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Evaluation of a Rectangular Rapid Flashing Beacon System at the Belmont Ridge Road and W&OD Trail Mid-Block Crosswalk

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16. Abstract:

On April 8, 2013, the Virginia Department of Transportation (VDOT) installed a Rectangular Rapid Flashing Beacon (RRFB) system at Belmont Ridge Road in Loudoun County that included two units at the Washington and Old Dominion (W&OD) Trail crossing in addition to advance warning units for the northbound and southbound travel directions. Recent studies have shown that the devices elicit a greater response from motorists and significantly increase driver yielding behavior at crosswalks when supplementing standard pedestrian crossing warning signs and markings. In July 2008, the Federal Highway Administration gave interim approval for optional use of RRFBs in limited circumstances. The interim approval allows for use as a warning beacon to supplement standard pedestrian warning signs and markings at a pedestrian or school crossing; where the crosswalk approach is not controlled by a yield sign, stop sign, or traffic-control signal; or at a crosswalk at a roundabout.

The purpose of this study was to evaluate the utility, effectiveness, and safety of the RRFB system at the intersection of the W&OD Trail and Belmont Ridge Road over a 1-year period. Of particular interest was (1) the percentage of trail users that pressed the push button to activate the RRFBs and whether this varied by mode (pedestrians vs. bicyclists); (2) motorist behavior when the RRFB system was activated versus not activated; and (3) trail user impressions of the system relating to perceptions of safety. Motorist and trail user data and interactions were collected in three separate video data collection efforts: 3 weeks, 5 months, and 1 year after the RRFB system installation. In addition, individual vehicle speed data were collected with a LIDAR gun, and on-site and online surveys were administered to obtain trail user opinions.

The results of the study indicated that the RRFB systems had a positive effect on motorist awareness. This was evidenced by the increased yield rates when the system was activated versus not activated; speed reductions when the system was activated; and trail user perspectives on increased opportunities to cross and increased safety at the crossing location. Additional conclusions were that the RRFB system is perceived by trail users as an enhancement to safety at the Belmont Ridge Road crossing; trail user perceptions of RRFB system benefits grow over time; there is a correlation between trail user activations and the presence of traffic; and trail users remain confused as to who has the right of way at the crossing location.

The study recommends the following: (1) VDOT's Operations Regions should continue to pursue opportunities to install and evaluate RRFB systems; (2) VDOT's Traffic Engineering Division should develop more specific guidance for RRFB system installations; and (3) the Virginia Center for Transportation Innovation and Research should conduct a crash analysis at Belmont Ridge Road 3 years after installation of the RRFB system.

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FINAL REPORT

EVALUATION OF A RECTANGULAR RAPID FLASHING BEACON SYSTEM AT THE BELMONT RIDGE ROAD AND W&OD TRAIL MID-BLOCK CROSSWALK

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In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Virginia Center for Transportation Innovation and Research
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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ABSTRACT

On April 8, 2013, the Virginia Department of Transportation (VDOT) installed a Rectangular Rapid Flashing Beacon (RRFB) system at Belmont Ridge Road in Loudoun County that included two units at the Washington and Old Dominion (W&OD) Trail crossing in addition to advance warning units for the northbound and southbound travel directions. Recent studies have shown that the devices elicit a greater response from motorists and significantly increase driver yielding behavior at crosswalks when supplementing standard pedestrian crossing warning signs and markings. In July 2008, the Federal Highway Administration gave interim approval for optional use of RRFBs in limited circumstances. The interim approval allows for use as a warning beacon to supplement standard pedestrian warning signs and markings at a pedestrian or school crossing; where the crosswalk approach is not controlled by a yield sign, stop sign, or traffic-control signal; or at a crosswalk at a roundabout.

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The study recommends the following: (1) VDOT's Operations Regions should continue to pursue opportunities to install and evaluate RRFB systems; (2) VDOT's Traffic Engineering Division should develop more specific guidance for RRFB system installations; and (3) the Virginia Center for Transportation Innovation and Research should conduct a crash analysis at Belmont Ridge Road 3 years after installation of the RRFB system.

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INTRODUCTION

In April 2009, the Virginia Department of Transportation (VDOT) installed experimental zig-zag pavement markings on Belmont Ridge Road in advance of the Washington and Old Dominion (W&OD) Trail crossing in Loudoun County, Virginia. Belmont Ridge Road was chosen as a study site was because of its high posted speed limit (45 mph), high traffic volumes (17,800 vehicles per day), roadway geometry (sharp vertical and horizontal curvature), high trail volumes, and motorists' limited sight distance of the W&OD Trail crossing zone.

The purpose of installing the zig-zag pavement markings was to increase motorist awareness in advance of the mid-block crossing location. A study conducted by Dougald at the Virginia Center for Transportation Innovation and Research (VCTIR) (hereinafter "zig-zag study")[1] found that the markings increased motorist awareness as indicated by lower average vehicle speeds within the zig-zag zone. Although the markings were proven to be successful in heightening motorist awareness, VDOT continues to hear concerns from the community about safety issues at the W&OD Trail crossing at Belmont Ridge Road. In 2011, the trail owner, i.e., the Northern Virginia Regional Park Authority (NVRPA), commissioned a consultant to evaluate the crossing and make recommendations for improvements.

In February 2012, NVRPA consultant prepared an *Existing Conditions Report*[2] for the following roadway crossings of the W&OD Trail:

- Belmont Ridge Road—Ashburn, Loudoun County
- Sterling Boulevard—Sterling, Loudoun County
- Wiehle Avenue—Reston, Fairfax County
- Hunter Mill Road—Vienna, Fairfax County
- Lee Highway—Arlington, Arlington County
- Columbia Pike—Arlington, Arlington County.

The evaluation criteria included motorist yield rate, trail user behavior, and trail user perspectives obtained via site surveys. At Belmont Ridge Road, the consultant found the following key characteristics:

- *85th Percentile Vehicle Speed:* northbound , 51 mph; southbound, 54 mph.

- *Yield Rate* (percentage of motorists who yield with a trail user present): 23 percent.

- *Compliant Trail Users* (observation of trail users coming to a complete stop at each STOP-controlled location): bicyclists, 57 percent; pedestrians, 95 percent.

- *Risky Trail Users* (observation of trail users forcing vehicles to yield and/or dodging moving vehicles): bicyclists, 13 percent; pedestrians, 0 percent.

- *Trail User Discomfort:* 30 percent felt uncomfortable crossing; 40 percent felt moderately uncomfortable.

The feeling of discomfort of those crossing Belmont Ridge Road was the highest of all locations studied. The study[2] also found that motorist yield rates tended to increase as the presence and visibility of the trail users increased and higher yield rates can reduce trail-user wait times and provide safe crossing opportunities.

In May 2012, the NVRPA consultant prepared a *Recommendations Report*[3] with the goal of "improving the safety, comfort, and priority of trail users" for the six intersections studied. For Belmont Ridge Road, two quick implementation recommendations were to improve site conditions for better sight distance of the trail and to install a Rectangular Rapid Flashing Beacon (RRFB) system to supplement the existing zig-zag markings.

RRFBs are user-actuated amber light-emitting diodes (LEDs) that supplement warning signs at unsignalized intersections or mid-block crosswalks and are a lower cost alternative to traffic signals and hybrid signals.[4] Recent studies have shown that the devices elicit a greater response from motorists and significantly increase driver yielding behavior at crosswalks when supplementing standard pedestrian crossing warning signs and markings.[5,6]

In July 2008, the Federal Highway Administration (FHWA) gave interim approval to state DOTs for optional use of RRFBs in limited circumstances. The interim approval allows for use as a warning beacon to supplement standard pedestrian warning signs and markings at a pedestrian or school crossing; where the crosswalk approach is not controlled by a yield sign, stop sign, or traffic control signal; or at a crosswalk at a roundabout.[7]

Prior to the consultant's 2012 recommendations to NVRPA,[3] in March 2011, VDOT submitted a Request for Experimentation to the FHWA seeking statewide interim approval to implement RRFBs on streets and highways under VDOT jurisdiction and under the provisions of Section 1A.10 of the FHWA's 2009 edition of the *Manual of Uniform Traffic Control Devices for Streets and Highways* (MUTCD).[8] The request is shown in Appendix A, and the subsequent FHWA approval is provided in Appendix B.

Upon receiving interim approval to install RRFBs, VDOT's Traffic Engineering Division provided guidance to VDOT districts on system installations and evaluations. With respect to installation, RRFBs should be considered only at locations that meet the following criteria:

- The pedestrian count is at least 20 in the peak crossing hour.

- There is a marked crosswalk existing or justified at the location.

- Other pedestrian options have been reviewed and determined by engineering judgment not to be applicable.

Additional criteria include the following:

- placement meets or exceeds minimum sight distance from driver's eye to the device on the side of the road or in the median (as applicable)

- roadway has a posted speed limit of 35 mph or less

- installed only for crossing a two-lane road, a four-lane road with median, or in limited cases a two-lane road with a center turn lane.

On April 8, 2013, VDOT installed an RRFB system at Belmont Ridge Road that included two units on each side of the road at the W&OD Trail crossing in addition to advance warning units for the northbound and southbound travel directions. All trail and roadway criteria are met at Belmont Ridge Road except for the posted speed limit (i.e., 45 mph is not ≤ 35 mph); however, VDOT'S Northern Virginia's traffic engineering staff believed that the potential safety benefits of the system outweighed the potential safety disbenefits (with regard to speed limit).

PURPOSE AND SCOPE

The purpose of this study was to evaluate the utility, effectiveness, and safety of the RRFB system installed by VDOT at the intersection of the W&OD Trail and Belmont Ridge Road over the 1-year period following installation. Of particular interest were (1) the percentage of trail users that pressed the button to activate the RRFBs and whether this varied by mode (pedestrians vs. bicyclists); (2) motorist behavior when the RRFB system was activated versus not activated; and (3) trail user impressions of the system relating to perceptions of safety.

The scope of the study was limited to the 1-year period following installation. In a separate study, crash data will be evaluated for the 3 years before and after installation of the RRFB system.

METHODS

To accomplish the study objectives, the following tasks were undertaken:

1. Review the literature.
2. Perform site review and collect field data.
3. Develop and distribute surveys.
4. Analyze field and survey data.
5. Develop recommendations.

Literature Review

A review of the literature was undertaken to gather information on studies conducted on RRFB installations throughout the United States. Of particular interest were methods used to evaluate RRFBs, either qualitative or quantitative, and installation guidelines and criteria. Resources used to perform this task were the VDOT Research Library and relevant Transportation Research Board databases. Because of the relatively recent FHWA interim approval to install RRFB systems, it was understood that the number of published studies might be limited.

Site Review and Data Collection

Site Review

The last site visit to Belmont Ridge Road prior to this study was during the zig-zag study[1] in April 2010. The location was revisited on April 8, 2013, the "turn on" date of the RRFB system. The purpose of the visit was to (1) see the work done by NVRPA and VDOT to improve site conditions; (2) witness the location and operation of the RRFBs; and (3) meet with VDOT's on-call contractor to determine the best location to place cameras to collect video data of the intersection of the trail and roadway.

W&OD Trail

The W&OD Trail is a completed rail-to-trail project in Virginia. The trail is 45 miles long and begins in the Shirlington area of Arlington County and terminates in Purcellville.[9] Figure 1 shows the trail and its intersections with various towns and cities along the Route 7 corridor. The W&OD Trail is currently used regularly by bicyclists and pedestrians; between 2 million and 3 million people use it each year, thus making the W&OD Trail one of the most successful rail-trails in the nation.[10]

The trail, which runs east/west in relation to Belmont Ridge Road, has yellow skip lines that run down the centerline of the trail. As the trail approaches the road crossing in both directions, the skip lines become solid lines. In addition to the centerline, other pavement markings on both approaches of the trail include advance rumble strips, stencils of "ROAD XING" and "STOP," and a STOP bar. Signage on the trail includes an advance STOP warning sign with a placard stating "CAUTION HIGH SPEED HIGH VOLUME TRAFFIC CROSSING AHEAD" and double-mounted STOP signs at the crossing. A high-visibility zebra crosswalk exists where the trail crosses Belmont Ridge Road. Figure 2 shows the eastbound and westbound approaches of the W&OD Trail.

Figure 1. The 45-Mile W&OD Trail[9]

(a) (b)

Figure 2. Eastbound Approach *(a)* and Westbound Approach (b) of W&OD Trail at Belmont Ridge Road

Belmont Ridge Road

Belmont Ridge Road intersects the W&OD Trail in the town of Ashburn in Loudoun County. At the intersection with the W&OD Trail, Belmont Ridge Road is a two-lane secondary road with a speed limit of 45 mph that runs in a general north/south direction. At its northernmost terminus is Route 7, which is approximately 1.3 miles north of the W&OD Trail crossing. The facility is rated as having a level of service (LOS) D, and in 2013 it carried an average daily traffic (ADT) of 12,000 vehicles with a driver population of mostly commuters. Approximately 6 percent of the vehicle volume is heavy trucks attributable in part to rock quarry and concrete plants nearby.

The geometry of Belmont Ridge Road consists of downhill grades on both north and south approaches to the crossing. Figure 3 shows the road profile in relation to the W&OD Trail crossing. The sight distance of the W&OD Trail crosswalk on the northbound and southbound approaches is approximately 660 and 1,750 feet, respectively. The northbound approach has a horizontal curve that decreases the viewing distance of the crossing, as opposed to the southbound approach, which has a relatively straight line of sight to the crossing.

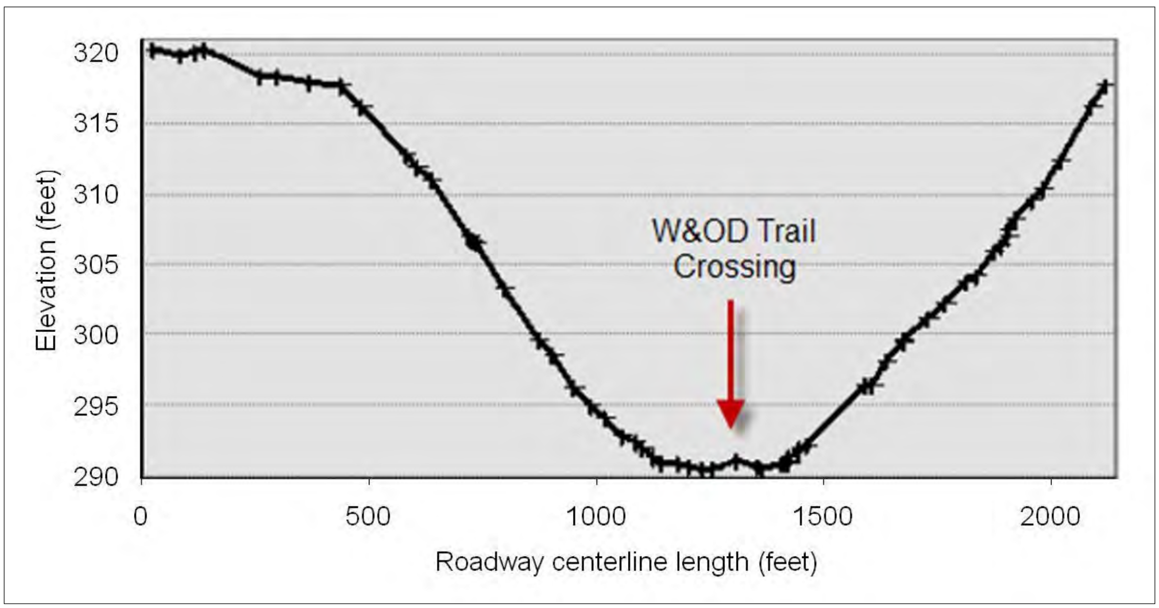


Figure 3. Road Profile of Belmont Ridge Road in Relation to W&OD Trail Crossing

Site Improvements

Based on the consultant recommendations from the NVRPA-commissioned study[3], NVRPA officials in consultation with VDOT and Loudoun County implemented the following action items to improve site conditions (Figure 4 shows an aerial schematic of the safety improvements):

- eliminated the ability of cars to pull onto and park on the existing bridle trail by installing split rail fencing along with NO PARKING signs on the east side of Belmont Ridge Road

- removed the existing bridle trail gravel east of Belmont Ridge Road and constructed a new horse trail route on the north side abutting the paved trail so that gravel trail users may cross at the existing crosswalk location

- installed a new paved path on the west side of Belmont Ridge Road leading from the existing paved trail north to the gravel bridle trail

- removed a street sign (Judith Lane) which was located on an abandoned driveway

- cleared vegetation to improve motorists' sight distance of the W&OD Trail.

