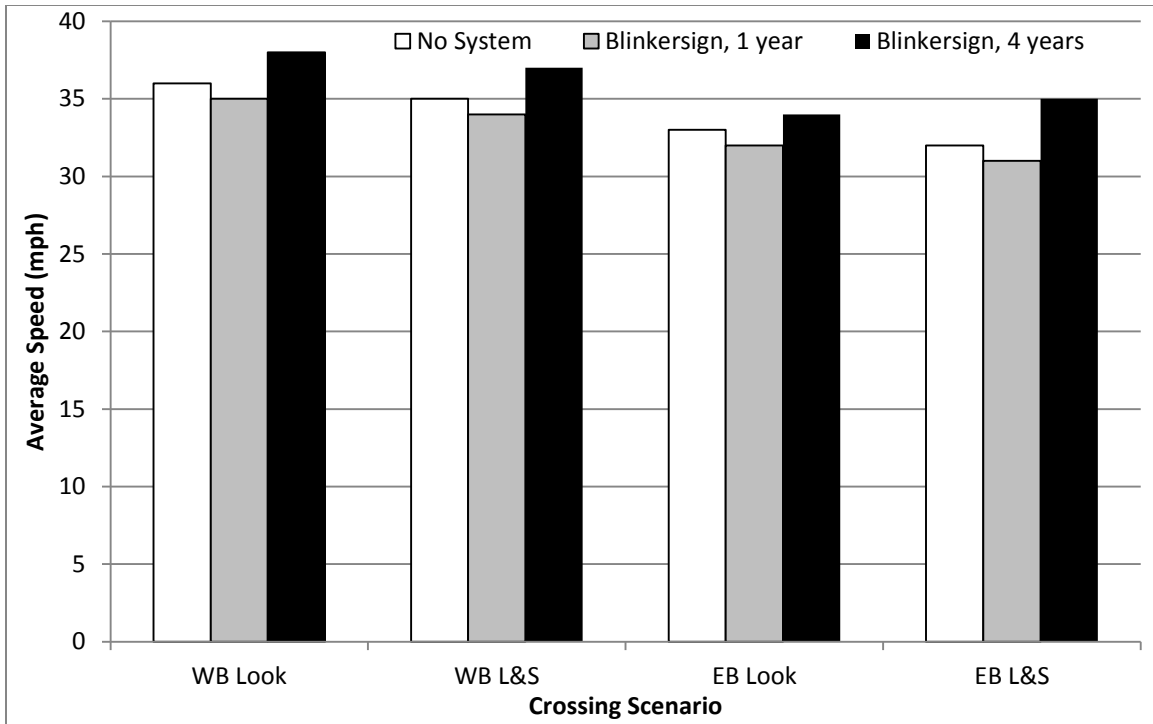


Figure 6 Average approach speeds.

Table 1 Average approach speeds (mph) and associated standard deviations.

System	WB Look only		WB Look and Step		EB Look Only		EB Look and Step	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
None	36	7.9	35	6.0	33	5.6	32	6.5
BS, Year 1	35	6.1	34	5.0	32	5.5	31	4.1
BS, Year 4	38	5.8	37	7.2	34	6.1	35	5.6

The standard deviation for all systems in both directions and crossing scenarios are comparable and reasonable as to suggest a small amount of variability within the data sets or in this case driver response. During the latest study, the average speeds are below (eastbound) or slightly above (westbound) the posted speed limit, the standard deviations imply that some

portion of the study population is traveling well above the speed limit of 35 mph assuming normal distribution. This evidence supports the need for an advanced warning system.

Deceleration Speed

The deceleration speed is the speed of the vehicle within the distance of 100 to 300 feet in advance of the crosswalk. This value represents the average speed that vehicles travel over the 200-foot distance. It is calculated by dividing the distance traveled, (100 to 300 feet = 200 feet) by the time, in seconds, it took the vehicle to travel that distance. This speed should reflect, when compared to the vehicle's approach speed, whether or not it has begun to slow down once recognizing the pedestrian or signal being activated.

A graphical representation exhibiting the average deceleration speeds for both east and westbound travel directions are shown in Figure 7. It should be noted that the figure includes speeds of all vehicles whether they yielded to the decoy pedestrian or not. Averages and associated standard deviation results are shown in Table 2.

The standard deviation for all systems in both directions and crossing scenarios are comparable based on the average speed results. Once again, standard deviations are relatively small indicating consistent driver behavior.

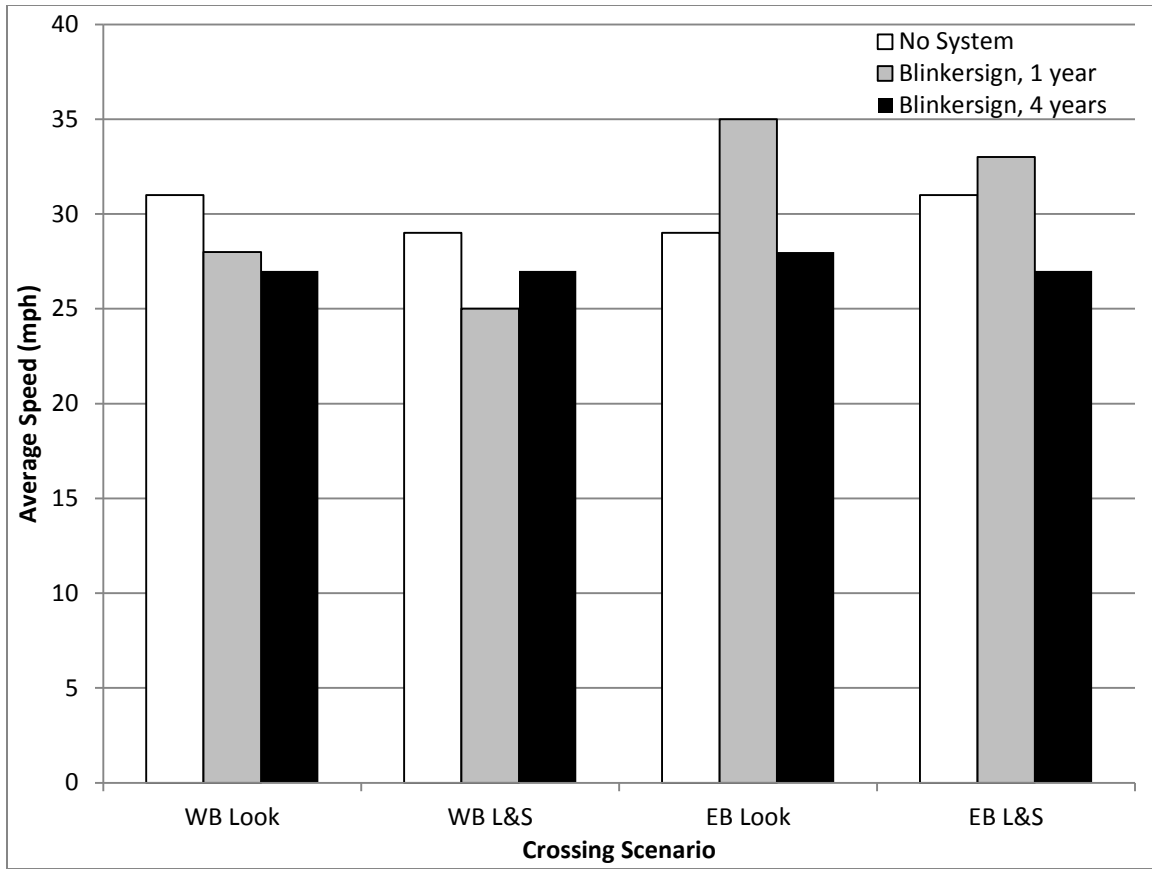


Figure 7 Average deceleration speeds.

Table 2 Average deceleration speeds (mph) and associated standard deviations.