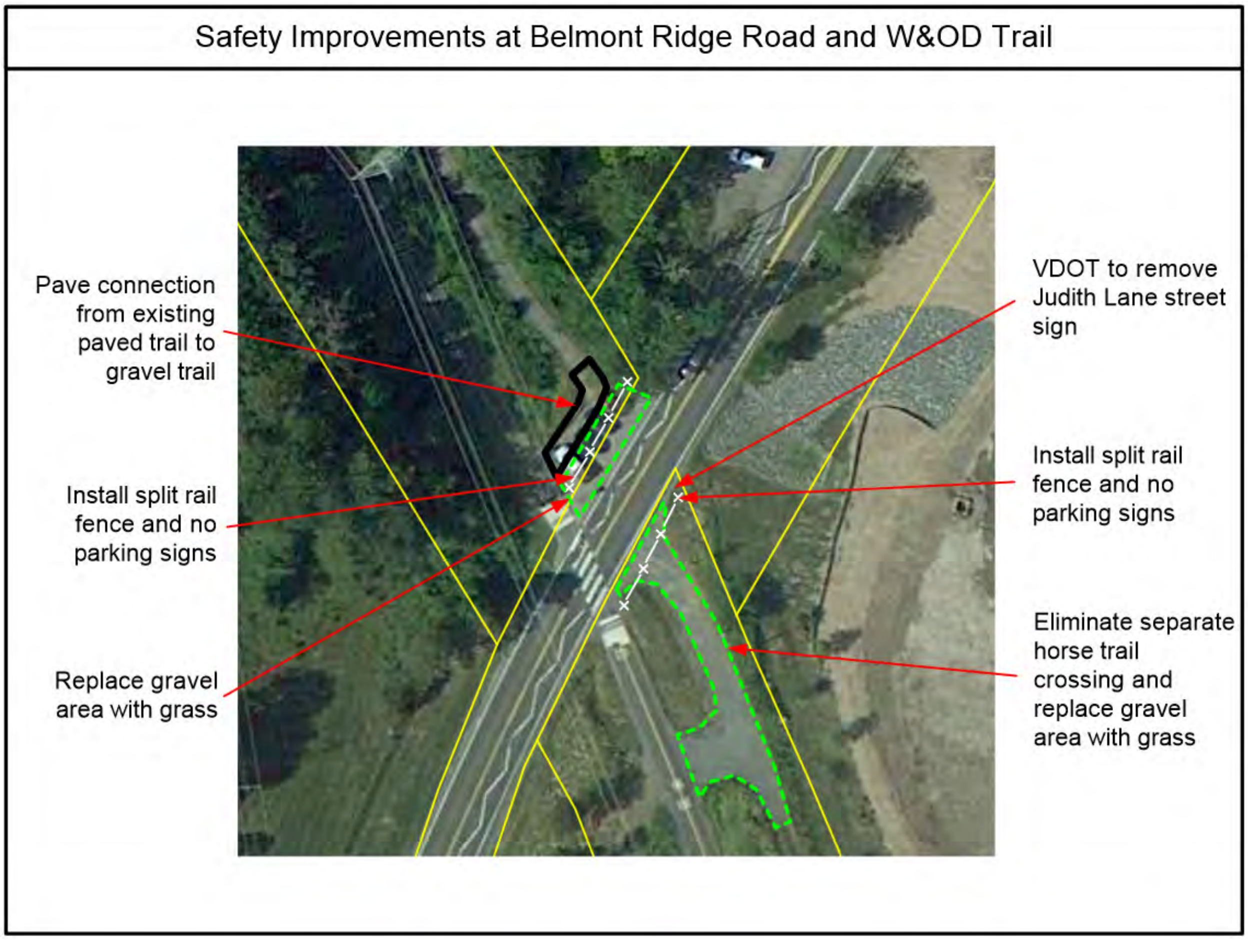


Figure 4. Aerial View of Site Improvements Made to Intersection of W&OD Trail and Belmont Ridge Road

RRFB Locations and Specifications

The RRFB system includes two poles located on the east and west side of Belmont Ridge Road at the intersection with the W&OD Trail crosswalk (see Figure 5) and two poles in advance of the crossing located 553 and 520 feet from the crosswalk in the northbound and southbound travel directions, respectively. At the crosswalk, each pole is mounted with double-sided W11-15 fluorescent yellow-green bicycle/pedestrian signs; W16-7P arrow signs; and high performance SB345 RRFBs. In addition, each pole has an SC315 network controller, a solar panel to power the network controller for wireless transmission to RRFBS on the upstream poles, and a pressure activated push button that is compliant with the Americans with Disabilities Act (ADA) and MUTCD. Above the push button is an R10-25 push button sign (see Figure 6).

Figure 5. RRFBs and Signage at W&OD Trail Crossing

Figure 6. RRFB Push Button and Sign

The upstream poles are mounted with W11-15 fluorescent yellow-green bicycle/pedestrian signs, W&OD TRAIL placards, and high performance SB345 RRFBs. Similar to the poles at the crossing, each upstream unit has an SC315 network controller and a solar panel to power the network controller for wireless communication transmission from the units at the crossing. Figure 7 shows the advance warning device on the northbound approach. A schematic of all the units on Belmont Ridge Road is shown in Appendix C.

Figure 7. Advance Warning RRFB and Signage on Northbound Approach of Belmont Ridge Road

When activated, the RRFB emits rapid, alternating amber LED bursts of light to warn motorists that trail users are at the crossing. According to manufacturer specifications, the pulses of light can be seen during daylight and nighttime at distances > 1,000 feet and > 1mile, respectively. Upon activation, The LED light stays on for 20 seconds. The timing calculation is given by

$$T = Z + R$$

where

T = the sum of the WALK allowance (Z) and the time required for a person to traverse the crosswalk (R)

Z = 7 seconds (typical WALK allowance)

R = length of the crossing (45 feet from stop bar to stop bar)/walking speed (3.5 feet/second).

The units include a smaller flasher that is oriented toward trail users so they can discern when the units are flashing.

Data Collection

It was postulated that data obtained during the zig-zag study[1] could be used as "before" data in a "before-after" RRFB installation analysis. However, because significant site improvements were made between the installation of the zig-zag markings and the RRFB system, a true before-after study could not be performed. In addition, the zig-zag study focused primarily on motorist awareness measured quantitatively via speed data and understanding of the markings measured qualitatively via surveys. To assess the effectiveness of the RRFB system, the current study compared speed data when the system was not activated (using data obtained during the zig-zag study) and when the system was activated. In addition, trail user and motorist interactions with and without RRFB activation and the utility of the RRFB system with respect to trail-user activation were evaluated over a 1-year period.

Trail User and Motorist Interaction

With the assistance of VDOT's on-call contractor, trail and roadway activity on each approach was analyzed via inconspicuously mounted cameras 3 weeks, 5 months, and 1 year after installation of the RRFB system. A black and white camera was elevated on a tripod with a 10-foot pole and placed approximately 150 feet south of the trail on the east side of Belmont Ridge Road. The height of the camera allowed for viewing the RRFBs and all four approaches of the intersection of the W&OD Trail and Belmont Ridge Road. Figure 8 shows the camera view of the intersection. The camera is attached by a cable to two self-contained digital video recorders (DVRs) in a waterproof case and a battery providing 120 hours of continuous recording. SD cards were inserted in the DVR as the recording media for the video.

Figure 8. Camera View of Intersection of Belmont Ridge Road and W&OD Trail

For each data collection day, approximately 14 hours of video were recorded—typically from 6 A.M. to 8 P.M. Table 1 shows the data collection periods. The days were chosen to capture typical weekday and weekend trail activity. Flexibility in data collection schedules was provided to account for weather (i.e., data collection events were postponed if poor weather such as cold temperatures or rain was in the forecast).

Table 1. Video Data Collection Days for Each Data Collection Period

3 Weeks After	5 Months After	1 Year After
Wednesday (5/1/13)	Wednesday (10/16/13)	Wednesday (4/9/14)
Thursday (5/2/13)	Thursday (10/17/13)	Thursday (4/17/14)
Saturday (5/4/13)	Saturday (10/19/13)	Saturday (4/5/14)
Sunday (5/5/13)	Sunday (10/20/13)	Sunday(4/6/14)

After each data collection period, video was reviewed and data were tabulated into an Excel spreadsheet for discrete trail user crossing events. For each crossing event, data tabulations included the following:

- mode of crossing (walker, cyclist, other) and number (singular crossing or number in a group)
- direction of crossing (westbound or eastbound)
- dismount or stop at the stop bar (yes/no)
- activation of flashers (yes/no)
- motorist yield (yes/no) and direction of yield (northbound [NB] / southbound [SB])
- number of motorists not yielding and direction (NB/SB).

After the video data were tabulated into Excel, the data were imported into Statistical Analytics Software (SAS) for processing and analysis. Of particular interest was the utility rate and effect of RRFB activations and whether trends changed over time. SAS inputs were configured in a stepwise process to provide the following outputs for each of the data collection periods:

1. *Number of trail person crossings by mode*. Pedestrians and bicyclists were the two classifications used. The pedestrian classification included walkers, joggers, skateboarders, and roller-bladers.

2. *Number of crossing instances defined as "potential RRFB activations."* In this analysis, the data were filtered to combine groups of two or more trail users crossing at the same time into distinct crossing events. For example, if three trail users were crossing at the same time, this was considered one potential RRFB activation event.

3. *RRFB activation rate.* After the number of candidate RRFB activations was determined, the activation rate was determined by dividing the number of activations by the number of potential RRFB activations.

4. *Traffic characteristics during potential RRFB activation events.* The purpose of this step was to develop a dataset where traffic was present during trail user crossing events. This was performed by filtering out instances where there were no motorist yielding events and trail users crossed without slowing/stopping. From these data, the RRFB activation rate when traffic was present could be determined.

5. *Effect of RRFB activation/non-activation on motorist yield rate.* The dataset developed in Step 4 provided the opportunity to analyze the effect of RRFB activation/non-activation on motorist yield rate. In this step, traffic was present during the time of crossing attempts and yields / no yields were tabulated to determine yield rate. This step could also be considered as a surrogate before-after RRFB installation analysis, with the before data being those instances where the RRFB was not activated and the after data being those instances where the RRFB was activated.

6. *Effect of activation/non-activation on immediate yields.* To account better for the effect of activation versus non-activation on yielding events, an analysis was performed that looked at immediate yields. In other words, when a trail user was attempting to cross, whether the first arriving vehicle in either or both directions yielded.

These six steps included documenting crossing events that were (1) pedestrians only, (2) bicyclists only, and (3) pedestrians and bicyclists crossing together. The purpose of categorizing the modes was to gain a better understanding of motorist reaction (measured in terms of yield rate) to each of the crossing modes. Additional analysis from the video included looking at the effect that groups of crossers versus single crossers had on motorist reactions.

Vehicle Speeds Obtained With LIDAR Gun

One week after the RRFB system was installed on Belmont Ridge Road, vehicle speeds were obtained when the RRFB system was activated. The purpose of this data collection effort was to analyze motorist reaction (in terms of speed) when a trail user activated the RRFBs and to compare the results with two sets of before data (speed data obtained before and after the installation of the zig-zag pavement markings).

As was performed during the zig-zag study,[1] staged trail users were positioned at the crosswalk/roadway interface and individual vehicle speeds were obtained with a light detection and ranging (LIDAR) gun by an upstream observer as vehicles progressed toward the crosswalk. The objective was to track vehicles in a free flow state (i.e., vehicles not impeded or influenced by other vehicles) on their approach to the crossings. Therefore, vehicles were not tracked if (1) it was determined that a leading vehicle was influencing the speed of a candidate vehicle and (2) if a vehicle or vehicles were queued at the crosswalk thus potentially influencing the approach speed of a candidate vehicle. Data were collected via a laptop equipped with a laser data transfer program. While a vehicle was tracked, its speed, range (distance from the LIDAR gun), and time (to the nearest 100th of a second) were recorded. The LIDAR gun has the capability of recording data approximately every 0.3 second. At each northbound and southbound approach, vehicle speeds were recorded for approximately 1½ hours during non-peak hours so as to lessen the potential for candidate vehicles to be affected by leading vehicles.

It was important that the observer with the LIDAR gun had a clear view of the crosswalk and was able to track vehicles before they encountered the upstream warning RRFB beacon through to the crosswalk markings. On the northbound approach of Belmont Ridge Road, the observer was positioned 550 feet upstream of the crosswalk. Ideally, this distance would have been longer in order to obtain more data before vehicles encountered the advance warning signage and RRFB, but the horizontal curvature obscured the view of the crosswalk. On the southbound approach, the observer had a clear view of the crosswalk from a much longer distance and therefore was able to be positioned 1,200 feet upstream of the crossing location.

Development and Distribution of Surveys

To gauge opinions of the RRFB system, surveys were administered to trail users on-site at the W&OD Trail and online to bicycle clubs 1 year after RRFB installation. The bicycle clubs surveyed via SurveyMonkey included Bike Loudoun, Potomac Pedalers Touring Club, Fairfax Advocates for Better Bicycling, the Reston Bicycle Club, and the Washington Area Bicyclist Association. The survey was designed to ascertain the overall opinions of the RRFB system held by frequent and infrequent trail users and those that frequently, sometimes, and never activated the system. The survey is shown, as administered, in Appendix D. Examples of specific survey questions included:

- How often do you bicycle or walk on the W&OD trail crossing at Belmont Ridge Rd?
- Have you ever pushed the button to activate the flashers at the roadway crossing?
- In what situations do you activate the flashers at the roadway crossing?
- When the flashers are activated, do you feel your waiting times to cross the road have decreased because of motorists slowing and/or yielding more frequently?
- Do you expect motorists to yield when the flashers are activated?
- Do you think the flashing beacon system increases, decreases, or has no impact on safety for bicyclists and walkers?
- In your opinion, who has the right-of-way (right to go first) at the trail crossing?

RESULTS AND DISCUSSION

Literature Review

Literature

Since the FHWA granted interim approval to use RRFBs in 2008, several locations throughout the United States have installed the system and performed studies to evaluate its effectiveness. The first RRFB installations were in 2008 at crosswalks on two high-speed multilane roadways in Miami Beach, Florida. In addition to RRFBs, several other countermeasures were included at the crossing locations such as leading pedestrian intervals, in-street yield signs, pedestrian countdown signals, and a reduction in the minimum green time for traffic signals. A before-after study was performed at both locations, and Shurbutt et al.[11] found that the combination of countermeasures led to significant improvements in pedestrian and driver compliance and ultimately a safer pedestrian environment. The RRFBs were attributed to an increase in motorist yielding events of 0 to 65 percent at one site and 1 to 92 percent at the other site.

After the Miami Beach study, Van Houten and Malenfant[6] reported on a comprehensive evaluation where RRFB systems were installed at 18 locations in St. Petersburg, Florida. The purpose of the St. Petersburg study was to examine the effectiveness of the system to increase motorist yielding to pedestrians and to compare the "rectangular stutter flash beacon" with other beacon devices (overhead and side-mounted). Baseline (before RRFB installation) data were collected at all locations, and subsequent data were collected 7, 30, 60, 90, 180, 270, 365, and 730 days after RRFB installations. Of the locations studied, most were four-lane, two-way facilities with a speed limit of 35 mph. About one-half of these locations had a median, and ADT ranged from 4,500 to 18,000 with an average of approximately 12,000. Only four sites were mid-block locations. The study showed that driver yielding increased from 20 to 30 percent in the before period to between 75 and 86 percent in the after period (averaged over the 2-year study period) at all sites.

In 2009, another study was conducted in St. Petersburg where an RRFB system was installed at the intersection of the Pinellas Trail and a busy four-lane urban street. Hunter et al.[5] evaluated the effectiveness of the RRFB via a before-after study on trail user delay, yielding behavior, avoidance maneuvers and conflicts, and complete crossings versus half crossings (trail users stopped in median). The study found that after the RRFB installation, motorists increased yielding from 2 percent in the before period to 54 percent in the after period when the flashers were activated, thereby reducing trail user crossing delays. In addition, the study showed that 32 percent of trail users pressed the button to activate the RRFBs, 49 percent did not push the button when attempting to cross, and 19 percent crossed with the RRFBs previously activated. The authors noted that additional education efforts were needed to increase the percentage of trail users pushing the button and increase motorist knowledge about the requirement to yield to pedestrians in crosswalks.

A 2011 report by Fitzpatrick et al.[12] titled *Evaluation of Pedestrian and Bicycle Engineering Countermeasures: Rectangular Rapid-Flashing Beacons, HAWKs, Sharrows,* *Crosswalk Markings, and the Development of Evaluation Methods* summarized the results of the St. Petersburg study[6] and information from RRFB installations in Illinois and Washington, D.C. One two-lane and one four-lane intersection were evaluated in Mundelein, Illinois, that had baseline (before) yielding percentages of 7 and 19 percent. Seven days after RRFB installation, yielding percentages increased to 62 and 71 percent, respectively. Thirty days after, the yielding percentages remained similar at 62 and 68 percent, respectively. Data from one four-lane intersection in Washington, D.C., revealed a baseline yielding percentage of 26 percent. After installation of the RRFB system, the 7- and 30-day evaluations showed an increase in yielding of 62 and 74 percent, respectively.

In June 2011, the New Jersey Department of Transportation installed an RRFB system on Route 4 in the Elmwood Park Borough. At the crosswalk location, Route 4 is a four-lane, 35 mph facility with an ADT of 39,490. Pedestrian counts and behavior and motorist behavior were recorded by observers for 3-hour periods during A.M. and P.M. peak travel hours in both the before and after data collection periods. The results showed that the percentage of pedestrians able to cross the roadway following a stopped motorist increased from 2.2 to 52.8 percent in the morning period and 2.3 to 35.8 percent in the after period.[13] In addition, the percentage of crossing events involving a full stop by motorists increased from 4.4 to 73.5 percent in the morning period and from 3.8 to 45.8 percent in the after period.

In November 2012, the City of Boulder, Colorado, developed guidelines for pedestrian crossing treatments including RRFBs.[14] The guidelines referenced data collected where RRFBs were installed. Data analysis showed that motorist compliance (yielding events) typically increased at RRFB locations with higher crossing volumes. However, at some locations there were increases in rear-end collisions and increases in pedestrians or bicyclists being hit in the crosswalk. The guidelines state:

> While the pedestrian-actuated flashing signs do not change the rules of the roadway, the effectiveness of encouraging vehicles to yield to pedestrians has resulted in more vehicles stopping for pedestrians, which has further resulted in more rear-end collisions (this same phenomenon exists when new traffic signals are installed in the roadway). It is possible that the increased compliance of motor vehicles yielding to pedestrians is also resulting in some pedestrians and bicyclists using less caution when they cross which in turn results in an increase in vehicle-pedestrian and vehicle-bicycle accidents.

Based on Boulder's evaluation of RRFBs and other pedestrian crossing treatments (High-intensity Activated crossWalK beacons [HAWKs] and pedestrian signals), installation recommendations were developed for uncontrolled locations using pedestrians per hour and vehicles per hour as criteria for low-speed (less than or equal to 35 mph) and high-speed (over 35 mph) roadways.

In 2012, the Oregon Department of Transportation (ODOT) developed guidelines for pedestrian control devices that were based on the results of studies found in the literature and ODOT field studies at six locations where various pedestrian beacon treatments, including RRFBs, were evaluated.[15] Specific guideline considerations included the following:

- posted speed limit

- presence of a median
- visibility of the crossing treatment
- crossing distance
- traffic volume
- pedestrian crossings
- surrounding environment (urban areas, shopping centers, transit locations, schools, and parks).

ODOT field studies showed that RRFB treatments with a median and without a median had compliance rates of 86.4 and 75.9 percent, respectively. The major ODOT recommendations for RRFB installations were that they "be installed on medians when side-mounted devices are considered and at locations where posted speeds of 40 mph or less unless additional features such as stripping, signing, and advanced warning RRFBs are used." At two intersections where the speed limit was 45 mph, studies showed excellent increase in compliance when advance warning RRFBs were used in conjunction with advance stop bars and signage, a high visibility ladder-striped crosswalk, and "DO NOT PASS" markings in advance of the crosswalk.

Discussion

The RRFB evaluation performed at Belmont Ridge Road offers a unique analysis opportunity compared to the studies found in the literature. Most of the studies referenced in the literature concerned multilane facilities (more than two lanes) with medians, advance yield to pedestrian signage, and speed limits of 35 mph or lower. The primary measure of effectiveness for the studies was compliance rate in the after installation period compared to the before period.