System	WB Look only		WB Look and Step		EB Look Only		EB Look and Step	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
None	31	6.7	29	6.9	29	5.8	31	5.9
BS, Year 1	28	8.7	25	5.7	35	7.1	33	6.7
BS, Year 4	27	4.8	27	5.9	28	6.2	27	4.6

Approach and Deceleration Speed Comparison

Approach and deceleration speeds hold an interesting comparison. In theory, it could be expected that average approach speeds would be greater than average deceleration speeds, as at least some portion of the population would slow down for a pedestrian in a crossing scenario. This held true for each scenario of the no-system and the BlinkerSign[®] year 4 studies and the

westbound year 1 study. Counter to all other scenarios, the data shows that the average vehicle sped up by more than 2 mph as they approached the activated signs and crosswalk in the two eastbound scenarios for the year 1 study. The data did not coincide well with field observations that suggested automobiles appeared to be slowing as they were in the other approach. One possible reason for the higher speed calculations was a benchmark used to time the automobile traverse was incorrect.

Changes in approach versus deceleration speeds are presented in Table 3. With no system in place the average vehicle decelerated by 4 mph once they had the opportunity to observe that a pedestrian was preparing to cross at the crosswalk. Once the BlinkerSigns[®] had been in place for about one year, the speed decrease actually went down to slightly less than 3 mph, but this includes the data discrepancy previously noted; if only the westbound lanes were represented, the average speed decrease was 8 mph, a large increase from no-system.

Table 3. Average speeds through both directions and crossing scenarios.

	With No System	BlinkerSigns[®] Year 1	BlinkerSigns[®] Year 4
Approach Speed	34.2	32.8	36.0
Deceleration Speed	30.2	30.1	27.1

Traditionally it may be expected that once a safety measure has been installed for a number of years drivers could become complacent with it and begin ignoring or disregarding it more out of habit. This would lead to statistics returning closer to their pre-system state. This was not the case at the four year pedestrian study as the speed decrease approached 9 mph once the BlinkerSigns[®] were activated, a very substantial decrease in speed. This indicates the BlinkerSigns[®] are still performing as desired.

A graphical comparison of the difference between approach and deceleration speeds is shown in Figure 8 and 9. Figure 8 plots approach speed (x-axis) and deceleration speeds (y-axis) couplets on a scatter plot for the no-system pedestrian study, while Figure 9 shows them for the BlinkerSign[®] year 4 study. The diagonal lines in each figure represent approach speeds equaling deceleration speeds. The more data points that are present below the line, the more vehicles slowed down during the studies. It is evident from the plots that the data shifts below the line in general with the BlinkerSigns[®] installed, indicating many more drivers slowed down when the system was activated than previously had with the pedestrian only as the visual key. The data shows that 71% slowed down with no system (a very respectable number when compared to data found from other locations and studies) while that number increased to 91% with the system and year 4.