What is not clear from the literature is the signage in place in the before period. If crosswalks were the only pedestrian treatments at the study locations in the before period, then adding signage, advance roadway pavement markings (such as stop or yield bars), and RRFB systems would greatly enhance the visibility of the crossing locations and therefore potentially influence the higher compliance rates found in the after period analyses. At Belmont Ridge Road, the before roadway characteristics included advance crosswalk warning signs, crosswalk signs at the high visibility crosswalk, and unique zig-zag pavement markings. Other than site improvements to improve the visibility of trail users, the after period included only the RRFB beacons installed on advance warning signage and signage at the crosswalk. Only the ODOT study[15] referenced locations where RRFBs were installed at roadways with a speed limit of 45 mph. At these locations, advance warning RRFBs were installed similar to those at Belmont Ridge Road; however, these sites were multilane facilities with medians.

Data Collection

Trail User and Motorist Interaction

Data on trail user and motorist interaction were obtained via video for three data collection periods: 3 weeks, 5 months, and 1 year after installation. Trail user and roadway activity was continuously monitored via video from 6 A.M. to 8 P.M. for 4 days (two weekdays and two weekend days) during each time period for a total of 168 hours of video review. The days of the week were chosen to evaluate typical weekday and weekend trail activity. The following provides results of the stepwise process to analyze the utility and effectiveness of the RRFB system at Belmont Ridge Road.

Number of Person Crossings by Mode

The first step in the data analysis process was to obtain the number of person crossings by mode. Table 2 shows the number of trail users and type (pedestrian or bicyclist) for each day and data collection period. It can be seen from the table that weekend trail activity was much higher than weekday activity and the number of bicyclists was much higher than the number of pedestrians. The ratio of weekend trail users to weekday trail users for all data collection periods combined was approximately 3:1 and the ratio of bicyclists to pedestrians was approximately 6:1 for all data collection periods combined.

Table 2. Number and Type of Trail Users

Time Period	3 Weeks After (2013)				5 Months After (2013)				1 Year After (2014)			
Day of Week/Date	Wed. 5/1	Thur. 5/2	Sat. 5/4	Sun. 5/5	Wed. 10/16	Thur. 10/17	Sat. 10/19	Sun. 10/20	Wed. 4/9	Thur. 4/17	Sat. 4/5	Sun. 4/6
Pedestrians	49	65	225	181	119	36	152	188	66	52	225	263
Bicyclists	395	552	1649	1296	557	287	665	986	355	358	1023	1352
Total	444	617	1874	1477	676	323	817	1174	421	410	1248	1615

Number of Crossing Instances Defined as Potential RRFB Activations

The next step was to determine the number of potential RRFB activations from Table 2. This process involved combining groups that crossed together at the same time into discrete crossing instances. For example, if three pedestrians were walking together, this was considered one potential RRFB activation event. In addition, if two or more trail users were crossing at the same time from opposite directions, this was considered one potential activation event. Table 3 shows the data upon combining groups into single crossing events. The data were split into “Ped Only,” “Bicycle Only,” and “Ped + Bicycle” events. The rationale for splitting the data into these three events was to understand how different crossing modes affected motorist behavior.

Table 3. Number of Potential RRFB Activations per Trail User Type

Time Period	3 Weeks After (2013)				5 Months After (2013)				1 Year After (2014)			
Day of Week/Date	Wed. 5/1	Thur. 5/2	Sat. 5/4	Sun. 5/5	Wed. 10/16	Thur. 10/17	Sat. 10/19	Sun. 10/20	Wed. 4/9	Thur. 4/17	Sat. 4/5	Sun. 4/6
Ped Only	21	36	87	67	48	23	75	103	51	39	128	146
Bicycle Only	224	349	778	609	389	219	361	541	273	261	557	718
Ped + Bicycle	19	19	73	54	21	5	23	41	9	4	35	50
Total	264	404	938	730	458	247	459	685	333	304	720	914

RRFB Activation Rate

After the numbers of potential RRFB activations by mode were determined, the data were analyzed to find the RRFB activation rate. The rate was simply determined by dividing the number of actual trail user RRFB activations by the number of crossing instances defined as potential RRFB activations events (as found in Table 3). Of particular interest was how the activation rate changed over time for each mode. Table 4 shows the results of this analysis. For pedestrian only crossings, the activation rate increased over time from 13.7 to 33 percent. For bicycle only crossings, the activation rate increased from 23.5 percent in the 3-week after period to 28.4 percent in the 5-month after period. The activation rate then dropped to 24.9 percent in the 1-year after period. For pedestrians and bicyclists crossing together, the activation rate increased from 35 percent in the 3-week after period to 46.9 percent in the 1-year after period.

Table 5 shows the activation rate over time for all groups combined. Over all crossing modes, the activation rate increased from 23.8 percent in the 3-week after period to 29.3 percent in the 5-month after period. In the 1-year after period, the activation rate dropped slightly to 27.3 percent. The average activation rate over all time periods and modes was 26.6 percent.

Table 4. RRFB Activation Rate for All Potential RRFB Activations

Time Period	Day of Week	Ped Only	No. of Acts.	Rate	Bicycle Only	No. of Acts.	Rate	Ped + Bicycle	No. of Acts.	Rate
3 Weeks After (2013)	Wed. 5/1	21	2	9.5	224	67	29.9	19	10	52.6
	Thur. 5/2	36	8	22.2	349	93	26.6	19	8	42.1
	Sat. 5/4	87	15	17.2	778	184	23.7	73	27	37.0
	Sun. 5/5	67	14	20.9	609	116	19.0	54	13	24.1
	Total	211	39	13.7	1,960	460	23.5	165	58	35
5 Months After (2013)	Wed. 10/16	48	21	43.8	389	129	33.2	21	17	81.0
	Thur. 10/17	23	5	21.7	219	67	30.6	5	4	80.0
	Sat. 10/19	75	30	40.0	361	110	30.5	23	9	39.1
	Sun. 10/20	103	16	15.5	541	123	22.7	41	11	26.8
	Total	249	72	28.9	1,510	429	28.4	90	41	45.6
1 Year After (2014)	Wed. 4/9	128	47	36.7	557	136	24.4	35	15	42.9
	Thur. 4/17	146	45	30.8	718	175	24.4	50	23	46.0
	Sat. 4/5	51	14	27.5	273	92	33.7	9	6	66.7
	Sun. 4/6	39	14	35.9	261	47	18.0	4	2	50.0
	Total	364	120	33.0	1,809	450	24.9	98	46	46.9

Acts. = activations.

Table 5. RRFB Activation Rate for All Crossing Modes Combined

Time Period	Crossing Instances	No. of Activations	Rate
3 Weeks After	2,336	557	23.8
5 Months After	1,849	542	29.3
1 Year After	2,256	616	27.3
Total	6,441	1,715	26.6

Traffic Characteristics During Potential RRFB Activation Events

Video and on-site observations of trail user crossings showed that in many instances, trail users did not activate the RRFB system because of available gaps in the traffic stream at the crossing location. Bicyclists in particular were likely to maintain their speed and cross without activating the flashers if sufficient gaps in traffic were present. The analysis therefore shifted to focus on the RRFB activation rate when traffic was present at the time of potential RRFB activation events. To accomplish this task, data were filtered to provide crossing instances where trail users stopped or slowed at the crossing and joined with instances where at least one motorist either yielded or did not yield. Table 6 shows the number of instances by mode over time where traffic was present during a potential RRFB activation event. As can be seen from the table, the activation rate increased for each mode from the 3-week after period to the 5-month after period. In the 1-year after period, the activation rate remained consistent for the Ped Only and Ped + Bicycles modes at roughly 50 percent where the Bicycle Only mode dropped from 44 to 39.9 percent. Figure 9 shows a graphical comparison of activation rate for all potential RRFB activation crossing events versus those activation events only when traffic was present.

Table 6. Activation Rate by Mode When Traffic Was Present

Mode	Time Period	Traffic Present	RRFB Activations	Rate
Ped Only	3 Weeks	113	35	31.0
	5 Months	124	63	50.8
	1 Year	195	98	50.3
Bicycle Only	3 Weeks	1,179	438	37.2
	5 Months	863	380	44.0
	1 Year	1,039	415	39.9
Ped + Bicycles	3 Weeks	123	50	40.7
	5 Months	124	63	50.8
	1 Year	195	98	50.3

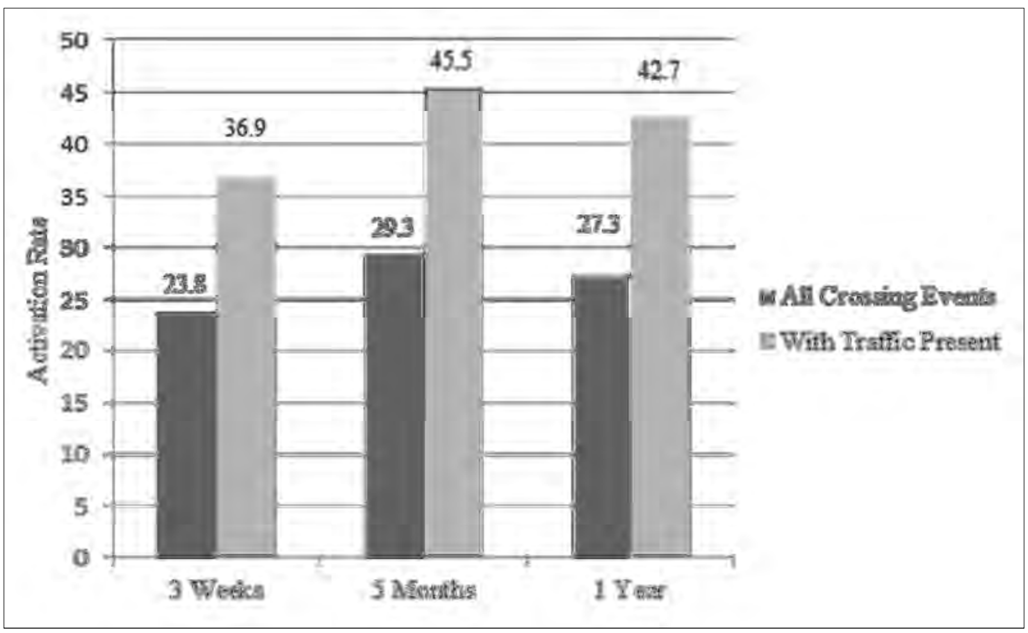


Figure 9. Comparison of RRFB Activation Rate for all Crossing Events Versus Crossing With Traffic Present

Effect of RRFB Activation/Non-activation on Yield Rate

With the dataset created in Table 6, a comparison could be made on motorist yield rate when the RRFB flashers were activated versus not activated. It should be noted that the data from the video were processed to incorporate yielding events where motorists had the time to yield. For example, when a trail user was at the stop bar waiting to cross, non-yielding events were filtered out if motorists did not have the time or distance to yield adequately. Since a true before analysis on yield rates was not conducted at the site, this step allowed for a surrogate before-after yield rate analysis because signage and roadway markings did not change from the before and after installation periods.

Table 7 shows the yield rate with no activation and Table 8 shows the yield rate with activation when traffic was present at the time of a trail user crossing event. Yield rate was determined by:

$$\frac{Number\ of\ yields}{Number\ of\ yields + Number\ of\ no\ yields}$$

For the no activation case, yield rates increased over time for each crossing mode. This provides an indication that motorists, who were mainly local commuters, had increased awareness of trail users. For the activation case, yield rates increased at a higher rate over time except for 5 months to 1 year in the Ped Only mode. Further, the Ped Only mode had the lowest average yield rates for both no activation and activation compared to the Bicycle Only and Ped + Bicycles modes. Interestingly, the Ped + Bicycles mode had the highest yield rates for both the no activation and activation scenarios. This could have been due to the uncertainty motorists had when encountering different modes of trail users waiting to cross at one instance and the enhanced conspicuity of multiple trail users.

Table 7. Yield Rate With No Activation

Mode	Time Period	Instances of No Activation	No. of Yields	No. of No Yield	Yield Rate
Ped Only	3 Weeks	172	64	213	0.23
	5 Months	177	83	131	0.39
	1 Year	244	115	159	0.42
Bicycle Only	3 Weeks	1,500	996	1,454	0.41
	5 Months	1,081	693	861	0.45
	1 Year	1,359	947	884	0.52
Ped + Bicycles	3 Weeks	107	107	165	0.39
	5 Months	49	36	35	0.51
	1 Year	52	64	53	0.55

Table 8. Yield Rate With Activation

Mode	Time Period	Instances of Activation	No. of Yields	No. of No Yield	Yield Rate
Ped Only	3 Weeks	39	42	57	0.42
	5 Months	72	91	54	0.63
	1 Year	120	126	114	0.53
Bicycle Only	3 Weeks	460	545	1,184	0.32
	5 Months	429	508	731	0.41
	1 Year	450	592	354	0.63
Ped + Bicycles	3 Week	58	67	129	0.34
	5 Months	41	62	71	0.47
	1 Year	46	62	31	0.67

A comparison plot of no activation versus activation yield rates over time for all modes combined is shown in Figure 10. As can be seen, the yield rate increases in both scenarios from 39 to 51 percent with no activation and from 32 to 61 percent with activation. The yield rate when the flashers were activated surpassed the rate when the flashers were not activated in the 1-year after period. This analysis should be interpreted with caution because of the random nature of vehicle arrivals and vehicle platoons.

Video and on-site observations showed that leading motorists can have an influence on the behavior of trailing motorists especially if the vehicles are in close proximity to each other. For example, in situations where there was a platoon of vehicles progressing toward the crosswalk, there may have been a very low yield rate whether or not the flashers were activated. To analyze the effect of flasher activation versus non-activation on vehicle platoons, Figure 11 shows the frequency of the number of "no yields" when flashers were activated versus not activated for all crossing modes combined. For each grouping of "number of no yields" in the 1-year after period, the frequency of instances of no yields without flasher activation was greater than the frequency with activation.

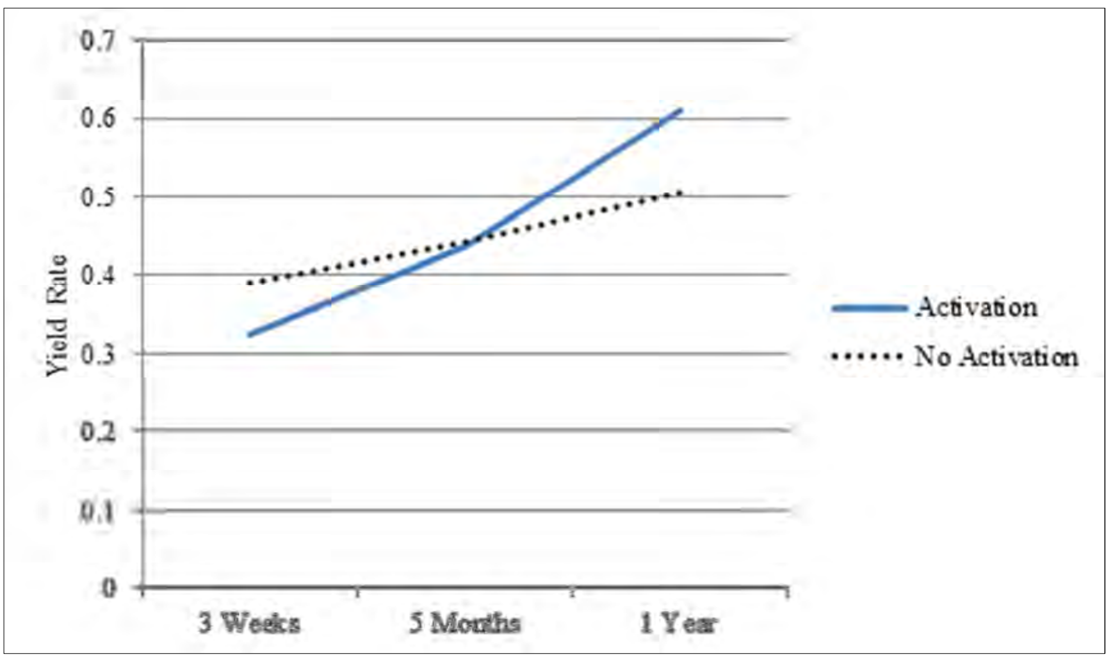


Figure 10. Comparison of Yield Rate With Activation Versus No Activation

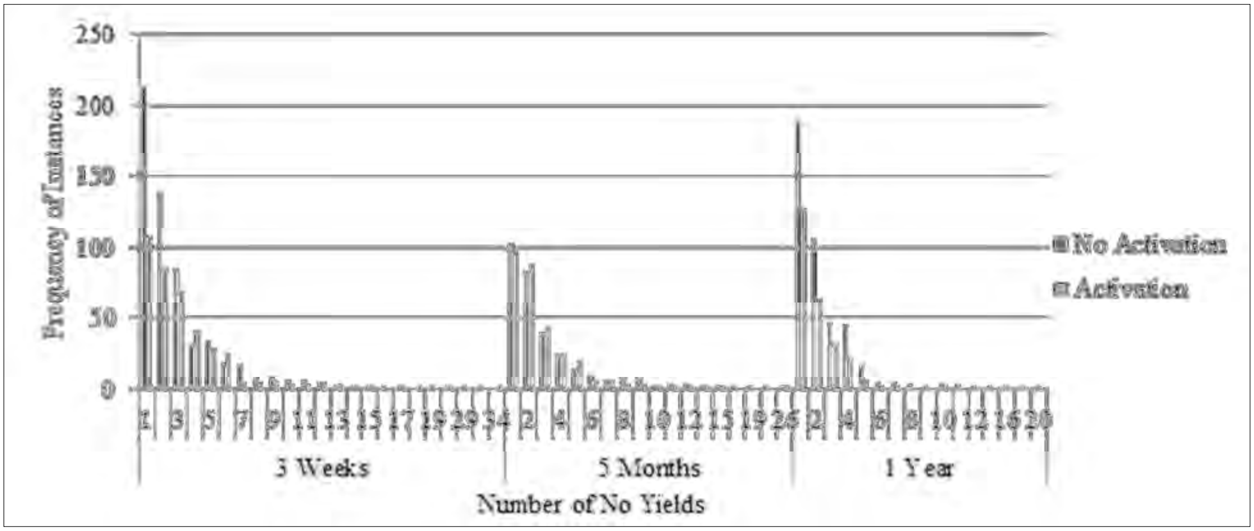


Figure 11. Frequency of Number of No Yields When Flashers Were Activated Versus Not Activated

Effect of Activation/Non-activation on Immediate Yields

As discussed, car following behavior in platoons can have a negative effect on yield rates. To account better for the effect of activation versus non-activation on yielding events, an analysis was performed that considered only immediate yields. In other words, when a trail user or groups of trail users were attempting to cross, an immediate yield event occurred if the first arriving vehicle in either or both travel directions yielded. Tables 9 and 10 show the instances of immediate yields over all time periods for each mode without and with activation, respectively. The dotted and solid lines in Figure 12 show a comparison between the rate of immediate yields with no activation versus the rate of immediate yields with activation, respectively. Except for the 3-week after period for both the Bicycle Only and Ped + Bicycles modes, the rate of immediate yields with activation was higher than that with no activation for each crossing mode and time period. In addition, yield rate increased over time when the flashers were activated for each crossing mode except Ped Only. With no activation, yield rates remained flat for all modes except the Ped + Bicycles mode. As was the case with overall yield rates, immediate yield rates for the Ped + Bicycles mode were higher than for the other crossing modes.