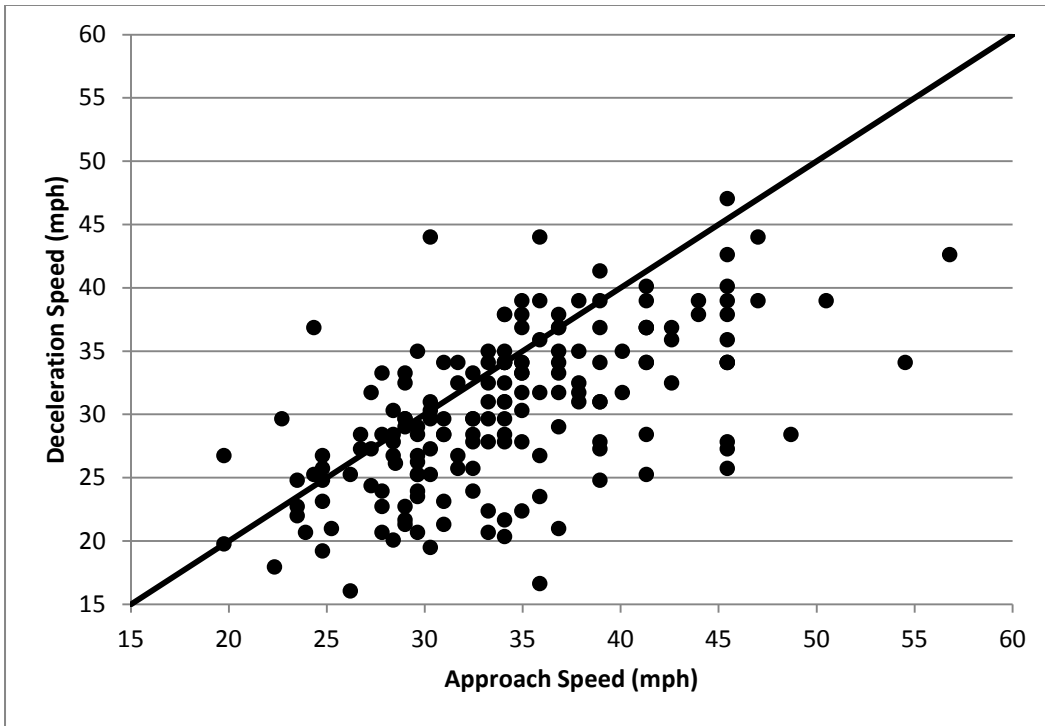


Figure 8. Deceleration vs. approach speed with no system.

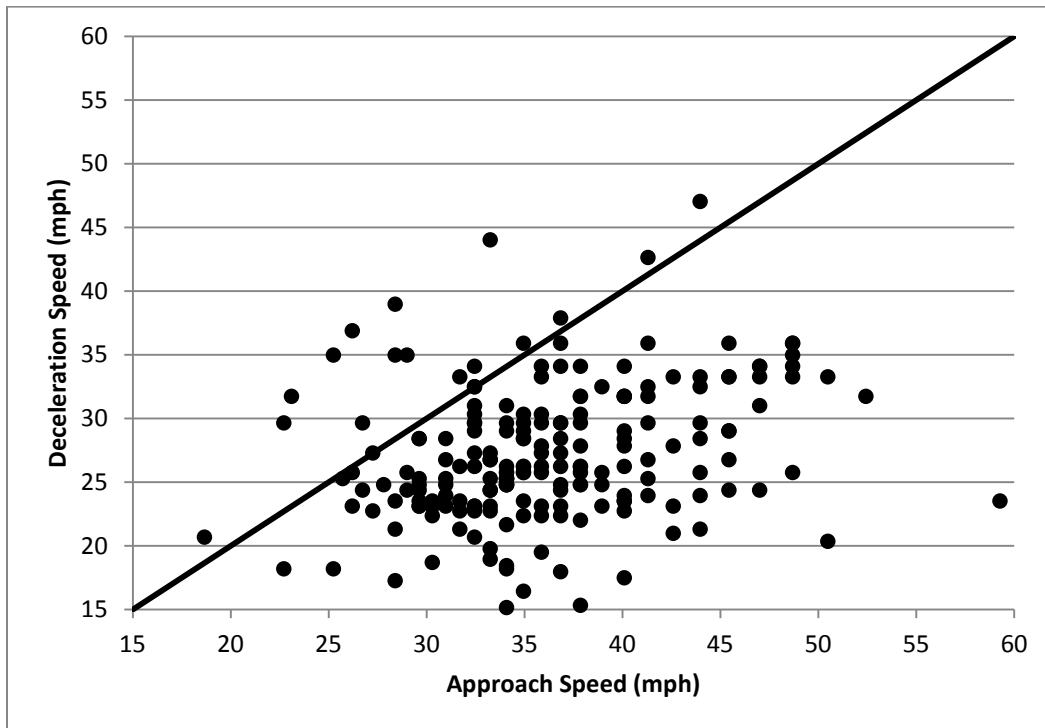


Figure 9. Deceleration vs. approach speed ~4 years after BlinkerSigns installed.

Yielding Compliance

Yielding compliance is the percentage of vehicles approaching the crosswalk during the staged experiment that yielded or stopped for the pedestrian. Table 4 shows the percentage of vehicles that yielded for the staged pedestrian during each crossing scenario for both lane directions.

Table 4. Vehicle yielding compliance.