Table 9. Instances of Immediate Yields with No Activation

Mode	Time Period	Instances of No Activation	No. of Immediate Yields
Ped Only	3 Weeks	172	42
	5 Months	177	43
	1 Year	244	56
Bicycle Only	3 Weeks	1500	418
	5 Months	1081	341
	1 Year	1359	450
Ped + Bicycles	3 Weeks	107	30
	5 Months	49	16
	1 Year	52	30

Table 10. Instances of Immediate Yields with Activation

Mode	Time Period	Instances of Activation	No. of Immediate Yields
Ped Only	3 Weeks	39	17
	5 Months	72	37
	1 Year	120	50
Bicycle Only	3 Weeks	460	104
	5 Months	429	136
	1 Year	450	230
Ped + Bicycles	3 Weeks	58	12
	5 Months	41	20
	1 Year	46	28

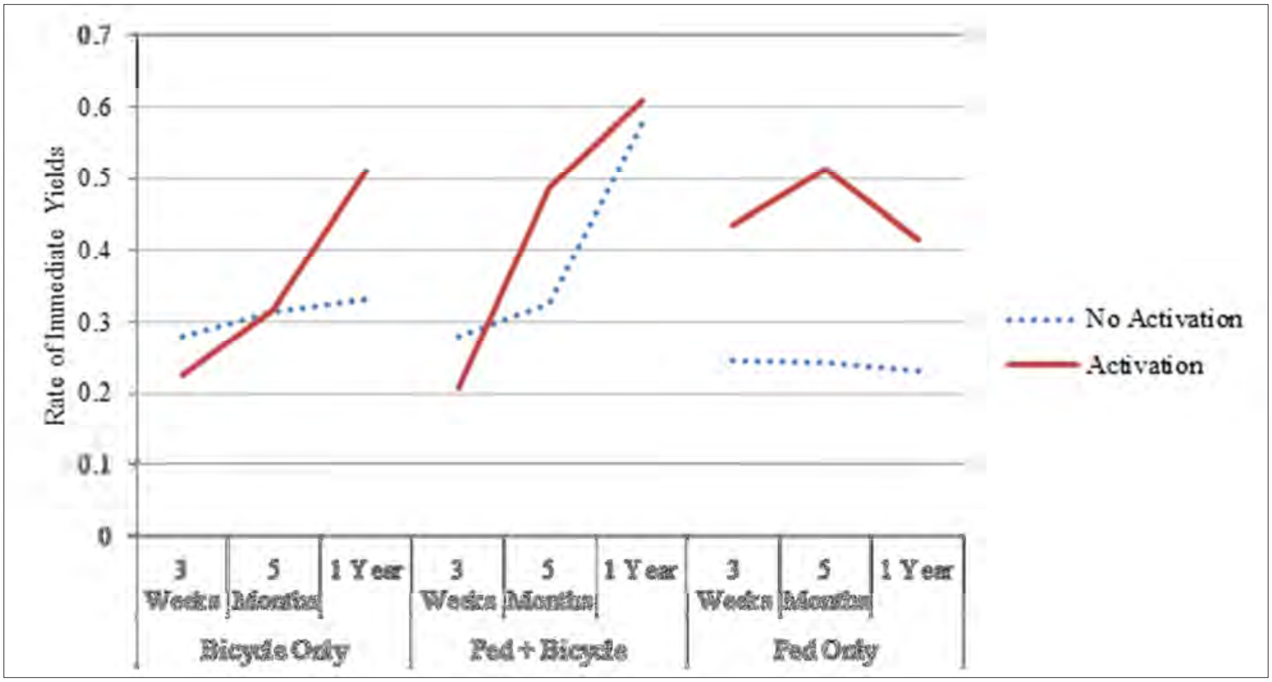


Figure 12. Rates of Immediate Yields per Crossing Mode With and Without Activation

Additional analyses were performed that compared the effect that groups of crossers had on immediate yields versus single crossers both with and without activating the RRFB system. Figures 13 and 14 show the no activation and activation cases, respectively. A comparison of the two figures shows that except for the 3-week after period, the immediate yield rates with activation for both groups and single crossings remained consistently higher than the immediate yield rates with no activation. Further, and as expected, groups of crossers tended to influence motorist behavior more than single crossers whether or not the flashers were activated. It is interesting to note that from the 3-week to 1-year period, groups of crossers in the Bicycle Only and Ped + Bicycles modes had steep increases in the immediate yield rate when the flashers were activated (0.24 to 0.58 percent and 0.21 to 0.61 percent, respectively), whereas the Ped Only mode had a steep decrease in immediate yield rate over time (0.76 to 0.47 percent).

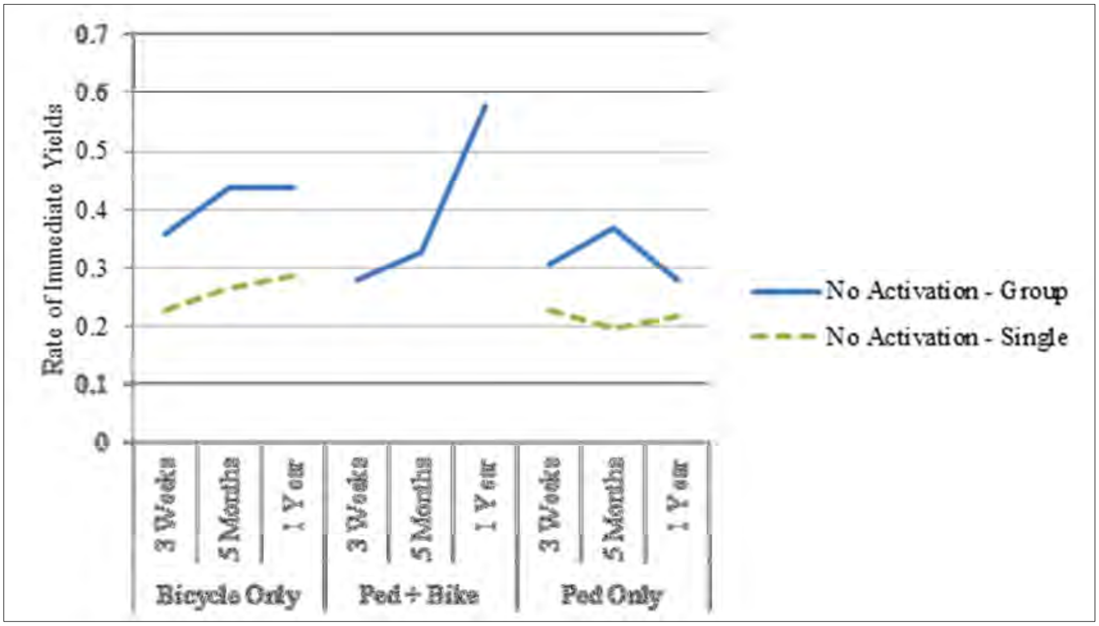


Figure 13. Rate of Immediate Yields With No Activation for Groups and Single Crossers

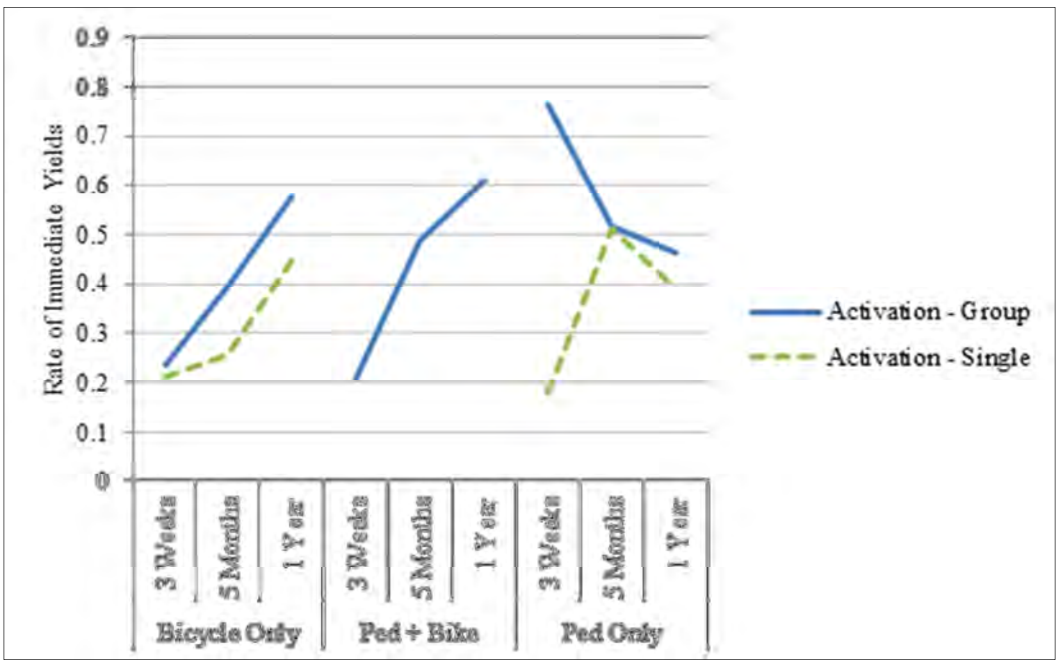


Figure 14. Rate of Immediate Yields With Activation for Groups and Single Crossers

Vehicle Speeds Obtained With LIDAR Gun

To obtain more information on motorist behavior and reaction when the RRFBs were activated, vehicle speeds were obtained by an observer using a LIDAR gun as vehicles progressed toward the crosswalk in both the northbound and southbound travel directions on Belmont Ridge Road. Speed data were recorded as a text file and exported to an Excel spreadsheet. Figure 15 shows a scatter plot comparison of individual data points (speed and range) for all vehicles tracked before the zig-zag markings were installed, 1 year after zig-zag installation, and after RRFB activation. The y-axis on each embedded scatter plot is speed in miles per hour and the x-axis is the distance in feet from the crossing. As can be seen from the scatter plots, RRFB activations had a much larger effect on motorists' speed as they approached the crosswalk. It should be noted that the number of individual speed data points was much lower in the "RRFB activation" period because of the high number of yielding events that occurred when the system was activated. As previously discussed, the intent was to capture vehicle speeds as motorists progressed through the crosswalk. Therefore, data points were excluded when there were yielding events. Because of the higher yield rates, the sampling of valid data points was lower.

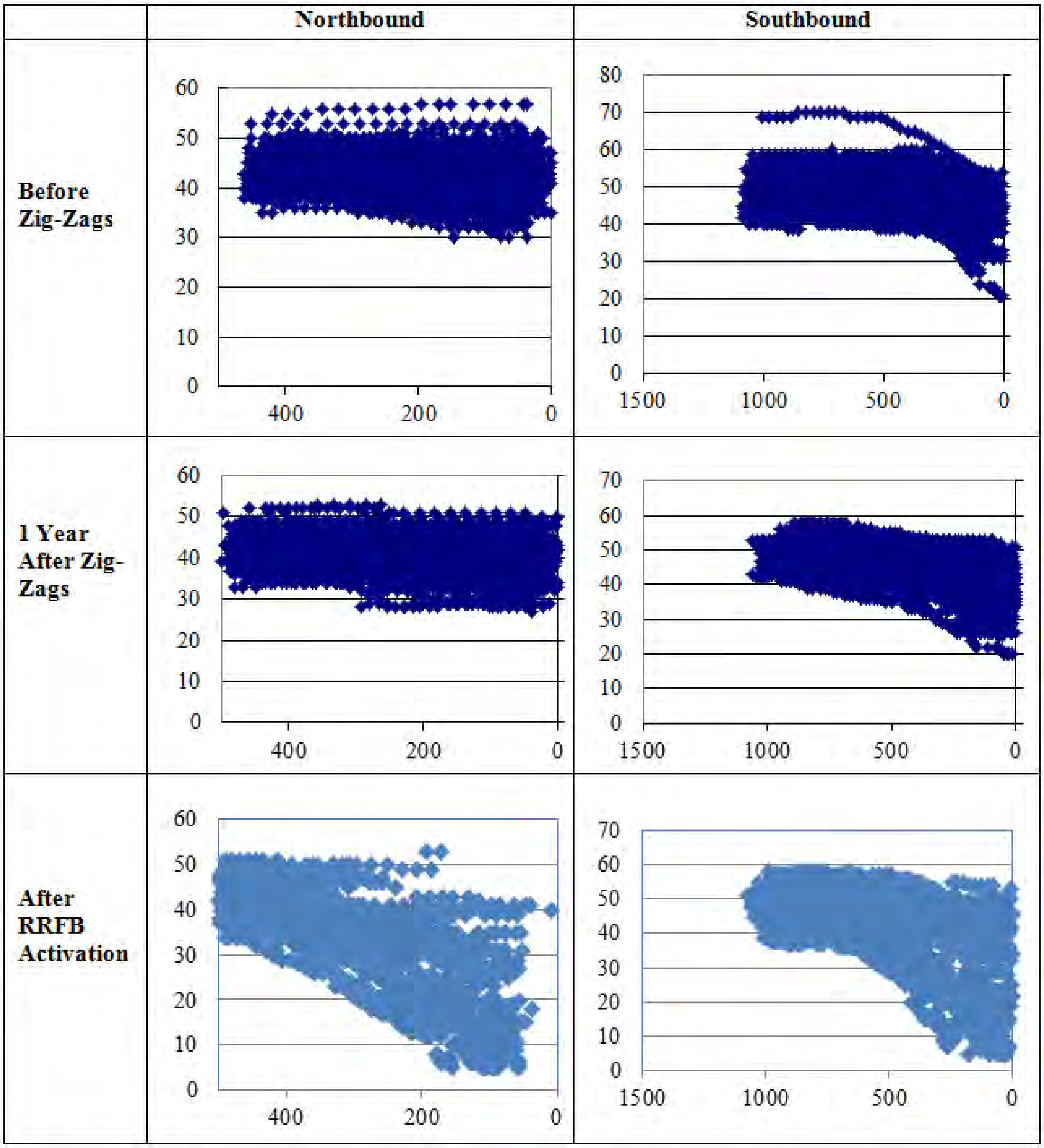


Figure 15. Scatter Plot of Speed Data Points

To exhibit this effect better, the next step was to extract individual vehicles from the output file. The raw data obtained in the field were then reduced to provide mean vehicle speeds in range bins. For the northbound approach on Belmont Ridge Road, the range bins were 0-100, 101-200, 201-300, 301-400, and 401-500 feet from the crosswalk. Because the observer's view of the crosswalk was limited by the horizontal curve on this approach, vehicles were tracked after they encountered the advance warning RRFB and signage. For the southbound approach, the observer was located 1,200 feet upstream of the crosswalk and thus was able to capture vehicle speeds before vehicles encountered the advance warning RRFB and signage. The range bins on this approach were 0-200, 201-400, 401-600, 601-800, and 801-1,000 feet from the crosswalk.

Speed profiles obtained from the LIDAR data for the northbound approach on Belmont Ridge Road are shown in Figure 16. The figure shows that when the RRFB was activated, mean speeds from 500 to 300 feet were not much different than in the before and 1-year after zig-zag installation periods. However, as motorists neared the crossing location at 200 feet to the crosswalk, mean speeds dropped a statistically significant amount compared to the before and 1-year after zig-zag installation periods.

Table 11 shows mean vehicle speeds collected during each data collection scenario for each distance bin and associated statistically significant differences. Detailed descriptive statistics for these data are summarized in Appendix E.

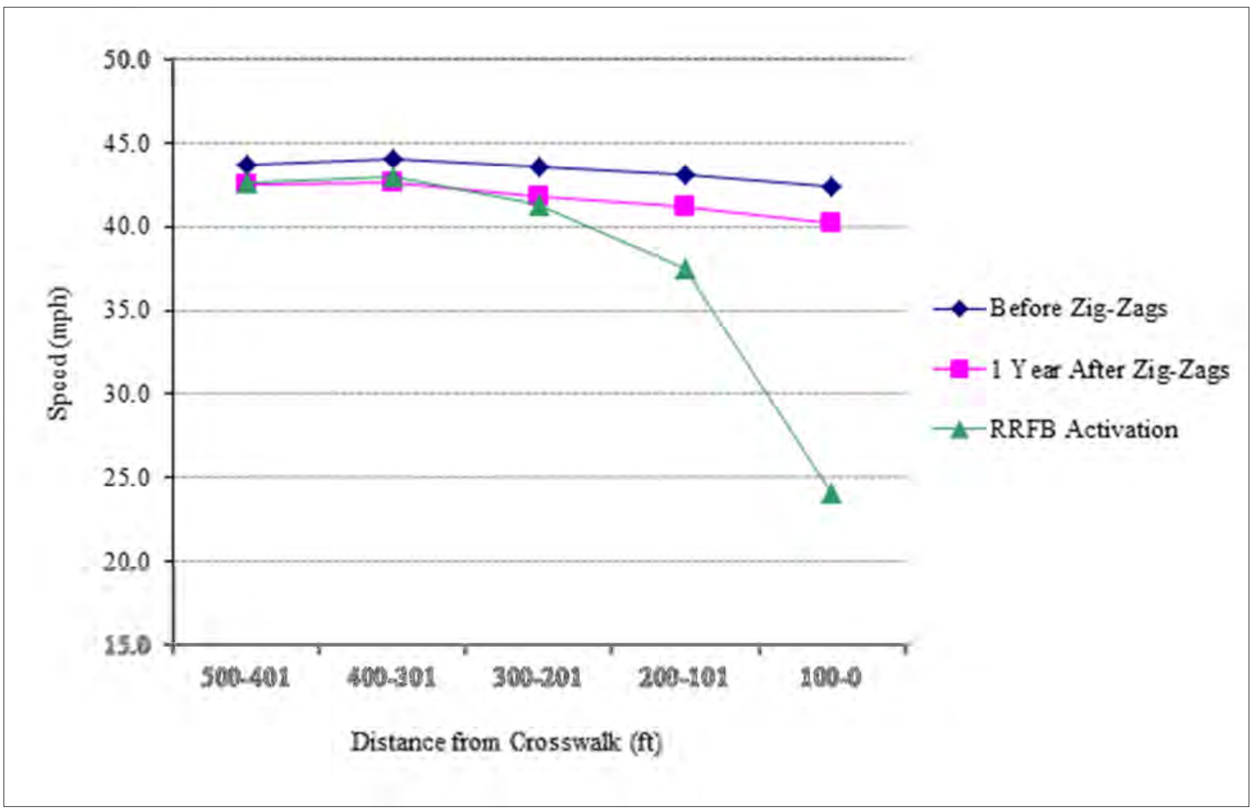


Figure 16. Mean Speed Profiles From LIDAR Data on Northbound Approach of Belmont Ridge Road

Table 11. Mean Speed Over Time per Distance Bin on Northbound Approach of Belmont Ridge Road

Period	500-401 feet	400-301 feet	300-201 feet	200-101 feet	100-0 feet
1 (Before Zig-Zags)	43.7	44.0 (2)	43.6 (2,3)	43.1 (2,3)	42.3 (2,3)
2 (1 Year After Zig-Zags)	42.5	42.6 (1)	41.8 (1)	41.1 (1,3)	40.2 (1,3)
3 (RRFB Activation)	42.6	42.9	41.3 (1)	37.5 (1,2)	24.1 (1,2)

( ) = speed significantly different from scenario (x) at α = 0.95.

For the southbound approach, mean speed profiles are shown in Figure 17. As was the case with the northbound approach, RRFB activations resulted in significant decreases in mean speeds as motorists approached the crossing location. Mean speeds in all three scenarios were statistically different from each other in the 400 to 201 and 200 to 0 distance bins.

Table 12 shows the mean vehicle speeds over time for each distance bin and associated statistically significant differences. Detailed descriptive statistics for these data are summarized in Appendix E.

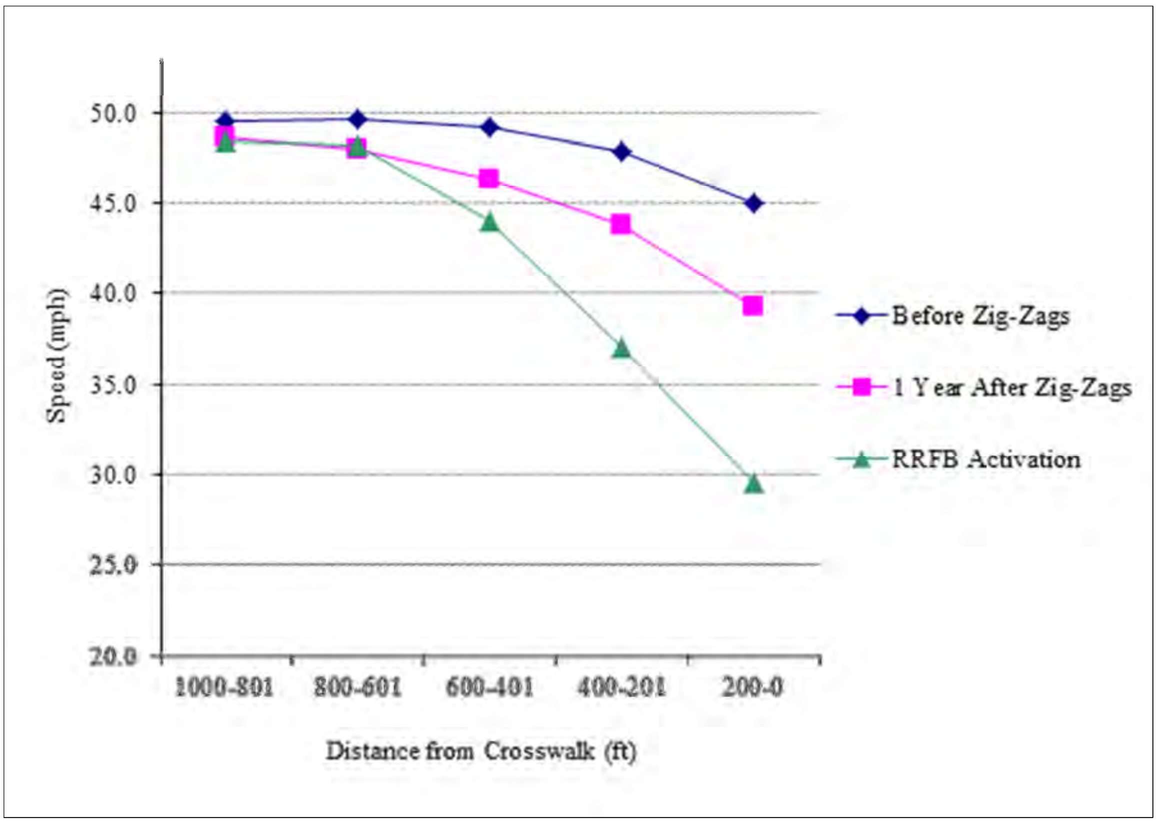


Figure 17. Mean Speed Profiles From LIDAR Data on Southbound Approach of Belmont Ridge Road

Table 12. Mean Speed Over Time per Distance Bin on Southbound Approach of Belmont Ridge Road

Period	1000-801 feet	800-601 feet	600-401 feet	400-201 feet	200-0 feet
1 (Before Zig-Zags)	49.5	49.6 (2)	49.2 (2,3)	47.9 (2,3)	45.0 (2,3)
2 (1 Year After Zig-Zags)	48.7	48.0 (1)	46.3 (1)	43.8 (1,3)	39.3 (1,3)
3 (RRFB Activation)	48.4	48.2	44.0 (1)	37.1 (1,2)	29.6 (1,2)

( ) = speed significantly different from scenario (x) at α = 0.95.

Survey Findings

A total of 224 surveys were conducted to ascertain opinions on the RRFB system at Belmont Ridge Road: 149 surveys were administered on-site at the W&OD Trail, and 75 surveys were received online from a SurveyMonkey link distributed to bicycle clubs in the Northern Virginia area. Because motorist reactions to the RRFB were captured via quantitative data analyses (i.e., yielding events and speed reduction), the survey focused on trail user opinions. The survey was designed to be brief (one page) yet capture the differences in opinions between frequent versus infrequent trail user opinions and the opinions of frequent and infrequent activators of the RRFBs. Survey questions and subject responses follow.

1. Within the past year, how often do you bicycle or walk on the W&OD trail crossing at Belmont Ridge Rd?
N (number of responses) = 224

Respondents considered frequent crossers at Belmont Ridge Road were those who answered crossing more than once or about once per week. Figure 18 shows that 56.3 percent of respondents were considered frequent crossers whereas 42.2 percent were considered infrequent crossers; 3.6 percent never crossed Belmont Ridge Road and were therefore disqualified from taking the survey.

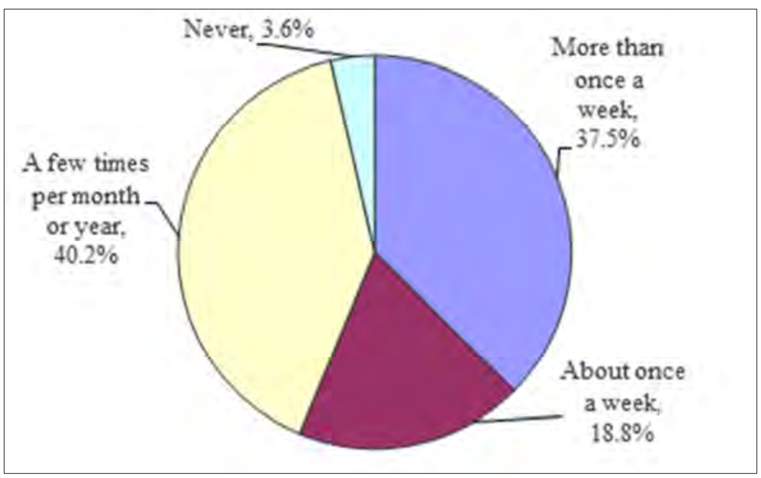


Figure 18. Survey Responses on Frequency of Trail Users Crossing Belmont Ridge Road

2. Have you ever pushed the button to activate the flashers at the roadway crossing?
N = 215

Results from this question were split into frequent versus infrequent crossers for the purpose of evaluating familiarity with the push button activation system: 126 responses were obtained from frequent crossers compared to 89 from infrequent crossers; Figure 19 shows the responses from both cases. The responses indicated that frequent crossers had pushed the button to activate the flashers more than infrequent crossers (89.7 versus 68.5 percent, respectively).

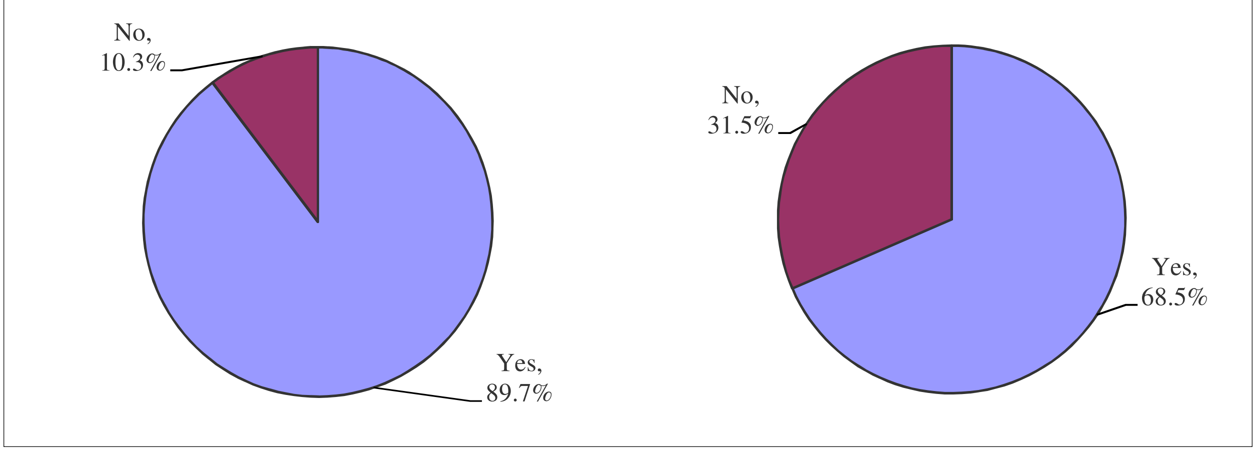


Figure 19. Survey Responses on Pushing the Button to Activate Flashers

3. In what situation do you activate the flashers at the roadway crossing?

N = 174

This question was posed only to those respondents who indicated they had activated the flashers. Responses to this question were also split into frequent (113 responses) versus infrequent (61 responses) crossers. Figure 20 shows the responses from both cases: 30.1 percent of frequent crossers indicated they activated the flashers every time they crossed the roadway versus 44.3 percent for infrequent crossers. This indicates that infrequent trail users tended to activate the flashers more often than frequent crossers whether or not traffic was present. The percentage of flasher activation when traffic was immediately present was similar for frequent and infrequent crossers (46.9 versus 42.6 percent, respectively), whereas 23 percent of frequent crossers activated the flashers only when traffic was present versus 13.1 percent for infrequent crossers. Familiarity with the Belmont Ridge Road crossing and assumptions of typical motorist behavior likely had an impact on situational activations.

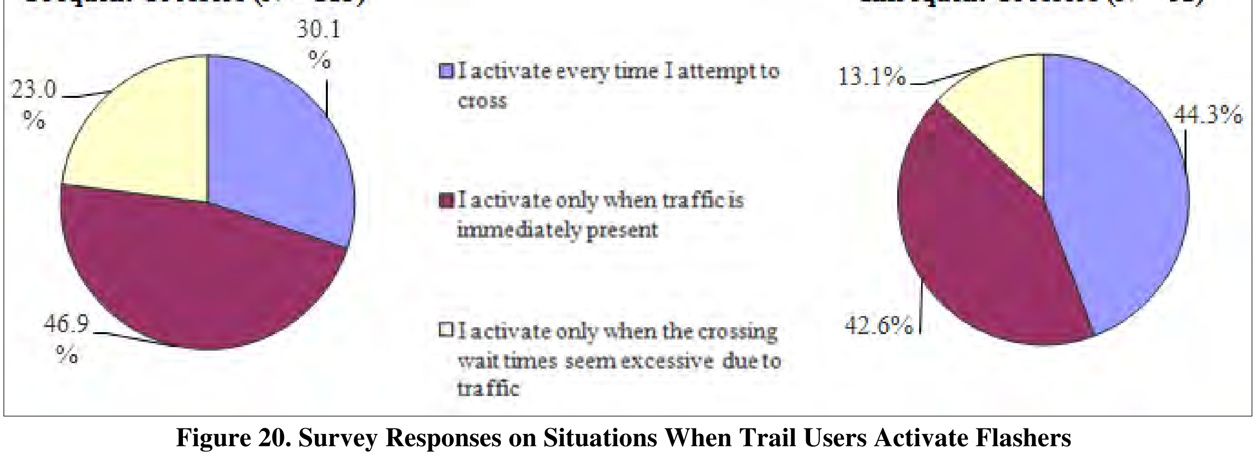


Figure 20. Survey Responses on Situations When Trail Users Activate Flashers

3. When the flashers are activated, do you feel your waiting times to cross the road have decreased because motorists are slowing and/or yielding more frequently?
N = 174

This question was posed only to those respondents who indicated they had activated the flashers. Figure 21 shows that 92.5 percent of respondents felt that waiting times to cross had often or sometimes decreased because of motorists slowing or yielding more frequently; 7.5 percent indicated that waiting times to cross had rarely decreased.

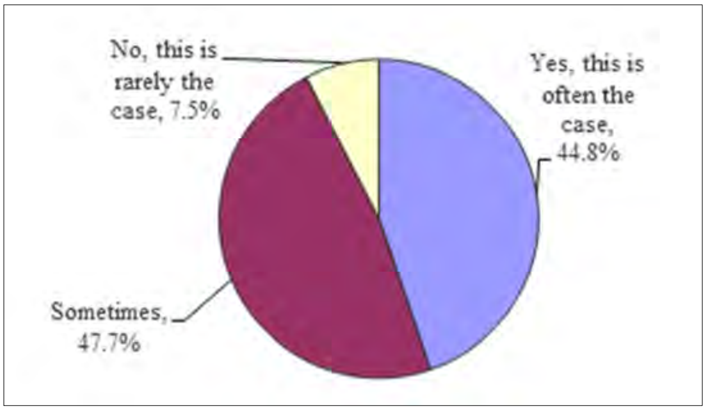


Figure 21. Survey Responses on Effect of Activation on Motorist Behavior

4. Do you expect motorists to yield when the flashers are activated?
N = 213

The purpose of this question was to ascertain trail user expectations of the RRFB system. Previous studies in the literature indicated that trail users may gain a false sense of security when activating the flashers. This question was divided into three response categories: (1) those that always activated the flashers, (2) those that sometimes activated (when traffic was immediately present or delay was deemed excessive), and (3) those that never activated the system. From Figure 22 it can be seen that 75.4 percent of crossers who always activated the system expected motorists to yield and 63.7 percent of crossers who sometimes activated the flashers expected motorists to yield when the flashers were activated. Of interest, 64.1 percent of respondents who never activated the system expected motorists to yield when the flashers were activated.

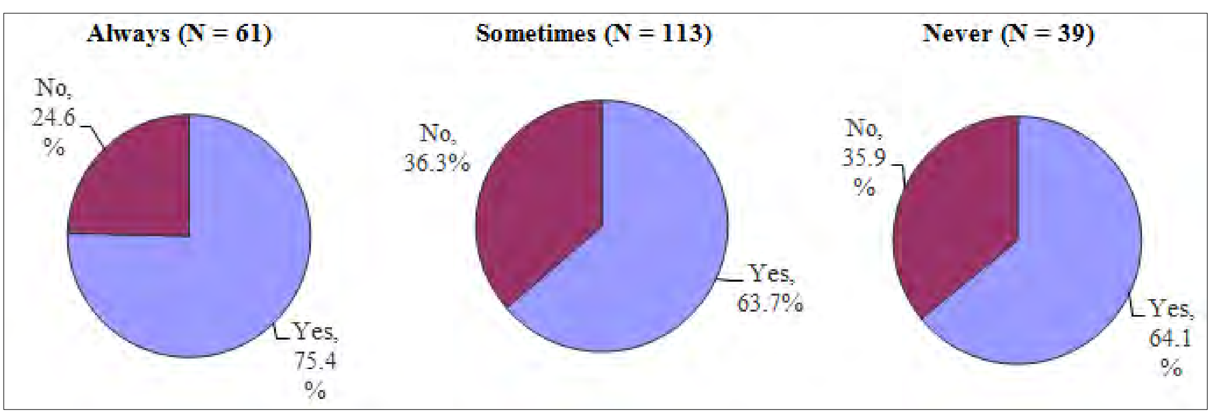


Figure 22. Survey Responses on Expectations for Motorists to Yield When Flashers Are Activated

5. Do you feel the flashing beacon system increases safety, decreases safety, or has no impact on safety for bicyclists and walkers?
N = 213

The responses to this question were again divided into three categories: (1) those who always activated the flashers, (2) those who sometimes activated the flashers (when traffic was immediately present or delay was deemed excessive), and (3) those who never activated the system. Figure 23 shows that 88.5 and 85.0 percent of crossers who always activated or sometimes activated the flashers, respectively, felt that the RRFB system increased safety for bicyclists and walkers: 76.9 percent of respondents who never activated the flashers felt that the RRFB system increased safety for bicyclists and walkers. Approximately 12 percent of crossers across all categories (always, sometimes, and never activate) felt that the system had no impact on safety for bicyclists and walkers; 10.3 percent of crossers who never activated the flashers felt that the RRFB system decreased safety for bicyclists and walkers.

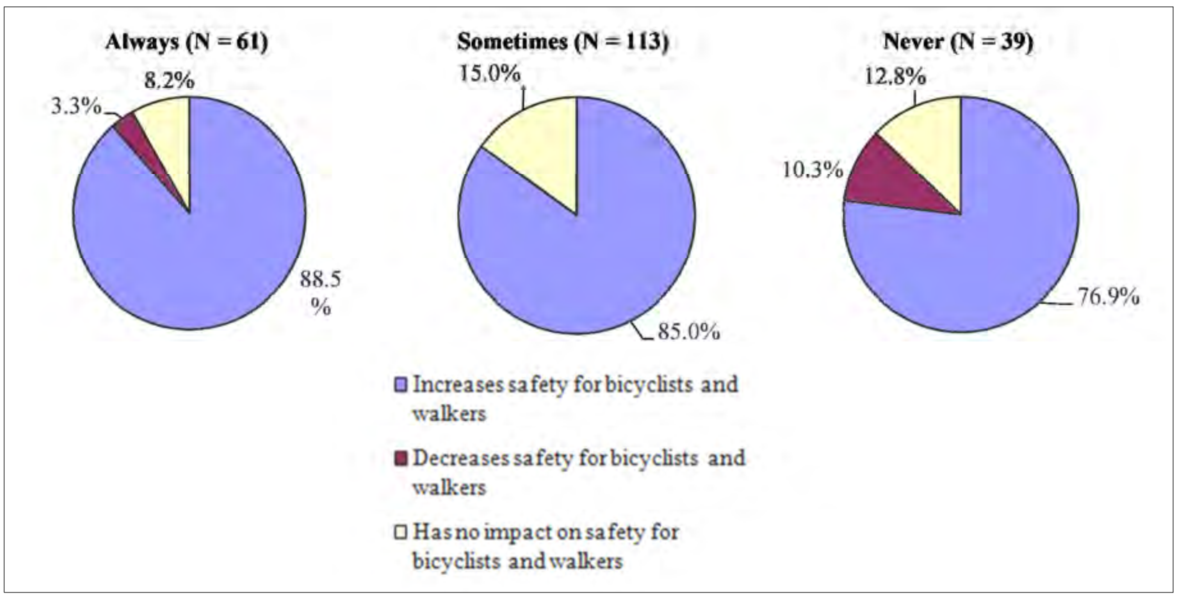


Figure 23. Survey Responses on Trail Users' Perception of Safety From RRFBs

6. In your opinion, who has the right-of-way (right to go first) at the trail crossing?
N = 213

Possible confusion with respect to right-of-way was observed in the field during the RRFB evaluation. The opinions expressed in response to this question corroborated these field observations (see Figure 24). Laws regarding right-of-way are written in the *Code of Virginia*. However, some view these laws as unclear, particularly at W&OD Trail crossings where STOP signs are directed toward trail users. A review of the *Code* was conducted for the zig-zag study[1] and is shown in Appendix F. The review found that pedestrians have the right-of-way at marked crosswalks and the STOP signs on the W&OD Trail do not have a strong foundation in the *Code*. However, in June 2013, Virginia's Office of the Attorney General issued an opinion on whether law enforcement officers may enforce the STOP signs posted by NVRPA on trails within the W&OD Regional Park. In the opinion of the Attorney General, the STOP signs were enforceable. This opinion is included in Appendix F.

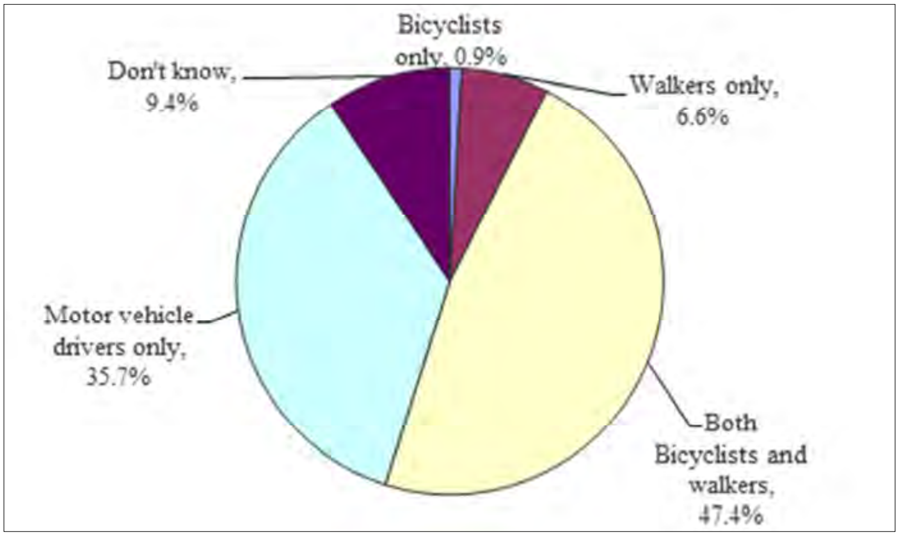


Figure 24. Survey Responses on Who Has Right-of-Way

7. On a scale of 1-5 please indicate your overall opinion of the Rectangular Rapid Flashing Beacon (RRFB) system with 1 being a highly unfavorable opinion and 5 being a highly favorable opinion.
N = 208

Figure 25 shows all responses to this question. Approximately 75 percent of respondents had either a favorable or highly favorable opinion of the RRFB system. Roughly 10 percent had either an unfavorable or highly unfavorable opinion of the RRFB system, and about 15 percent did not have a strong opinion either way. Respondents were also asked to indicate why they answered the question as they did. Comments from trail users are shown in Appendix G.

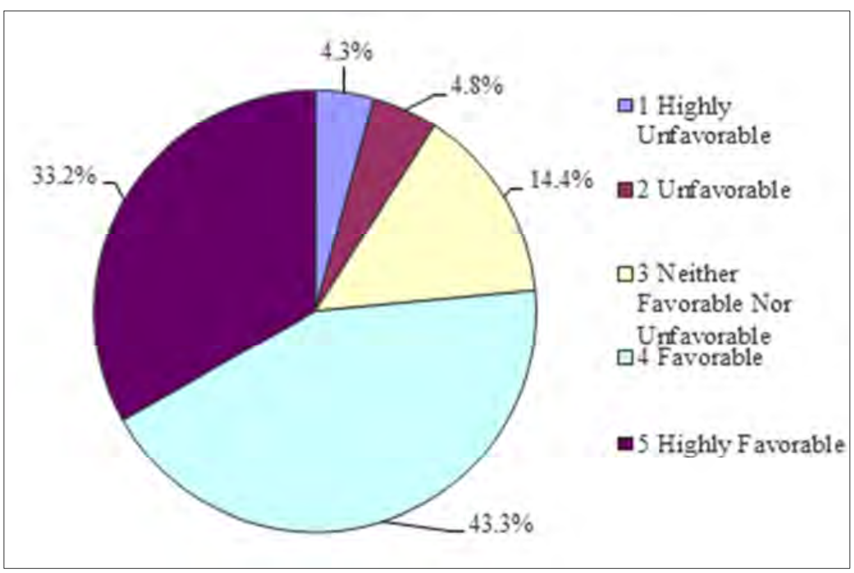


Figure 25. Survey Responses on Overall Opinion of the RRFB System

8. Please provide any other comments you have about the RRFB system and/or comments about the W&OD Trail.
N = 59

Fifty-nine comments were recorded from trail users and are shown in Appendix H.

CONCLUSIONS

- *RRFB systems have a positive effect on motorist yield rates.* This is evidenced by results of previous studies in which the primary measure of effectiveness was yield rate. Previous locations evaluated by others were typically at intersections on multilane facilities with a speed limit of 35 mph or lower.

- *The RRFB system installed at Belmont Ridge Road had a positive effect on motorist awareness.* This was evidenced by the increased yield rates when the system was activated versus not activated, speed reductions when the system was activated, and trail user perspectives on increased opportunities to cross and increased safety at the crossing location. In addition, the data showed that there was an increase in yield rate over time even when the RRFB system was not activated. This indicates that the mere presence of the RRFB system induced behavioral modifications or possibly a "conditioning" of motorists to be more prepared to yield for trail users.

- *The RRFB system is perceived by trail users as an enhancement to safety at the Belmont Ridge Road crossing of the W&OD Trail.* The survey revealed that most trail users felt the system increased safety for bicyclists and walkers. In addition, most respondents viewed the system favorably.

- *Trail user perception of RRFB system benefits grew over time.* Video analyses showed that the rate of trail user activation of the RRFB system increased over the 1-year study period, and the survey indicated that trail users felt that motorists slowed or yielded more frequently when the flashers were activated.

- *There is a correlation between trail user activation of the RRFB system and the presence of traffic.* Data analyses showed that the rate of activation increased over time when traffic was present. The average activation rate when traffic was present across all modes of crossers in the 5-month and 1-year after periods was roughly 48 percent compared to 36 percent in the 3-week after period.

- *W&OD Trail users are confused as to who has the right-of-way at the crossing location.* Approximately one-half of the survey respondents felt that bicyclists and walkers had the right-of-way, but roughly one-third of the respondents felt motorists had the right-of-way; 10 percent indicated not knowing who had the right-of-way. This confusion has the potential to increase the risk of crashes at all locations where the W&OD Trail intersects a roadway.

RECOMMENDATIONS

1. *With the support of VCTIR, VDOT's Traffic Engineering Division should develop more specific guidance for RRFB installations*. The guidance should consider crosswalk user level of service (measured as a function of roadway geometry and traffic conditions), safety implications, and the use of advance warning devices.

2. *VDOT's Traffic Engineering Division should update its guidelines for the installation of marked crosswalks to include RRFBs as a Level 4 device.* The RRFB installation guidance developed in Recommendation 1 should be referenced in the updated marked crosswalk guidelines.

3. *VDOT's Operations Regions should continue to pursue opportunities to install and evaluate RRFB systems*. RRFB installations should follow guidance developed in Recommendation 1, and the evaluations should be performed (1) to add to the body of knowledge of RRFB effectiveness, and (2) to update and enhance the developed RRFB guidance. To encourage crossers to activate the flashers where RRFB systems are installed, VDOT should consider installing more prominent push button signage and engaging in public information campaigns about the benefits of the system as well as the rights and duties of motorists, pedestrians, and bicyclists at mid-block crosswalks.

4. *VCTIR should conduct a crash analysis 3 years after RRFB installation*. The purpose of the crash analysis would be to determine if the RRFB system caused a significant difference in crash occurrence at the site compared to the before installation period. To allow for a more robust statistical analysis, crash data from a control (or comparison) site should be analyzed.

BENEFITS AND IMPLEMENTATION PLAN

Benefits

The study found that the RRFB system enhanced safety at the crossing of Belmont Ridge Road and the W&OD Trail by increasing motorist awareness of pedestrians and bicyclists. This was evidenced by the higher yield rates, motorist speed reductions, and trail user perception of increased safety after the RRFB system was installed. Motorist inattention and excessive approach speed are often contributing factors in a crash involving a pedestrian or bicyclist. It is logical to assume, therefore, that the RRFB system can lead to a reduction in crashes, both between a vehicle and a pedestrian or bicyclist and between vehicles. The following discussion is based on the supposition that deployment of RRFB systems will result in crash avoidance.

In an economic analysis, the costs of crashes that are prevented or avoided are assumed to be the economic benefit of the countermeasure. In this case, costs are related to the installation of the RRFB system. Table 13 shows a comparison of the costs for installing two countermeasures: a four-pole RRFB system (median installations or advance warning devices) and an overhead flashing beacon system. Initial installation costs include labor, equipment, and traffic control and, where applicable, materials, design, survey, and electrical service. Initial costs and costs over a 5-year period are shown. The maintenance cost for RRFBs is estimated to be $1,950 over a 5-year period. This includes battery replacement and general maintenance.

Table 13. Costs Associated With Installation of Countermeasures

Countermeasure	Initial Installation Cost	Total Cost Over 5 Years[a]
RRFBs on 4 Poles	$71,800[b]	$73,800[d]
Overhead Flashing Beacons	$96,000[c]	$103,200[e]

[a] Not discounted to present value.
[b] Labor, equipment, materials, and engineering.
[c] Design, survey, labor, equipment, maintenance of traffic, and electrical service.
[d] Includes maintenance and battery costs of approximately $100 per year per pole.
[e] Includes maintenance and utility costs of $750 per year per beacon.

For this assessment, both countermeasures were assumed to have the same effect on crash avoidance. Several studies have estimated crash modification factors (CMFs) for flashing beacons installed in advance of crosswalks, on overhead mast arms at crosswalks, and in advance of intersections. Although the estimated factors vary depending on an assortment of roadway geometric and traffic characteristics, an estimated value of 0.82 was used in this analysis based on an average value from previous research.[16-18] Accordingly, this percentage was used to estimate the impact the RRFB system would have on crash avoidance. At Belmont Ridge Road, there were 23 crashes 5 years before the installation of the RRFBs. Applying the CMF to this number, it is estimated that the RRFBs would prevent four crashes over a 5-year period.

The VDOT Highway Safety Improvement Program (HSIP)[19] costs for crashes were used to estimate a monetary benefit from crash reductions over a 5-year period for the three countermeasures shown in Table 14. Those costs per crash were as follows:

- fatality: $3,760,000
- incapacitating injury: $188,000
- evident injury: $42,200
- possible injury: $22,900
- property damage only: $6,500.

Table 14 compares the benefit/cost (b/c) ratio of the countermeasures using the costs per crash figures and the installation/maintenance costs shown in Table 13. Each cost per crash type was quadrupled because it was estimated that four crashes would be avoided for each countermeasure over a 5-year period. A b/c ratio greater than 1.0 is desirable as it shows that the savings resulting from the benefits of a countermeasure exceed its costs. Based on the b/c ratios shown, the benefits of a four-pole RRFB system exceeded a "do nothing" approach for any crashes with possible injury and more severe injuries. Comparing four-pole RRFB systems with overhead flashing beacons, the b/c ratios are similar except that overhead flashing beacons result in a b/c ratio of less than 1 at a possible injury crash type.

Table 14. Costs and Benefits Assessment of Countermeasures

Crash Type	Cost ($) per 2 Crashes Avoided (Benefit)	Benefit-Cost Ratio	
		4-Pole RRFB System	Overhead Flashing Beacons
Fatality	15,040,000	204:1	146:1
Incapacitating Injury	752,000	10:1	7:1
Evident Injury	168,800	2.3:1	1.6:1
Possible Injury	91,600	1.2:1	0.9:1
Property Damage Only	26,000	0.4:1	0.3:1

Implementation Plan

Installation of RRFB systems is currently approved by FHWA with conditions at uncontrolled crosswalks. VDOT has developed additional cursory guidance for their use to include study criteria.

With respect to Recommendation 1, VCTIR staff will research and develop draft guidance for the installation of RRFBs. The draft will be reviewed and subject to approval by a working group of VDOT district traffic engineers. Final guidance will be submitted to the state traffic engineer for approval as an Instructional and Informational Memorandum (IIM) to be promulgated to VDOT districts. Upon approval and dissemination of the RRFB guidelines, VDOT's Traffic Engineering Division should implement Recommendation 2 via updating VDOT's *Guidelines for the Installation of Marked Crosswalks* to include RRFBs as a Level 4 device.

Recommendation 3 will be implemented when requests for RRFB installations are received. The VDOT district receiving the request (or initiating the request) should consult both the FHWA conditional requirements and VDOT guidance to ensure site suitability. Because VDOT's guidelines include study criteria, the installing region should perform a before evaluation to include at a minimum:

- *Pedestrian and/or bicyclist counts.* Counts should be obtained to approximate typical weekday peak and weekend peak volumes.

- *Number of crosser/motorist conflicts.* When a crosser or crossers are attempting to enter the crosswalk, conflicts with motorists should be noted. A *conflict* is defined as a condition where either the crosser slows or stops because of vehicular traffic and/or a motorist slows or stops to allow a crosser to traverse the crosswalk.

- *Motorist yield rate.* From the data obtained on conflicts, motorist yield rate can be calculated.

Once sufficient before data are collected, the RRFB system should be installed. Installation of the system should coincide with an education campaign about the system and the rights and duties of motorists and crossers at crosswalks. Approximately 1 month after the RRFB installation, a round of after data should be collected using the same procedures and time periods as the before data collection effort. Additional data that should be collected are RRFB activation rates. Results of the before-after analyses should then be sent to VDOT's Traffic Engineering Division for review and archiving.

Recommendation 4 regarding the crash analysis 3 years after RRFB installation will be carried out by research staff at VCTIR 3 years from the time of installation of the RRFB system at Belmont Ridge Road. The results of the analyses will be prepared and distributed to VDOT's Northern Virginia Traffic Engineering Division as an interoffice memorandum.

ACKNOWLEDGMENTS

A number of individuals contributed to this research, and the author appreciates their help and support: Linda Evans, Noah Goodall, Yue Liu, Cathy McGhee, Ramkumar Venkatanarayana, and Lewis Woodson from VCTIR; Randy Dittberner and Ivan Horodyskyj from VDOT; and Richard Tepel (Potomac Pedalers Touring Club), Pat Turner (Bike Loudoun), and Bruce Wright (Fairfax Advocates for Better Bicycling) from the Northern Virginia area bicycle clubs.

REFERENCES

1. Dougald, L.E. *Best Practices in Traffic Operations and Safety, Phase II: Zig-zag Pavement Markings.* VTRC 11-R19. Virginia Transportation Research Council, Charlottesville, 2010.

2. Toole Design Group. *Washington and Old Dominion Trail Six Intersection Study: Existing Conditions Report.* Northern Virginia Regional Park Authority, Fairfax Station, February 2012a.

3. Toole Design Group. *Washington and Old Dominion Trail Six Intersection Study: Recommendations Report.* Northern Virginia Regional Park Authority, Fairfax Station, May 2012b.

4. Federal Highway Administration. Rectangular Rapid Flash Beacon (RRFB). May 2009. http://safety.fhwa.dot.gov/intersection/resources/techsum/fhwasa09009/. Accessed April 21, 2015.

5. Hunter, W.H., Srinivasan, R., and Martell, C.A. Evaluation of Rectangular Rapid Flash Beacon at Pinellas Trail Crossing in Saint Petersburg, Florida. In *Transportation Research Record: Journal of the Transportation Research Record*, No. 2314. Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 7-13.

6. Van Houten, R., and Malenfant, J.E.L. *An Analysis of the Efficacy of Rectangular-shaped Rapid-Flash LED Beacons to Increase Yielding to Pedestrians Using Crosswalks on*

Multilane Roadways in the City of St. Petersburg, FL. n.d. http://mutcd.fhwa.dot.gov/resources/interim_approval/ia11/stpetersburgrpt/index.htm. Accessed April 21, 2015.

7. Furst, A.T. MUTCD – Interim Approval for Optional Use of Rectangular Rapid Flashing Beacons (IA-11). Memorandum, July 16, 2008. http://mutcd.fhwa.dot.gov/resources/interim_approval/ia11/ia11_rrfb_iapmemo.pdf. Accessed February 6, 2014.

8. Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways*. Washington, D.C., 2009.

9. BikeWashington.Org. The Washington and Old Dominion Trail. http://bikewashington.org/trails/wad/wad.htm. Accessed March 31, 2011.

10. *The Friends of the Washington & Old Dominion Trail.* http://www.wodfriends.org/. Accessed May 12, 2008.

11. Sherbutt, J., Van Houten, R., Turner, S., and Huitema, B. Analysis of Effects of LED Rectangular Rapid-Flash Beacons on Yielding to Pedestrians in Multilane Crosswalks. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2140. Transportation Research Board of the National Academies. Washington D.C., 2009, pp. 85-95.

12. Fitzpatrick, S.T.C., Van Houton, R., Hunter, W.H., and Turner, S. *Evaluation of Pedestrian Engineering Countermeasures: Rectangular Rapid Flashing Beacons, HAWKs, Sharrows, Crosswalk Markings, and the Development of an Evaluation Methods Report.* Texas Transportation Institute, College Station, 2011.

13. Zegeer, C., Nabors, D., and Lagerway, P. Pedestrian Safety Guide and Countermeasure Selection System. Case Study No. 100. *Rectangular Rapid Flash Beacons Near a NJ Rail Station: Elmwood Park and Fairlawn Boroughs.* http://www.pedbikesafe.org/PEDSAFE/casestudies_detail.cfm?CM_NUM=54&CS_NUM=100. Accessed September 16, 2014.

14. City of Boulder. *Pedestrian Crossing Treatment Installation Guidelines.* November 2011. http://nacto.org/docs/usdg/boulder_crossing_guidelines_boulder.pdf. Accessed May 2014.

15. Hunter-Zaworski, K., and Mueller, J. *Evaluation of Alternative Pedestrian Traffic Control Devices.* FHWA-OR-RD-12-09. Federal Highway Administration, Washington, D.C., 2012.

16. Raghvan, S., Carter, D., Eccles, K., Persuand, B., Lefler, N., Lyon, C., and Amjadi, R. *Safety Evaluation of Flashing Beacons at STOP-Controlled Intersections.* FHWA-HRT-08-044. Federal Highway Administration, Washington, D.C., 2008.

17. Fitzpatrick, K., and Park, E.S. *Safety Effectiveness of the HAWK Pedestrian Treatment.* TRB 88th Annual Meeting Compendium of Papers CD-ROM. Washington, D.C., 2009.

18. Gan, A., Shen, J., and Rodriguez, A. *Update of Florida Crash Reduction Factors and Countermeasures to Improve the Development of District Safety Improvement Projects.* Florida Department of Transportation, Tallahassee, 2005.

19. Virginia Department of Transportation, Traffic Engineering Division. *Highway Safety Improvement Program, Fiscal Year 2008-2009.* Richmond, 2007.

APPENDIX A

VDOT LETTER REQUESTING INTERIM APPROVAL TO INSTALL RRFBs

COMMONWEALTH of VIRGINIA

DEPARTMENT OF TRANSPORTATION
[illegible]
[illegible]

Gregory A. Whirley
Commissioner

March 29, 2011

Mr. Scott Wainwright
Office of Transportation Operations
Federal Highway Administration
1200 New Jersey Avenue, SE, HOTO-1
Washington, DC 20590

Dear Mr. Wainwright:

The Virginia Department of Transportation (VDOT) is requesting statewide interim approval to implement rectangular rapid flashing beacons (RRFB) on streets and highways under VDOT jurisdiction. VDOT is not asking for a state wide blanket approval for all jurisdictions.

VDOT agrees to the following terms, set forth in Section 1A.10, Paragraph 18, of the 2009 Manual on Uniform Traffic Control Devices (MUTCD) and in Interim Approval Memorandum IA-11, dated July 16, 2008:

- VDOT will maintain an inventory list of location(s) where the RRFB is placed.
- VDOT will restore the site(s) of the interim approval to a condition that complies with the provisions in the MUTCD within 3 months following issuance of a final rule on the use of RRFB.
- VDOT will terminate the use of RRFB implemented under the interim approval at any time that it is determined significant safety concerns are directly or indirectly attributable to the implementation of the RRFB.
- VDOT agrees that the FHWA's Office of Transportation Operations has the right to terminate the interim approval at any time if there is an indication of safety concerns.
- VDOT will comply with the design and operational requirements as outlined in the Interim Approval Memorandum.

If there are any questions regarding this interim approval request, please contact Harry Campbell at (804) 786-6374 or via email to Harry.Campbell@VDOT.Virginia.gov.

Sincerely,

Raymond J. Khoury, P.E.
State Traffic Engineer

APPENDIX B

FHWA APPROVAL LETTER

U.S. Department of Transportation
Federal Highway Administration

APR 11 2011

1200 New Jersey Avenue, SE
Washington, D.C. 20590

In Reply Refer To: HOTO-1

Raymond J. Khoury, P.E.
State Traffic Engineer
Virginia Department of Transportation
1401 East Broad Street
Richmond, VA 23219-2000

Dear Mr. Khoury:

Thank you for your letter of March 29 requesting approval to use Rectangular Rapid Flashing Beacons (RRFB) on a blanket basis at uncontrolled crosswalks on roadways under the jurisdiction of the Virginia Department of Transportation. Your request is made under the provisions of Section 1A.10 of the 2009 edition of the Manual on Uniform Traffic Control Devices (MUTCD) and our Interim Approval memorandum IA-11 dated July 16, 2008.

Your request is approved. Please develop and periodically update a list of all locations where RRFB are installed on State highways in Virginia. Your specific approval has been numbered "IA-11-68 - **RRFB** - Virginia DOT." Please reference this number in any future correspondence.

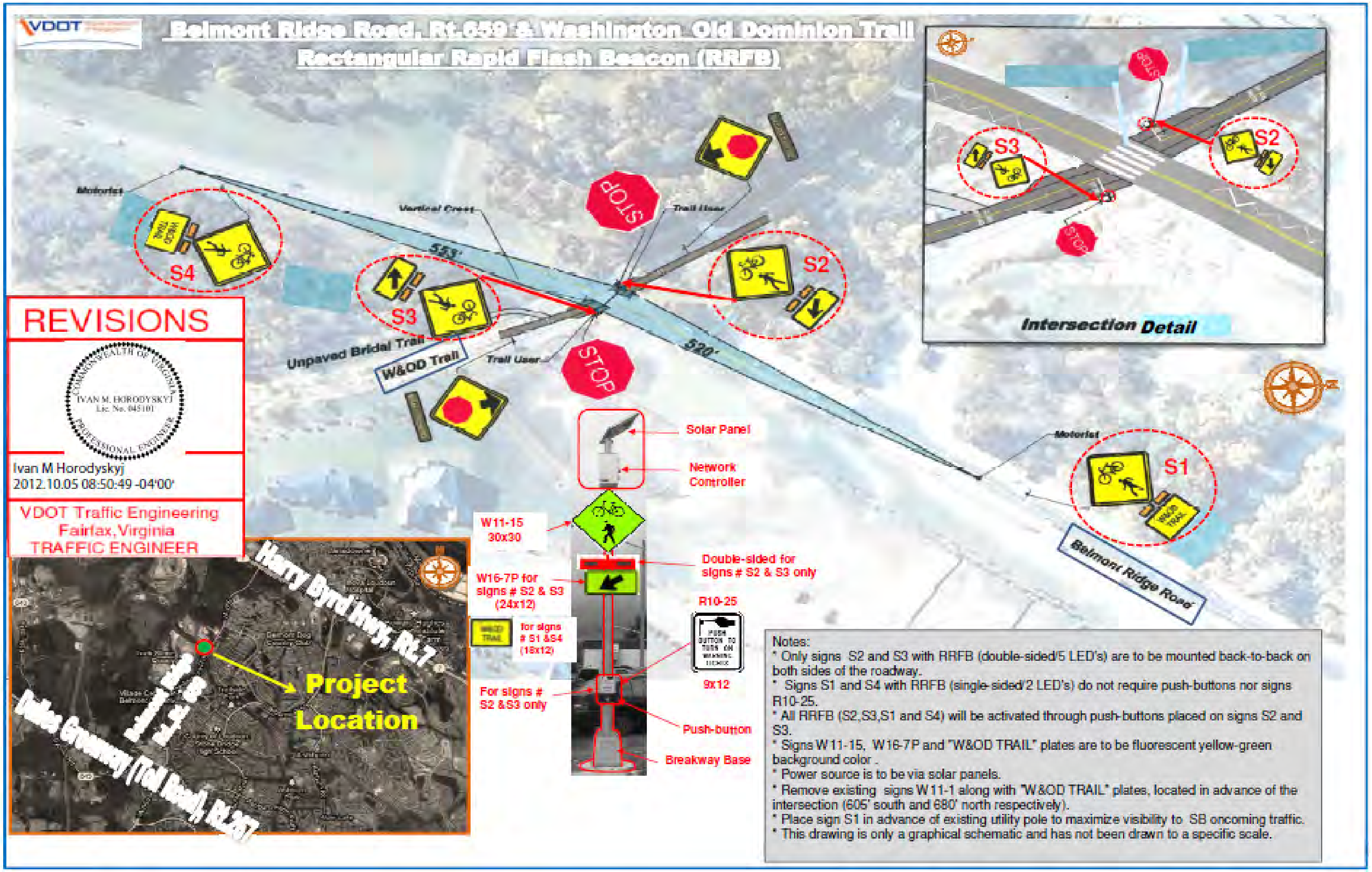
Thank you for your interest in improving pedestrian safety. If we can be of further assistance on this matter, please feel free to contact Mr. Scott Wainwright of our MUTCD Team by e-mail at **scott.wainwright@dot.gov** or by telephone at 202-366-0857.

Sincerely yours,

for Mark R. Kehrli
Director, Office of Transportation Operations

APPENDIX C

RRFB LOCATION SCHEMATIC AT BELMONT RIDGE ROAD



APPENDIX D

VIRGINIA DEPATRMENT OF TRANSPOTATION
RECTANGULAR RAPID FLASHING BEACON SURVEY

VIRGINIA DEPARTMENT OF TRANSPORTATION SURVEY

Rectangular Rapid Flashing Beacon

(1) How often do you bicycle or walk on the W&OD trail crossing at Belmont Ridge Rd?

- ☐ More than once a week
- ☐ About once a week
- ☐ A few times per month or year

(2) Have you ever pushed the button to activate the flashers at the roadway crossing?

- ☐ Yes
- ☐ No (skip questions 3 and 4)

(3) In what situations do you activate the flashers at the roadway crossing?

- ☐ I activate every time I attempt to cross
- ☐ I activate only when traffic is immediately present
- ☐ I activate only when crossing wait times seem excessive due to traffic

(4) When the flashers are activated, do you feel your waiting times to cross the road have decreased because of motorists slowing and/or yielding more frequently?

- ☐ Yes, this is often the case
- ☐ Yes, this is sometimes the case
- ☐ No, this is rarely the case

(5) Do you expect motorists to yield when the flashers are activated?

- ☐ Yes
- ☐ No

(6) Do you think the flashing beacon system:

- ☐ Increases safety for bicyclists and walkers
- ☐ Decreases safety for bicyclists and walkers
- ☐ Has no impact on safety for bicyclists and walkers

(7) In your opinion, who has the right-of-way (right to go first) at the trail crossing? (Check one)

- ☐ Bicyclists only
- ☐ Walkers only
- ☐ Both bicyclists and walkers
- ☐ Motor vehicle drivers only
- ☐ Don't know

(8) On a scale of 1-5 please indicate your overall opinion of the Rectangular Rapid Flashing Beacons with 1 being a highly unfavorable opinion and 5 being a highly favorable opinion. (circle one)

1	**2**	**3**	**4**	**5**
Highly Unfavorable	Unfavorable	Neither Favorable Nor Unfavorable	Favorable	Highly Favorable

Please use the space below to indicate why you answered question 6 as you did. Please add any other comments you have about the Rectangular Rapid Flashing Beacon system (use back of sheet if needed):

APPENDIX E

BELMONT RIDGE ROAD NORTHBOUND AND SOUTHBOUND DESCRIPTIVE STATISTICS FROM LIDAR DATA

Table E1. Northbound Descriptive Statistics

Scenario	Distance from Crosswalk (ft)	N	Mean (mph)	Std. Deviation (mph)	95% Confidence Interval (mph)	
					Lower Bound	Upper Bound
Before Zig-Zags	500-401	110	43.7	3.4	43.0	44.5
	400-301	156	44.0	3.3	43.4	44.6
	300-201	168	43.6	3.6	43.0	44.1
	200-101	156	43.1	4.1	42.5	43.7
	100-0	146	42.3	4.8	41.7	42.9
1 Year After Zig-Zags	500-401	187	42.5	3.5	41.9	43.1
	400-301	192	42.6	3.6	42.0	43.2
	300-201	187	41.8	4.0	41.2	42.4
	200-101	177	41.1	4.7	40.5	41.7
	100-0	175	40.2	4.9	39.6	40.8
RRFB Activation	500-401	25	42.6	4.1	40.9	44.3
	400-301	66	42.9	3.8	42.0	43.8
	300-201	52	41.3	4.7	40.0	42.6
	200-101	35	37.5	7.5	34.9	40.1
	100-0	37	24.1	10.9	20.5	27.7

Table E2. Southbound Descriptive Statistics

Scenario	Distance from Crosswalk (ft)	N	Mean (mph)	Std. Deviation (mph)	95% Confidence Interval (mph)	
					Lower Bound	Upper Bound
Before Zig-Zags	1000-801	137	49.5	3.8	48.8	50.2
	800-601	164	49.6	4.0	49.0	50.3
	600-401	180	49.2	4.0	48.6	49.8
	400-201	175	47.9	4.2	47.3	48.5
	200-0	165	45.0	4.9	44.4	45.6
1 Year After Zig-Zags	1000-801	117	48.7	3.7	47.9	49.6
	800-601	152	48.0	4.1	47.2	48.7
	600-401	154	46.3	4.1	45.6	47.1
	400-201	150	43.8	4.8	43.0	44.5
	200-0	132	39.3	6.2	38.5	40.1
RRFB Activation	1000-801	52	48.4	4.9	47.0	49.8
	800-601	62	48.2	5.1	46.9	49.5
	600-401	56	44.0	7.0	42.1	45.9
	400-201	54	37.1	9.8	34.4	39.8
	200-0	45	29.0	13.6	24.9	33.1

APPENDIX F

REVIEW OF THE CODE OF VIRGINIA

The results of surveys revealed differing opinions about who has the right-of-way at the W&OD Trail intersections. Of those responding, 36 percent thought motor vehicles have the right-of-way; 55 percent thought trail users; and 9 percent did not know. These percentages underscore the level of uncertainty about right-of-way at the trail crossing. As previously discussed, STOP signs are directed toward trail users at Belmont Ridge Road and high-visibility crosswalks are installed at the roadway crossings. In question, however, is whether or not the STOP signs legally apply to W&OD Trail users at the crosswalks.

With regard to pedestrian right-of-way, § 46.2-100 of the *Code* states that a crosswalk is "any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface" and § 46.2-924(A) specifies that "the driver of any vehicle on a highway shall yield the right-of-way to any pedestrian crossing such highway at any clearly marked crosswalk." The *Code* appears clear that pedestrians have the right-of-way at marked crosswalks, which would obviously include those at Belmont Ridge Road.

Two provisions in the *Code* refer to pedestrian control on highways: § 46.2-925 stipulates that where pedestrian control signals exhibiting the words, numbers, or symbols meaning "Walk" or "Don't Walk," such signals shall indicate and apply to pedestrians to cross or not to cross a highway. Further, § 46.2-924(B) states: "No pedestrian shall enter or cross an intersection in disregard of approaching traffic." Since the *Code* does not specify that STOP signs control pedestrians, it appears that pedestrians are not bound to obey STOP signs at Belmont Ridge Road.

The next step in the review of the *Code* was to investigate references to bicyclists on multi-use paths: § 46.2-904 states: "A person riding a bicycle, electric personal assistive mobility device, motorized skateboard or scooter, motor-driven cycle, or an electric power-assisted bicycle on a sidewalk, shared-use path, or across a roadway on a crosswalk, shall have all the rights and duties of a pedestrian under the same circumstances." Based on the *Code* provisions for pedestrians, this language suggests that bicyclists on the W&OD Trail are not legally bound to obey the STOP signs at Belmont Ridge Road.

Further review of the *Code* with respect to vehicles (including bicycles) entering a public highway revealed the following: § 46.2-821 states:

> Vehicles before entering certain highways shall stop or yield right-of-way. The driver of a vehicle approaching an intersection on a highway controlled by a stop sign shall, immediately before entering such intersection, stop at a clearly marked stop line, or, in the absence of a stop line, stop before entering the crosswalk on the near side of the intersection, or, in the absence of a marked crosswalk, stop at the point nearest the intersecting roadway where the driver has a view of approaching traffic on the intersecting roadway. Before proceeding, he shall yield the right-of-way to the driver of any vehicle approaching on such other highway from either direction.

Based on this language it would seem appropriate to argue that bicyclists must stop at the STOP sign and yield to mainline traffic. However, § 46.2-100 considers bicycles as "vehicles" only "while operated on a highway." Since the W&OD Trail is not a highway, it could be argued that this provision would not apply to bicyclists on the W&OD Trail.

With regard to language in the *Code* regarding vehicles entering a public highway from a road other than a highway, § 46.2-826 states: "The driver of a vehicle entering a public highway or sidewalk from a private road, driveway, alley, or building shall stop immediately before entering such highway or sidewalk and yield the right-of-way to vehicles approaching on such public highway and to pedestrians or vehicles approaching on such public sidewalk." Again in this case, however, bicycles are not considered "vehicles" by § 46.2-100 because "a private road, driveway, alley, or building" does not meet the *Code's d*efinition of a "highway." Therefore, this code provision does not appear to apply to bicyclists on the W&OD Trail.

These intricacies of the *Code* may not be known to motorists approaching a W&OD Trail crossing. Motorists see STOP signs directed at trail users and may logically conclude that they have the right-of-way. In June 2013, the Office of the Attorney General issued an opinion on whether law enforcement officers may enforce STOP signs posted by the Northern Virginia Regional Park Authority (NVRPA) on trails located within the W&OD Regional Park. The following is the response:

Response

It is my opinion that law enforcement officers may enforce against trail users stop signs installed on the W&OD Trail if such signs represent a rule or regulation of the NVRPA.

Background

You relate that the NVRPA seeks to establish uniform guidelines for the control of cycling traffic through the eight jurisdictions along the W&OD Trail. The W&OD Trail consists of a 10 foot wide, 45 mile long paved trail for walking, running, cycling, and skating, and 30 miles of a parallel gravel trail for horseback riding. The W&OD Trail passes through four towns, three counties, and one city. Trail users encounter potential collision with automobiles or other vehicles at the 70 road grade crossings.

Applicable Law and Discussion

The Northern Virginia Regional Park Authority is established as an authority under the Virginia Park Authorities Act.[1] Each authority established under the Virginia Park Authorities Act is

[1] VA. CODE ANN. §§ 15.2-5700 through 15.2-5714 (2012).

authorized and empowered . . . [t]o adopt such rules and regulations from time to time, not in conflict with the laws of this Commonwealth, concerning the use of properties under its control as will tend to the protection of such property and the public thereon. No such rule or regulation shall be adopted until after descriptive notice of an intention to propose such rule or regulation for passage has been published in accordance with the procedures required for the adoption of general county ordinances and emergency county ordinances as set forth in § 15.2-1427, mutatis mutandis. The full text of any proposed rule or regulation shall be available for public inspection and copying during regular office hours of the authority at a place designated in the published notice.[2]

Thus, the NVRPA clearly is authorized to adopt rules and regulations, including traffic provisions, in furtherance of protecting persons using any property within its control.

The violation of any such rule or regulation adopted by the NVRPA is deemed by law to be a Class 4 misdemeanor.[3] Thus, "the General Assembly has declared the violation of a park authority's rules and regulations to be a misdemeanor, which is a crime, an offense against the state."[4] It is the duty of sheriffs and local police officers to enforce state laws.[5] Consequently, no further legal justification is required to allow local police, sheriffs, or sheriff's deputies to enforce park rules or regulations requiring trail users to stop prior to entering a highway.[6]

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[2] Section 15.2-5704(17) (2012).

[3] Section 15.2-5705 (2012).

[4] 1985-86 Op. Va. Att'y Gen. 255, 255 (responding to the Loudoun County Sheriff that sheriffs indeed have a duty to enforce the rules and regulations adopted by regional park authorities located in Loudoun County while noting that the sheriff retains exclusive control over the assignment of personnel and the day-to-day operations of his office).

[5] *See* §§ 15.2-1609 (2012), 15.2-1704(A) (2012).

[6] The enforceability of stop signs along the trail was addressed in part with recently enacted legislation that enables localities to adopt ordinances requiring users of shared-use paths to stop before crossing highways at marked crosswalks subject to fine not to exceed $100. 2013 Va. Acts chs. 507, 681. In its correspondence with you, the NVRPA argues the W&OD Trail might be considered a "highway" and, as such, signs governing traffic on the trail posted by NVRPA would be eligible for traffic enforcement from local sheriff and police departments. Because of the conclusion reached herein, it is unnecessary to address this alternative argument. In addition, this opinion declines to determine the sufficiency of current signage.

I further note that "highway" is generally defined as

> the entire width between the boundary lines of every way or place open to the use of the public for purposes of vehicular travel in the Commonwealth, including the streets and alleys, and, for law-enforcement purposes, (i) the entire width between the boundary lines of all private roads or private streets that have been specifically designated "highways" by an ordinance adopted by the governing body of the county, city, or town in which such private roads or streets are located and (ii) the entire width between the boundary lines of every way or place used for purposes of vehicular travel on any property owned, leased, or controlled by the United States government and located in the Commonwealth.

VA. CODE ANN. § 46.2-100 (Supp. 2012).

Conclusion

Accordingly, it is my opinion that law enforcement officers may enforce against trailer users stop signs installed on the W&OD Trail if such signs represent a rule or regulation adopted by NVRPA under the Virginia Park Authorities Act.[7]

With kindest regards, I am

Very truly yours,

Kenneth T. Cuccinelli, II
Attorney General

APPENDIX G

RESPONDENT COMMENTS ON SURVEY QUESTION 7

drawers attention to W&OD trail users crossing the roadway
I do not favor the yellow flashing beacon because this is a system that many motorists are not familiar with and many do not stop when the yellow beacon is flashing. VDOT has the yellow beacon in several locations in the City of Fairfax. When these lights are activated, I have seen motorists ignore and continue driving. These lights have even caught me off guard. Now that I am familiar with these lights, when they are activated, I look everywhere for the pedestrian before proceeding. VDOT must educate drivers that they are supposed to stop and make sure that no pedestrian is present before proceeding. A few weeks ago in the City of Fairfax, the light was activated and pedestrians were present and a driver just ignored the light and continued driving. I started blowing my horn to try to get the driver to stop. I was shocked that both warnings were ignored.
every little bit helps. if nothing else, it makes drivers more aware of us.
Today I observed the crossing for about 20 minutes. Most riders did NOT activate the RRFB. Sometimes drivers slowed of stopped, irregardless of whether the signal was on or not. I do not know why some trail users choose to not activate the RRFB, or if they even noticed the buttons.
I think it gives trail users a false sense of security.
the biggest factor is the attitude of the car drivers. who may or may not yield
I rode this trail before the system was put in and it has made huge difference in safety and driver consideration.
The flashing light is not part of the drivers license test. Big signs remind people that people on bikes or walking or running have the right of way!
Traffic (cars) drive too fast and rear end each other. Cyclists rarely stop and rear-end those who do.
It makes the cars more aware of the crossing.
I don't trust people will stop with the flahsers.
False sense of security
Flashing beacons are better than not having it.
It increases awareness of bikers. Makes vehciles take notice. Hopefully it will increase safety for all.
Need to install real light flashers. Are on curve and cars going too fast to see small lights.
Flashing beacon has helped but it's still a very dangerous intersection.
Slightly favorable.
I think it is helpful during high traffic periods especially for families
Without the flashers there is excessive speeding on Belmont Ridge Rd. If you start to cross, you have little chance when someone is at 60 mph.
Have experienced the flashers only once so far. Generally speaking, I like ANYTHING that increases bicycle safety vis-a-vis automobiles.
Beacons are favorable, however not always effective
I believe it is an effective system.
Cars think they have to stop.
The beacon lights make it easier for cars to see cyclists.
Drivers to be aware there is a cycle path there = awareness to look
Anything to help everyone's safety is a good thing.
Motor vehicle drivers might play more attention, but rarely stop.
1) Awareness 2) Wakes up some of the drivers who think they don't have to stop at crosswalks.
Anything that causes drivers to slow down and get their attention to the road helps! I say as both a cyclist and driver.
It is a couresy awareness signal, so would prefer it was a crossing where motorists had to stop.
Anything to get morotists to notice people at this busy intersection is extremely positive.
A motor vehicle stop light should be added

It is more likely that the cars will stop.
I want an overpass bridge for bikers
It gets the attention of motorists.
Cars/drivers usually noticed bright-flashing, so then they also notice things around the lights.
Added safety. Cars need to know we're here or they won't stop.
Makes everyone aware and alert
Anything helps. The drivers in Virginia (Northern) are crazy. The beacon has improved the crossing.
Signals incoming cars of possible hazards. The crossing has some blind spots for cars.
Traffic typically does not stop unless it is activated. Maybe 20% vehicles stop w/out it flashing.
The rapid flashing system does not seem to be used frequently
Any lights to increase awareness of the bike trial should increase safty in my opinion.
Some drivers yield, some do not.
Brings awareness to crosswalk
I think it helps some. It doesn't hurt.
lets motorists know that people are actively crossing
I've noticed that motorists are stopping and slowing at this crossing, much more so than before the RRFB was in place. Regarding who has the right of way in the earlier question, it depends. If bicyclists and pedestrians are waiting at the crosswalk and motorists have time to safely stop, then the trail users have the right of way.
an actual stop signal with a relatively short activation wait would be far preferable
The RRFB makes it safer and easier to cross Belmont Ridge Rd during high volume traffic periods.
It works as intended. Can be used when needed and does not impede traffic when not.
While RRFBs provide an increased measure of safety, the rules regarding right of way in crosswalks are unnecessarily complex. It isn't completely clear when the cyclist/ped "gains" the right of way based on the language in the statute and regulation. This would likely require a legislative change
My experience has been that before the lights it would take forever to cross and now cars stop. Well done.
A signal with a red light would be much preferable to a signal with a blinking yellow. There is not a good reason to avoid requiring cars to come to a stop at such a dangerous crossing.
The RRFB was a nice try. However, this is hands down the worst intersection on the W & OD. The high speed and often heavy traffic is rarely sensitive to cyclists and pedestrians.
I think it is favorable over having nothing. It's less favorable than a traffic light.
This is a potentially dangerous intersection and the flashing lights do an outstanding job of alerting car drivers to the presence of trial users. As if often the case, many drivers have no problem letting trail users cross, but aren't aware of their presence until it is too late to stop. This slows them down and then they can easily extend the courtesy to cyclists, walkers and other trail users.
The flashing causes confusion. Some motorists slam on their brakes. Others ignore it. The issue is a flasher does not mean "stop" it means "hey keep alert!". Technically motorists are not required to stop. If VDOT placed a traffic light at that intersection, then motorists would stop more consistently, similar to the light at Catoctin Cir.
While these don't work all the time. There are still drivers who don't want to stop for a bike, jogger, walker under any circumstances, but they certainly have helped. This is a very dangerous crossing. And I both drive and ride my bike across it. I know when I see the flash, it's a reminder for me that I need to be extra careful driving through there and be prepared to stop when able. They don't hurt. And they have certainly helped me and made me feel safer crossing there..
Anything that will catch a motorists attention and alert them to the presence of trail users is a good thing.
The fact that the beacon can be activated by trail users so road traffic begins to associate the flashing beacon with crosswalk use is helpful. However, riders and joggers that are in to much of a hurry to use the beacon and assume drivers will stop with little or no warning are as much of a problem as the cars. Ther needs to be education and enforcement on all users of the crossing.
Belmont Ridge Road is a high speed, medium traffic "country" road, carrying some heavy truck traffic, gravel trucks, as well as cars, The W&OD trail crosses near the base of a hill. There is a zebra crossing painted on the road, but no traffic light. The RRFB activates flashing lights far enough away from the zebra crossing so that the drivers have a chance to see them and slow down and stop as they approach the crossing.

The flashing lights are very effective. Motorists almost always stop to allow trail users to cross. The flashing lights ensure that other motorists (not just the first car in line) can see what is happening and can slow down in response. I live in Ashburn and often drive on Belmont Ridge Rd., in addition to riding the trail, so I have seen this intersection many times from both perspectives. As a driver, I find the lights to be effective and I find that stopping to allow trail users to cross is safe.
Love these things.....just not sure that is the best location for it. Auto speeds are high there for several reasons....
it alerts motor vehicle drivers that trail users are waiting to cross. MOST people stop for it which makes it safer
It makes the fact that there is a crossing much more visible and encourage s drivers to slow down
This type of signal device is uncommon and I think it is confusing to motorists.
needs a bridge
I support any better solution for safety of the people when walk or bike.
this type of system is in regular use out West and should be installed more often in the NOVA area, particularly in high traffic areas that are used by walkers and cyclists.
Anything that draws motorists attention to the need to slow dow, stop and or exercise caution seems a good thing. Unrealistic to expect cyclists to stop and push a button. Button are generally not in a place that makes it easy. Automatic sensor system makes more sense.
Vehicles will not stop unless the light is red.
For what it does it is not worth the money. the money could be better spent on roadway improvements.
All it has done is cause cyclists to have to slow to a stop, push the button, and then wait to see if someone is going to still blast through and kill us. Why not just make it a stop light or do some traffic enforcement out on Belmont road of the motorists who are going 50 miles an hour? If they're going that fast, and the RRFB is activated, they can't stop -- and if we've entered the crosswalk already, having activated it, we're toast. Motorists have learned that the RRFB means nothing in terms of traffic enforcement, so they blow it off just like they ignore speed limits.
While I believe the RRFB system is better than nothing, I believe it is very confusing to drivers. Drivers don't know whether they need to stop or yield... they don't know who has the right of way... I believe a flashing sign that says "Yield to bicycles" or "STOP for trail users" would be a better option (or a good complement to the RRFB system).
I like to be certain that the cars see me. I think the light helps.
The pavement marking and flashing lights do increase awareness. Some motorist still seem intent on maintaining curising speed regrdless of whetther or not a walker or bike is at the crossing.with light activated. Much better situationsince installation.
It provides extra visibility of the crossing
It is an improvement on the previously hazardous situation. I did not rate 'highly favorable' as the design could be tweaked to better sign/inform the bike/ped users about depressing the button and the benefit to them of doing so.

APPENDIX H

SURVEY RESPONDENT ADDITIONAL COMMENTS

These lights can work if the drivers are educated to stop.
I'm going to wait to cross in any case. The beacon does seem to get drivers attention and is probably more acceptable to them than a stop sign would be. Maybe you'd consider one of these at the Hunter Mill Road crossing of the W&OD? Bikers seems a little aggressive there and traffic goes almost as fast.
There seems to be confusion among drivers as to whether to stop or not, resulting in some danger to the cyclists. In the 20 minutes I was watching, I observed a near rear-end collision in the south-bound lane: a driver stopped suddenly at the crossing, causing the following vehicle to slam on its brakes. I imagine this happens frequently. The zig-zag lines have completely worn off on BBR. I thought that the results of a study showed they caused some slowing of traffic. (But perhaps not as effective as the RRFB.) I believe that this intersection is one of the most dangerous on the W&OD Trail. Loudoun County has plans to widen Belmont Ridge Road, and as you know, at that time the intersection will become a separated-grade crossing.
A grade-separated crossing would be great at this location.
Not a regular user of W&OD Trail, but have found system effective for crosswalks in DC.
Trucks don't stop. They go 55 mph. Thanks for your service. You are going a great job.
Most experienced bikers don't use flashers.
Fix is an overpass. If Luckstone truck behind me (as motorist), I am not stopping for a trail user. The truck can't stop quickly behind me. If someone dies, they will change the system.
Traffic is moving fast, not clear most motorists are familiar with it. Separate issue... consider this system for intersection before Smith's Switch Station.
Although it is helpful, I think a bridge or tunnel would be best solution.
Often drivers stop to the surprise of drivers behind them. I've seen abrupt stops often.
Get an overpass!
Lots of fast moving traffic and trucks. Sometimes I avoid the intersection and turn around. A bridge would be best option.
We do not need a crosswalk. The uncertainty is still dangerous. Too many people don't know the law.
Eliminate parking off Belmont Ridge Rd.
Would prefer a bridge or fly-over.
Not alll motorists know what to do. Inconsistent and unreliable.
At some point there needs to be a traffic signal at this crossing.
Motorists have become indifferent to the lights.
Never know what to expect. Sometimes motorists stop. Not other times. Zig-zag works great.
We need motorists to actually pay attention and follwow the yield sign. Sometimes they do not stop. It is a very risky crossing.
Please keep the lights or make more of them + speed bumps.
It is a fairly hight traffic zone adn vehicles don't stop.
Bikes are supposed to stop if they have a stop sign but drivers often yield to us.
Vehicle code of Commonwealth of VA is confusing re "zebra crossings" for cyclists.
I don't trust drivers to see or obey.
Because of the speed and density of traffic a quick stop system would be most safe.
Need a tunnel
Tunnel!
Bicyclists and walkers at the crosswalk get right of way if waiting to cross. They must however approach slowly and/or stop first.
This is a dangerous intersections. We need a bridge for bikers.

It seems many motorists simply don't pay attention
In Roadway Warning Lights are great.
Can you please talk neighboring states into putting in this system!
Please put in Sterling on W&OD. Very dangerous!!
Need one at Crestview Rd in Sterling
This intersection needs a bridge.
I would prefer a stop light at this crossing
Need more of these systems at other high speed/high volume locations
I've noticed that many cyclists don't push the button to activate the signal. I think many, many cyclists have become discouraged by the long wait times at most traffic signals and they treat this signal like other traffic signals by just using their judgement about when to cross. At least that was my impression when the signal was first installed. I haven't seen that many cyclists at this intersection lately; maybe behavior has changed.
I first biked crossed Belmont Ridge Rd on the W&OD trail back in 1985. There was essentially no traffic at all back then. Due to population explosion in Loudoun County, the high-speed traffic at this intersection can be very dangerous for walkers and bicyclists trying to cross the road. Probably the only thing safer than the RRFB would be an actual red light that could be activated by pedestrians/bikers, or an overpass bridge on the W&OD.
I am disappointed that VDOT has refused to put in a red signal, prioritizing automobile throughput over cyclist and pedestrian safety. I hope that VDOT institutes a new trial with a PHB rather than an RRFB.
The only good solution is to drop the speed limit, install a traffic light, or build a bridge. Belmont Ridge Road is a blight on an otherwise stellar recreational facility.
I like the flashing lights but it may cause bikers and walker to have a false sense of security while crossing Belmont Ridge because they may think that all traffic will slow down and that is not the case. In many instances, I have observed one car stop but the other side does not. If bikers and walks are not very careful, they may step into the road way while watching the stopped car and not notice the other side is not yielding to pedestrians. Rumble strips in the road way and the bike path is a good way to slow down both the drivers and bikers. This is what they use on the 90 mile Silver Comet Trail near Atlanta.
THANK YOU!
I find it much easier to cross there with the signals installed. Something similar should be installed at the Hunter Mill crossing near the Vienna/Reston border.
I would like to see a system similar to RRFB at other locations. Sterling Blvd would be a good location.
It needs a bridge or tunnel to be safe there.
I wish there were more RRFBs! In Fairfax county there are many dangerous crossings - wiehle, sunrise valley etc.. In Loudoun County there is the BBQ crossing (Ashburn Farm Rd) - its busier than Belmont Ridge but visibility for motor vehicles is much better there. Smith Switch might be a good option for a RRFB
The volume of traffic is so high and the speeds are so fast on this road. I don't see that anything other than a bridge will improve safety.
needs bridge, and belmont ridge road should be 4 lanes
Outstanding VDOT - very glad to see this!
This is a good crossing for the experiment because it is heavily traveled by cars that tend to drive at excessive speed.
There should be a speed zone down to 25 or 30 through there. THAT would be effective.
The technology exists for a sensor, camera, or infrared light system that would activate flashing beacons, stop lights, pedestrian crossing lights, or light up stop signs when a pedestrian or bicycle is approaching, without the need to push a button. An example of this technology can be found here: http://www.migmapd.com/. This would avoid delays between when the trail user pushes the button and when the beacons activate, and also adjust the flashing time for the lights depending on whether it's a fast bicycle crossing or a disabled person walking, for example.
I wish that Virginia's pedestrian crossing law was like DC or North Carolina where vehicles have to yield to pedestrians who are in the crosswalk. My understanding is that in Virginia, vehicles are under no obligation to allow pedestrians to cross even in a crosswalk. Many drivers are courteous and let pedestrians and bicyclists cross, but safety is still a concern.
The zig zag striping in the road is just confusing from a driving standpoint and creates a slicker surface when the roads are wet.

Can't wait for the overpass to get built!
1. We need better educational mechanisms and processes to inform drivers/peds/bicyclists about the operational change, how it works,who has right-of-way, safety benefits as well as cautions about the system limitations. 2. Suggest creating a permanent trailhead-type sign board at this location to explain design, results, operation, etc. Due to the bench on the east side, this is already a rest location for many along the trail. The sign board could both be an educational tool as well as a positive feature showing safety progress. 3. There is caution and hesitation about using newer treatments among agencies even when costs are low relative to potential safety benefit. Suggest putting results in form where it can be readily disseminated within Virginia: suggest also including information about costs and implementation to assist DOT staff in future applications in other locations.