Direction	No System	BlinkerSign [®] Year 1	BlinkerSign [®] Year 4
	% Vehicles Yielding	% Vehicles Yielding	% Vehicles Yielding
Looking Only			
EB	78	65	62
WB	31	78	52
Looking and Stepping			
EB	63	88	74
WB	54	88	66
Overall Average			
Overall	56	80	64

For example, there was a 31% yielding compliance rate before any system was installed, in the looking only scenario for the westbound direction. One year after the installation of the BlinkerSigns, the amount of cars stopping rose to 78% of the westbound vehicles, and then dropped again to 52% at year 4. Overall, the percentage of traffic that yielded to pedestrians increased following the installation of the pedestrian hybrid beacon crosswalk system. When no system was in place 56% of the overall traffic yielded, compared to 80% compliance with the activated system at year one, then fell somewhat to 64% at year 4. The overall percentages are comprised of both directions and crossing scenarios. Of the two scenarios, it is interesting to note the considerable increase in driver compliance when the decoy pedestrian acts as if they are crossing the road by beginning to step out into the crosswalk. This indicates that a subset of the population only complies with crosswalks and crosswalk systems when they feel compelled to avoid hitting a pedestrian.

SUMMARY AND RECOMMENDATIONS

After analyzing the results from the speed studies, the BlinkerSign® system has proven more effective, and therefore safer, than having no system in place. Following installation of the signs, yielding compliance increased by 14% on average, and remained 8% higher after 4 years. In addition, lower speeds have been shown from vehicles as they near the crosswalk. There have been no documented complaints from vehicular or pedestrian traffic. The system will continue to be examined for any visible damage, complaints and vehicular or pedestrian accidents in the future to ensure its advantages. Further deployment should be considered at high pedestrian count unsignalized intersections or crosswalks.

REFERENCES

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EXPERIMENTAL FEATURE WORKPLAN

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION

CATEGORY II WORK PLAN FOR
Permanent Demarcation for Pedestrian Crosswalks
Work Plan No. WP 2005-R-3

OBJECTIVE OF STUDY:

To evaluate the performance a proprietary permanent demarcation for a pedestrian crosswalk. This evaluation will help to determine the safety benefits of highly visible crosswalks in heavy vehicular and pedestrian traffic areas.

LOCATION:

On US 4 between MM 3.00 to MM 3.10, in the town of Hartland, VT, near the Quechee Gorge Visitors Center

MATERIAL:

Various materials may be used to accomplish the objective. These include:

1. Colored aggregate bituminous materials (see NAPA)
2. Pigmented modified Portland Cement (Lambert Corporation)
3. Polymer Concrete with colored aggregates (Lafarge North America)
4. LED fixtures (HIL-Tech Ltd)

COST:

Cost is dependant on the type of materials used as well as the amount required to complete the job. Cost was estimated for a crosswalk with a dimension of eight feet by thirty feet.

The following costs are for materials only (unless noted otherwise) and prices are not quoted from the manufacturers.

Colored aggregate bituminous material cost approximately \$60.00 per ton. It will take approximately 9 tons to fill the 8x30 crosswalk or \$540.

Pigmented modified Portland Cement cost \$150 per sy. An 8'x30' crosswalk has 26.6 sy, this would cost \$3,990.

Polymer concrete with colored aggregate is approximately \$200 per sy. 26.6 sy times \$200 equals \$5,320 for an 8'x30' crosswalk.

LED fixtures cost \$35.00 per Linear ft. If the length of the crosswalk is 30 feet than for both sides of the crosswalk it would cost \$2100 installed.

SURVEILLANCE AND TESTING:

Research personnel will monitor the installation of the materials and visually inspect them each spring and fall for the duration of the study. Research personnel will also be present for any maintenance activities involving the materials to evaluate the ease and cost of those activities. The surveillance shall include the following:

- 1) Durability of the material (ASTM D913-03, (Evaluating Degree of Resistance to wear of traffic Paint), ASTM D4383-03, (Plowable, Raised retroreflective Pavement Markers)).
- 2) Delineation performance under various light and weather conditions
- 3) The effects of the materials on snow removal operations, as well as the effect of plowing operations on the materials.
- 4) Photographic documentation on the products performance
- 5) Visibility at installation and periodically afterwards

DURATION OF THE STUDY:

The duration of the study will be three years.

REPORTS:

An initial report will be prepared to include the installation of the materials, with subsequent reports on an annual basis. A final report will be published after the three year duration, and any interim reports will be published as warranted.

Agency of Transportation Reviewed

By:

Materials and Research Section

Date:

Donald H. Lathrop, P.E.
Materials & Research Engineer
Date: