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Virginia Transportation Research Council

research report

Evaluation of the Cross Alert System on the Virginia Capital Trail in James City County

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16. Abstract

The Virginia Capital Trail is a bicycle and pedestrian trail that connects Virginia's past and present capitals of Jamestown, Williamsburg, and Richmond along the scenic Route 5 highway corridor. The trail crosses Route 5, a two-lane roadway with a 55 mph speed limit, between Route 613 and the Chickahominy Riverfront Park in James City County. The Virginia Department of Transportation (VDOT) installed a Cross Alert system by Cross Alert Systems, Inc., at the crossing to provide a warning to motorists of the presence of pedestrians and bicyclists. VDOT also installed a number of other safety enhancements on each approach to the crossing.

Given the expense of the system, VDOT was concerned about its cost-effectiveness and asked the Virginia Transportation Research Council to conduct an evaluation of the existing crossing, including its effectiveness and the safety of bikers and pedestrians who use the crossing. The evaluation consisted of analyzing motorists and biker/pedestrian actions when the beacons of the Cross Alert system were flashing and not flashing.

Key findings included the following:

- There is ample opportunity for bikers and pedestrians to cross Route 5 safely.
- The flashing yellow beacons increase motorist awareness of bikers and pedestrians at the crossing.
- According to respondents to a survey of trail users, the Cross Alert system improves safety and the flashing beacons contribute the most to safety.
- The Cross Alert system had operational problems concerning flashing of the beacons, biker actuation of the flashing beacons, and timing of the flashing beacons were erratic.
- When the Cross Alert system is activated, there is a potential for rear-end collisions when motorists yield to bikers or pedestrians approaching the crossing.

The study recommends that VDOT immediately investigate the erratic nature of the system's operation at the Route 5 crossing and refrain from deploying the system until these problems are resolved. If these operational problems are resolved satisfactorily, VDOT should consider the deployment of a system similar to the Cross Alert system at other appropriate locations.

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In Cooperation with the U.S. Department of Transportation
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Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
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DISCLAIMER

The contents of this report reflect the views of the authors, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Virginia Department of Transportation or the Commonwealth Transportation Board. This report does not constitute a standard, specification, or regulation.

ABSTRACT

The Virginia Capital Trail is a bicycle and pedestrian trail that connects Virginia's past and present capitals of Jamestown, Williamsburg, and Richmond along the scenic Route 5 highway corridor. Two of the eight phases of the trail are complete, and at one point, the trail crosses Route 5, a two-lane roadway with a 55 mph speed limit, between Route 613 and the Chickahominy Riverfront Park in James City County. The Virginia Department of Transportation (VDOT) installed a Cross Alert system by Cross Alert Systems, Inc., at the crossing on November 11, 2006, to provide a warning to motorists of the presence of pedestrians and bicyclists. VDOT also installed a number of other safety enhancements on each approach to the crossing, including two sets of transverse rumble strips, a post-mounted advance warning "bicycle crossing ahead" sign, and pavement markings in the travel lane of a bicycle symbol followed by the word "X-ING."

Counties along Route 5 have expressed interest in installing Cross Alert systems at other roadway crossings on the trail, and given their cost, approximately $36,000 each, VDOT is concerned about their cost-effectiveness. Accordingly, VDOT asked the Virginia Transportation Research Council to evaluate the existing crossing, including its effectiveness and the safety of bikers and pedestrians who use it. The system was already in operation when the evaluation began, thus precluding "before and after" installation studies. The evaluation consisted of analyzing motorists and biker/pedestrian actions when the beacons of the Cross Alert system were flashing and not flashing.

Key findings included:

- There is ample opportunity for bikers and pedestrians to cross Route 5 safely.
- The flashing yellow beacons increase motorist awareness of bikers and pedestrians at the crossing.
- According to respondents to a survey of trail users, the Cross Alert system improves safety and the flashing beacons contribute the most to safety.
- The Cross Alert system had operational problems concerning flashing of the beacons, biker actuation of the flashing beacons, and timing of the flashing beacons were erratic.
- When the Cross Alert system is activated, there is a potential for rear-end collisions when motorists yield to bikers or pedestrians approaching the crossing.

The study recommends that VDOT immediately investigate the erratic nature of the system's operation at the Route 5 crossing and refrain from deploying the system until these problems are resolved. If these operational problems are resolved satisfactorily, VDOT should consider the deployment of a system similar to the Cross Alert system at other appropriate locations.

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INTRODUCTION

The Virginia Capital Trail is a bicycle and pedestrian trail that connects Virginia's past and present capitals of Jamestown, Williamsburg, and Richmond along the scenic Route 5 highway corridor. The Virginia Capital Trial Foundation is partnering with the Virginia Department of Transportation (VDOT) and other state agencies and stakeholders to construct the trail, which will traverse 50+ miles and five jurisdictions when it is completed in 2010. The trail will be paved and constructed in accordance with American Association of State Highway and Transportation Officials guidelines for bike and pedestrian facilities[1] (i.e., it will be paved with asphalt 8 to 10 ft in width, have 2-ft shoulders, and comply with the requirements of the Americans with Disabilities Act). The trail is designed for non-motorized use and will serve hikers, bicyclists, pedestrians, joggers, skaters, birders, families taking short day trips, and chaperoned school children on eco-field trips. It is open during daylight hours only.[2]

The project is being constructed in eight phases, and the first two, Greensprings and Chickahominy Riverfront, are now open.[3] The current status of each phase can be obtained from VDOT's website at http://www.virginiadot.org/projects/newcaptrail_welcome.asp. At one point, the Chickahominy Riverfront trail crosses Route 5, a two-lane roadway with a 55 mph speed limit. The crossing is located in James City County between Route 613 and the Chickahominy Riverfront Park (see Appendix A). The latest published counts from VDOT show an annual average daily traffic of 3,400 vehicles in 2006.[4] To provide warning to motorists of the presence of pedestrians and bicyclists at the crossing location, a Cross Alert system manufactured by Cross Alert Systems, Inc., was installed on November 11, 2006. Figure 1 shows the installed system (additional photographs are provided in Appendix B). The photograph in Figure 1 was taken prior to the official opening of the Chickahominy Riverfront Phase on May 1, 2007.

The Cross Alert system consists of a red light-emitting diode (LED) light and stop sign that are aimed at path users and an amber LED light and warning sign that are aimed at roadway vehicular traffic. The system is powered by a solar panel with a battery backup and activated by path activity via an infrared motion sensor. The companion signs on the other side of the road are activated via radio signal when the first sign detects motion on the path. This system also

Figure 1. Cross Alert System on Route 5 in James City County, Virginia. *The photograph was taken prior to the official opening of the Chickahominy Riverfront Phase on May 1, 2007.*

includes an integrated trail counter to provide a count of trail users who cross the intersection. All signs comply with the requirements of the *Manual on Uniform Traffic Control Devices*.[5]

Solar power significantly reduces installation costs for the system by eliminating the need for connection to the power grid. Radio linkage between signs eliminates the need for hanging or burying wires. The system is capable of running in a configuration with up to four sign poles, all of which can be triggered together by path activity. This allows for amber warning lights to be placed and aimed at oncoming vehicles up to 500 ft from the crossing, which is the case at the Route 5 crossing.

VDOT has installed a number of other safety enhancements on each approach to the crossing to supplement the Cross Alert system, and these can be seen in the photographs of the crossing in Appendix B. Signs and pavement markings that motorists encounter as they approach the crossing are listed here; components of the Cross Alert system are also listed for reference.

- set of transverse rumble strips

- post-mounted advance warning bicycle crossing ahead sign (W11-1), a single flashing yellow beacon, an advisory plate “when flashing,” and an advisory plate with “45 mph”; signs and plates are fluorescent yellow-green; the flasher is remotely activated by a radio signal from actuation at the crossing (part of the Cross Alert system)

- second set of transverse rumble strips

- post-mounted advance warning bicycle crossing ahead sign (W11-1) in fluorescent yellow-green

- pavement markings in the travel lane of a bicycle symbol followed by the word "X-ING"

- post-mounted advance warning bicycle crossing ahead sign (W11-1), a single flashing yellow beacon, and an advisory plate "when flashing" (part of the Cross Alert system).

Counties along Route 5 have expressed interest in installing Cross Alert systems at other roadway crossings on the Virginia Capital Trail; however, given their cost, approximately $36,000 each, VDOT is concerned about their cost-effectiveness. Accordingly, VDOT asked the Virginia Transportation Research Council (VTRC) to conduct an evaluation of the existing crossing.

PURPOSE AND SCOPE

The purpose of this research was to evaluate the effectiveness of the Cross Alert system installed on the Virginia Capital Trail at its crossing of Route 5 in James City County between Route 613 and the Chickahominy Riverfront Park and the safety of bikers and pedestrians who use the crossing. The primary measure of effectiveness was vehicle speeds with and without the flashers.

As the system was already in operation when this study was begun, "before and after" studies could not be undertaken. The evaluation in this study was, therefore, conducted for a 3-day period after the Cross Alert system had been in use for approximately 6 months.

METHODS

The following tasks were undertaken to achieve the research objectives:

1. Collect vehicle data, including volumes, speeds, and instances of yields.

2. Collect biker and pedestrian data, including volumes and personal opinions concerning the system.

3. Analyze the data collected to determine if the warning flashers of the Cross Alert system caused motorists to reduce their speed as they approached the crossing when a biker or pedestrian was present at the crossing.

Collect Vehicle Data

Volumes

VDOT collects traffic volume data annually on Route 5 at a location in close proximity to the Chickahominy Riverfront crossing. These data are collected over a 2-day period once per year. Because the data collection period for this study (late October 2007) differed from VDOT's most recent data collection period (the most recent VDOT data were obtained in January 2007), the researchers found it necessary to obtain traffic volume information during the study's data collection period. Also of interest to the researchers was the percentage of trucks on Route 5 because of the construction of the Chickahominy Bridge on Route 5 just west of the Virginia Capital Trail crossing. A camcorder was set up to obtain video of the crossing during the data collection periods (approximately 7 hours over a 3-day period). The video was later used to count the number of vehicles and trucks.

Speeds

As noted previously, the Cross Alert system was installed prior to the implementation of this research. Accordingly, the evaluation focused on vehicle speeds with the system activated and not activated. Key parameters for the speed evaluation included the direction of vehicle travel and whether a biker/pedestrian was approaching from the south (Williamsburg) or the north (Chickahominy Riverfront Park). The latter was considered important because the roadway geometry resulted in motorists having different sight distances depending on which side of the roadway the biker/pedestrian was waiting. Consideration of these parameters and the need to collect background speeds resulted in the 10 data collection scenarios described in Table 1.

Table 1. Study Scenarios for Data Collection and Analysis

Scenario	Motorist Direction of Travel on Route 5	Flasher Status	Biker/Pedestrian Location at Crossing[a]
Eastbound			
EB-1	Eastbound to Williamsburg	On	North side of Route 5
EB-2	Eastbound to Williamsburg	On	South side of Route 5
EB-3	Eastbound to Williamsburg	Off	North side of Route 5
EB-4	Eastbound to Williamsburg	Off	South side of Route 5
EB-5	Eastbound to Williamsburg	Off	No bikers (Baseline)
Westbound			
WB-1	Westbound to Richmond	On	North side of Route 5
WB-2	Westbound to Richmond	On	South side of Route 5
WB-3	Westbound to Richmond	Off	North side of Route 5
WB-4	Westbound to Richmond	Off	South side of Route 5
WB-5	Westbound to Richmond	Off	No bikers (Background)

[a]The north side is toward Chickahominy River Park; the south side is toward Williamsburg.

A light detection and ranging (LIDAR) speed gun was used to collect vehicle speeds as motorists approached the crossing for each of the scenarios described in Table 1. The LIDAR guns were connected to laptops installed with a laser data transfer program. While tracking a vehicle, speed, range (distance from LIDAR gun), and time (to nearest 100th of a second) were recorded. The LIDAR gun has the capability of recording data approximately every 0.3 second. Two members of the research team were inconspicuously positioned with the LIDAR guns approximately 730 ft in advance of the crossing; the intent was to capture vehicle speeds before the first set of flashing beacons and continue capturing speeds as the vehicle approached the crossing. Figure 2 shows the locations of the observers in relation to the advance warning flashers and the crossing for both the eastbound and westbound travel directions. In order to expedite the data collection effort, staged bikers were used for all speed measurements; i.e., VTRC personnel with bicycles were used as surrogates for actual trail users.

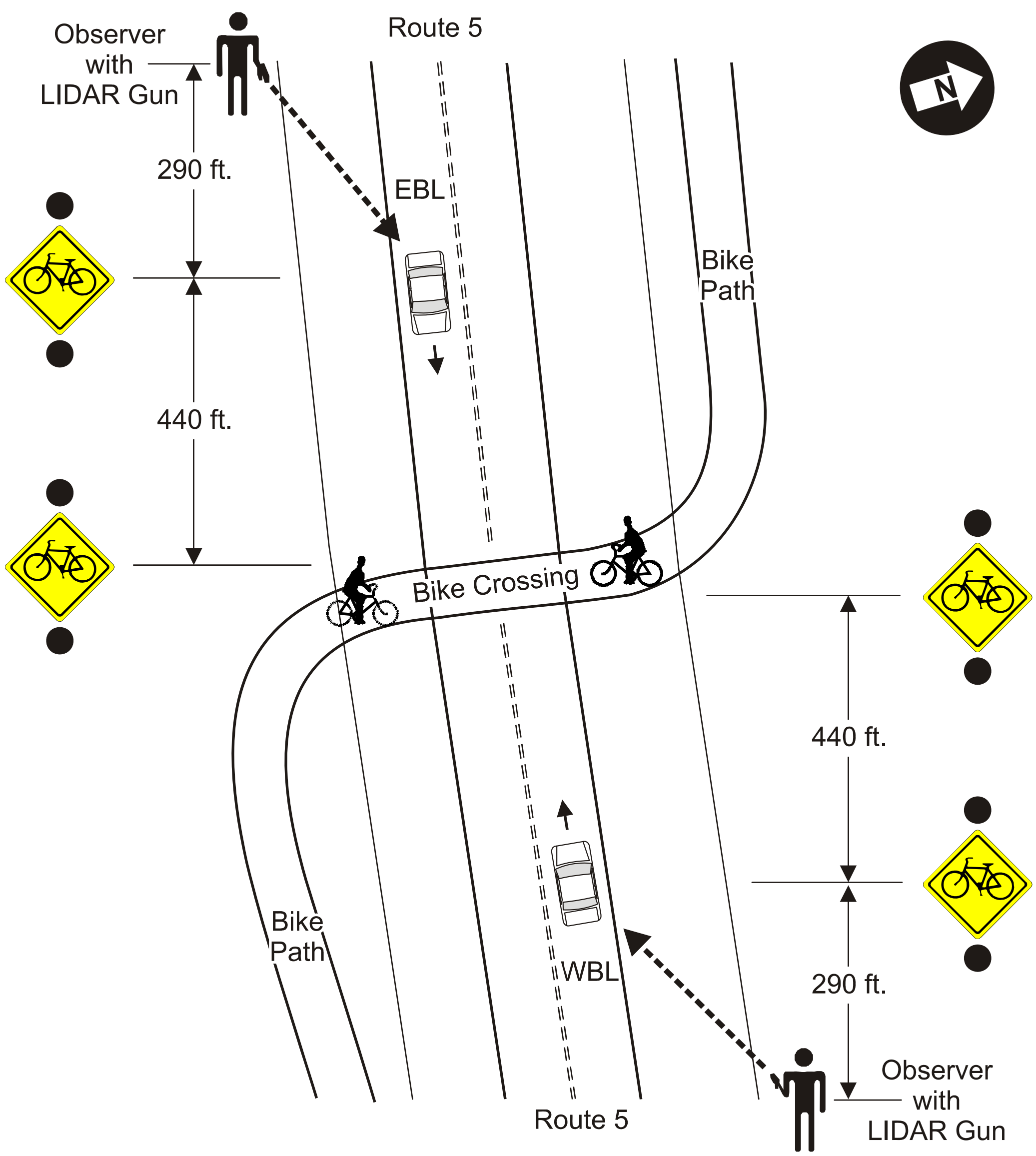

Figure 2. Observer Locations Relative to Warning Signs. *LIDAR = light detection and ranging, EBL = eastbound lane, WBL = westbound lane.*

Yields

The video discussed earlier was analyzed to count the number of times a motorist yielded or did not yield to a biker/pedestrian waiting to cross Route 5 at the crossing.

Collect Biker and Pedestrian Data

Video from the previously described camcorder setup also allowed estimates of the number of bikers and pedestrians who used the crossing while speed data were being collected, i.e., weekday counts. Weekend counts of bikers were obtained by placing automatic traffic recorders and tubes on the trail.

In order to obtain information from bikers and pedestrians who had used the crossing about their experiences with and opinion of the crossing enhancements, particularly the Cross Alert system, a questionnaire survey was developed (see Appendix C). These were emailed to all 320 members of the Williamsburg Area Bicyclists and all of the approximately 50 members of the Tidewater Appalachian Trail Club. These organizations were recommended for the survey by VDOT's Statewide Bicycle and Pedestrian Program Coordinator. Those who received the survey were instructed to complete the questionnaire only if they had used the crossing. An additional five bikers using the trail were interviewed at random during the course of field data collection.

Analysis of Data

Data were analyzed to determine if the Cross Alert system warning flashers caused a reduction of vehicle speeds as motorists approached the crossing when a biker or pedestrian was present. In addition, the video was analyzed to determine vehicle and truck volumes during the data collection periods and the instances of motorists yielding to bikers or pedestrians waiting to cross. Finally, the results of the questionnaire surveys were compiled to gauge the perceptions of bikers and pedestrians regarding the crossing location and the Cross Alert system.

RESULTS AND DISCUSSION

Vehicle Data Collection

Volumes

The raw counts of all vehicles observed in the video are provided in Appendix D. Table 2 presents a summary of the findings based on an analysis of the video data. During the data collection periods, there was an average of 226 total vehicles per hour on Route 5. These vehicles were split almost equally between the eastbound and westbound directions. There was an average of 48 trucks per hour (trucks were defined as tractor-trailers, dump trucks, box trucks, recreational vehicles, vehicles pulling trailers), split almost equally by direction. This resulted in a truck percentage of 21 percent.

Table 2. Summary of Findings from Video

Direction, Mode, or Event	Vehicles per Hour	Trucks[a] per Hour	% Trucks	Bikers per Hour	No. of Pedestrians	No. of Yields
Eastbound to Williamsburg	111	24	21			
Westbound to Richmond	115	25	21			
Total	226	48	21			
Bikers				4		
Pedestrians					1	
Instances of motorist yielding						16[b]

[a]Tractor-trailers, dump trucks, box trucks, recreational vehicles, vehicles pulling trailers.
[b]Fourteen of the instances of yield were for staged bikers.

Speeds

As previously discussed, LIDAR guns were used to record individual vehicle speeds. Table 3 shows an example of a speed and range output file for three vehicles.

Table 3. LIDAR Gun Speed and Range Output File

Vehicle 1		Vehicle 2		Vehicle 3	
Speed (mph)	Distance (ft)	Speed (mph)	Distance (ft)	Speed (mph)	Distance (ft)
-46	154	-46	170	-53	96
-46	194	-46	211	-53	142
-46	215	-46	230	-53	165
-46	236	-46	251	-52	189
-46	275	-45	271	-52	212
-45	294	-45	310	-52	235
-45	313	-45	331	-52	258
-44	334	-45	350	-52	281
-44	353	-45	370	-52	304
-44	372	-45	390	-52	327
-43	390	-45	410	-52	350
-43	409	-45	430	-52	373
-42	427	-44	450	-46	456
-42	446	-44	469	-46	476
-41	463	-44	489	-46	496
-40	480	-44	508	-45	516
-39	497	-44	527	-45	535
-38	513	-43	546	-43	573
-38	529	-43	565	-43	591
-37	546	-43	584	-42	610
-36	562	-43	603	-42	628
-36	577	-42	621	-41	645
-36	593	-42	640		
-35	608	-42	659		
-34	622	-42	678		
-34	637	-42	696		
-33	651	-42	714		
-32	665				
-32	678				

The minus (-) sign before the speed number indicates that the vehicle was moving away (receding) from the observer.

The raw data obtained in the field were then reduced to provide mean individual vehicle speeds in 100-ft segments (for each vehicle the raw data provided approximately four or five speeds per 100 ft). To allow for cleaner data representation and analyses, individual vehicle speeds were averaged 0-100, 101-200, 201-300, 301-400, 401-500, and 501-600 ft from the crosswalk. Table 4 is an example of how this was accomplished for the same vehicles shown in Table 3.

Mean individual vehicle speeds per 100-ft segments were then averaged for all samples across each scenario. For example, if mean vehicle speeds for Vehicles 1, 2, and 3 shown in Tables 3 and 4 were obtained during the same scenario, the mean speed of all three vehicles 0-100 ft from the crosswalk would be:

$$\frac{32.8 + 42.0 + 41.0}{3} = 38.8\ \text{mph}$$

Table 4. Average Vehicle Speeds per 100-ft Segment

Distance from Crossing (ft)	Mean Vehicle Speeds (mph)		
	Vehicle 1	Vehicle 2	Vehicle 3
600-501	46.0	46.0	52.5
500-401	45.5	45.3	52.0
400-301	43.3	45.0	52.0
300-201	39.7	44.0	45.8
200-101	35.7	42.8	43.0
100-0	32.8	42.0	41.0

Westbound

Upon calculating mean speeds per 100-ft segments for each scenario, plots were created for the purpose of identifying trends in speed profiles. Figure 3 shows mean speed profiles for each of the five westbound scenarios as vehicles approach the crossing in the westbound direction.

The profiles indicated that the flashing beacons had an effect on motorist reactions in terms of initial speed reduction. At 501 to 600 ft from the crossing, the mean speeds with flashers on (Scenarios 1 and 2), were 46.3 and 48.8 mph, respectively, whereas mean speeds without flashers on (Scenarios 3-5) were 50.4, 53.5, and 53.6 mph, respectively. In addition, the profiles indicate that as vehicles approached the crossing, mean speeds decreased in all scenario cases. With flashers on and a biker present (Scenarios 1 and 2), mean vehicle speeds from 600 ft to the crossing were consistently lower than with flashers off and a biker present (Scenarios 3 and 4). The data also indicated that crossing direction influenced motorist reaction. Mean vehicle speeds were lower with flashers either on or off when a biker crossed from the north side (Scenarios 1 and 3, respectively) than when a biker crossed from the south side (Scenarios 2 and 4, respectively). This finding may be attributed to motorists having a clearer view of a biker on the north side of the crossing and thus able to gauge a biker’s intentions better (i.e., a biker intending to yield vs. not intending to yield).

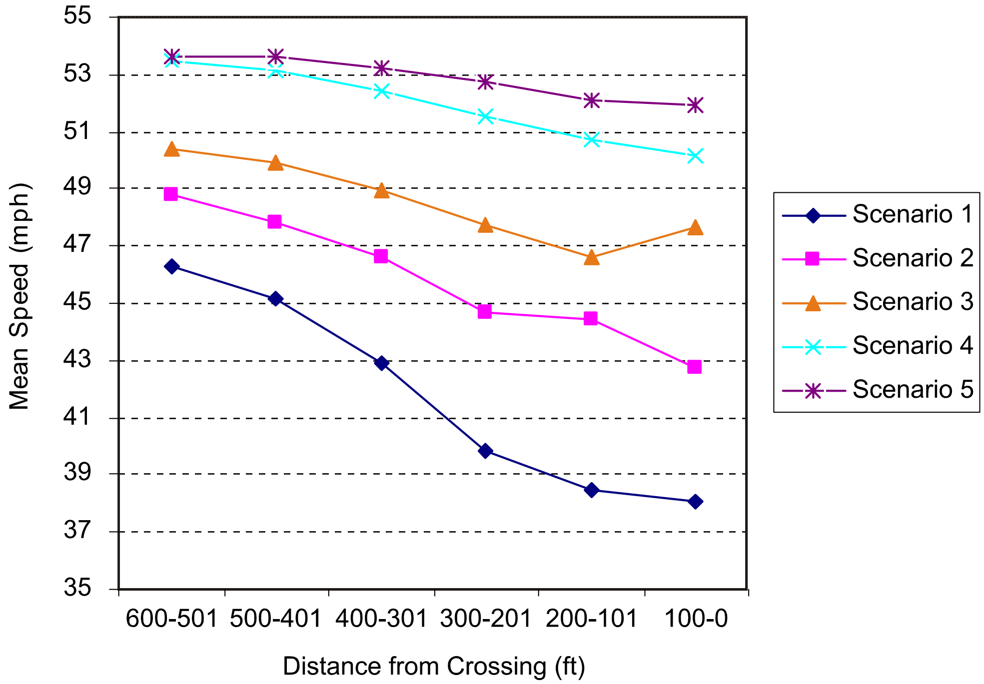

Figure 3. Mean Speed Profiles for Each Scenario for Westbound Vehicles. *The scenarios are defined as follows: 1 = flashers on, biker present on north side; 2 = flashers on, biker present on south side; 3 = flashers off, biker present on north side; 4 = flashers off, biker present on south side; 5 = flashers off, no biker present.*

To illustrate better how the ranges in mean speeds differed between scenarios from 600 to 0 ft, a plot of mean speed vs. scenario was constructed and is shown in Figure 4. Mean speeds for each 100-ft segment in Scenario 1 ranged from a high of 46.3 mph (600-501 ft) to a low of 38.1 mph (100-0 ft), thus showing a mean speed reduction of 8.2 mph as vehicles approached the crossing. Scenarios 2 through 5 show mean speed reductions of 6.1, 3.8, 3.3, and 1.7 mph, respectively. These results indicate that greater speed reductions occurred when flashers were on and a biker was present (8.2 mph in Scenario 1 and 6.1 mph in Scenario 2) compared to when flashers were off and no biker was present (3.8 mph in Scenario 3 and 3.3 mph in Scenario 4). In addition, the results indicate that greater speed reductions occurred when a biker was present at the crossing (with flashers on or off) than when no biker was present (Scenario 5). To determine if mean speeds across the range of distances for each scenario were significantly different, multiple comparison tests for all pair-wise differences between the scenario means were conducted. The results are shown in Table 5.

In terms of significant mean speed differences with flashers on vs. flashers off, multiple comparison tests at a 95 percent confidence level ($\alpha = 0.05$) indicated that Scenario 1 differed significantly from Scenarios 3 and 4. On the other hand, Scenario 2 differed significantly from Scenario 4 but not Scenario 3. There was a significant difference in mean speeds between Scenarios 1 and 2 (a biker present, flashers on), indicating that the direction of a biker's approach was a factor in speed differential. Similarly, there was a significant difference in mean speeds between Scenarios 3 and 4 (a biker present, flashers off), indicating that the direction of a biker's approach was a factor in the speed differential. The difference in mean speeds between Scenario 4 (52.2 mph) and Scenario 5 (52.8 mph) was not significant. In both cases, the flashers were off.

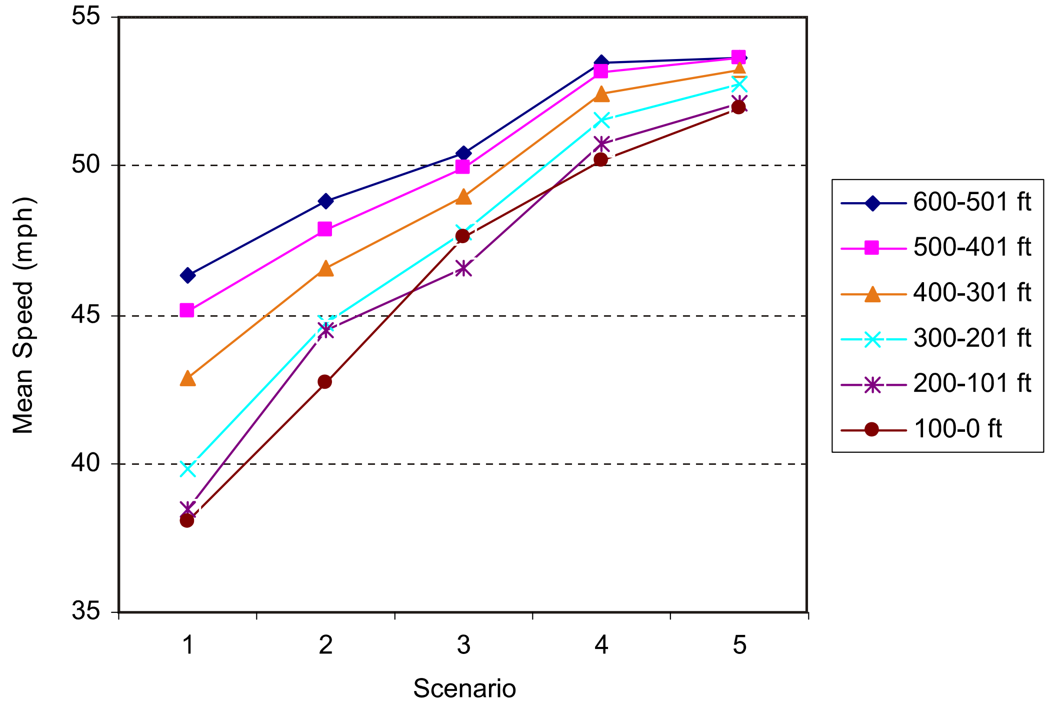

Figure 4. Mean Speed Profile for Each 100-ft Section for Westbound Vehicles. *The scenarios are defined as follows: 1 = flashers on, biker present on north side; 2 = flashers on, biker present on south side; 3 = flashers off, biker present on north side; 4 = flashers off, biker present on south side; 5 = flashers off, no biker present.*

Table 5. Statistical Comparisons Between Scenarios for Westbound Vehicles

Scenario	Sample Size	Mean Speed (mph)	Standard Error (mph)	95% Confidence Interval	
				Lower Bound (mph)	Upper Bound (mph)
1 (flashers on , biker present north side)	37	42.2	0.89	40.5	44.0
2 (flashers on, biker present south side)	43	46.7	0.82	45.1	48.3
3 (flashers off, biker present north side)	36	48.5	0.90	46.7	50.2
4 (flashers off, biker present south side)	36	52.2	0.90	50.5	54.0
5 (flashers off, no biker present)	46	52.8	0.80	51.2	54.3

Eastbound

Obtaining continuous individual vehicle speed data was more difficult in the eastbound travel direction than in the westbound travel direction. This was due in large part to the observer remaining inconspicuous while locking in on vehicles with the LIDAR gun. This compromised the observer's ability to maintain a direct line of sight on the vehicles as he or she approached the crossing. Obtaining speed samples closer to the crossing (i.e., 0-300 ft) was particularly problematic.

Mean speed profiles for each of the five scenarios in the eastbound direction are shown in Figure 5. The profiles indicate that mean speeds generally decreased as vehicles approached the crossing in Scenarios 1 through 4, whereas speeds remained relatively constant in Scenario 5. Anomalies in the data collected in Scenarios 2 and 3 occurred at approximately 200 ft from the crossing, with mean vehicle speed trends changed from decreasing to increasing. The factors contributing to the trend anomalies may include (1) smaller sample sizes contributing to larger variances and standard errors in mean speeds, and (2) motorists changing speeds upon nearing the crossing because of the ability to gauge biker intentions (i.e., a biker intending to yield or not yield).

As was the case in the westbound travel direction, the flashing beacons seemed to have an effect on motorist reactions in terms of initial speed reduction. At 600-501 ft from the crossing, the mean speeds in Scenarios 1 and 2 (flashers on, a biker present) were 47.4 and 44.0 mph, respectively, whereas mean speeds without flashers on (Scenarios 3-5) were 48.3, 47.9, and 49.7 mph, respectively. However, as vehicles progressed from 600 ft to the crossing, more variation occurred in mean speeds within each scenario as compared to the westbound travel direction. The range in mean speeds across distances for each scenario in the eastbound travel direction is more clearly seen in Figure 6.

The differences in the highest mean speed and the lowest mean speed in the eastbound travel direction were less distinct than in the westbound direction (see Figure 6). The mean speed differences for Scenarios 1 through 5 were 2.7, 3.2, 2.6, 4.3, and 0.6 mph, respectively, indicating greater vehicle speed reduction when a biker was present (Scenarios 1-4) as compared

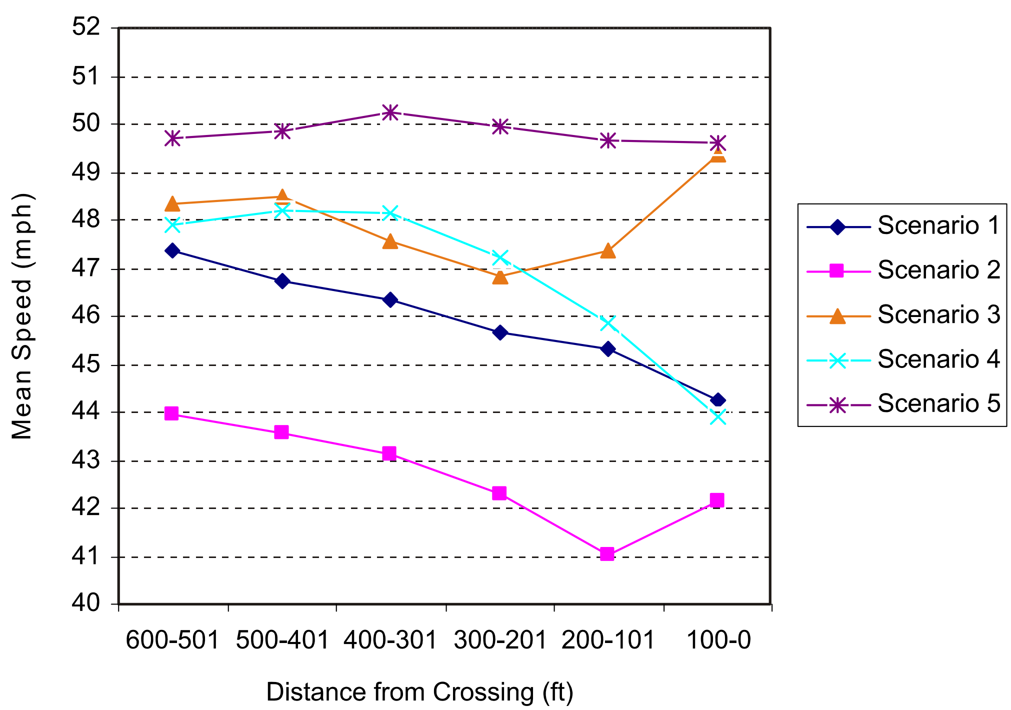

Figure 5. Mean Speed Profiles for Each Scenario for Eastbound Vehicles. *Scenarios are defined as follows: 1 = flashers on, biker present on north side; 2 = flashers on, biker present on south side; 3 = flashers off, biker present on north side; 4 = flashers off, biker present on south side; 5 = flashers off, no biker present.*

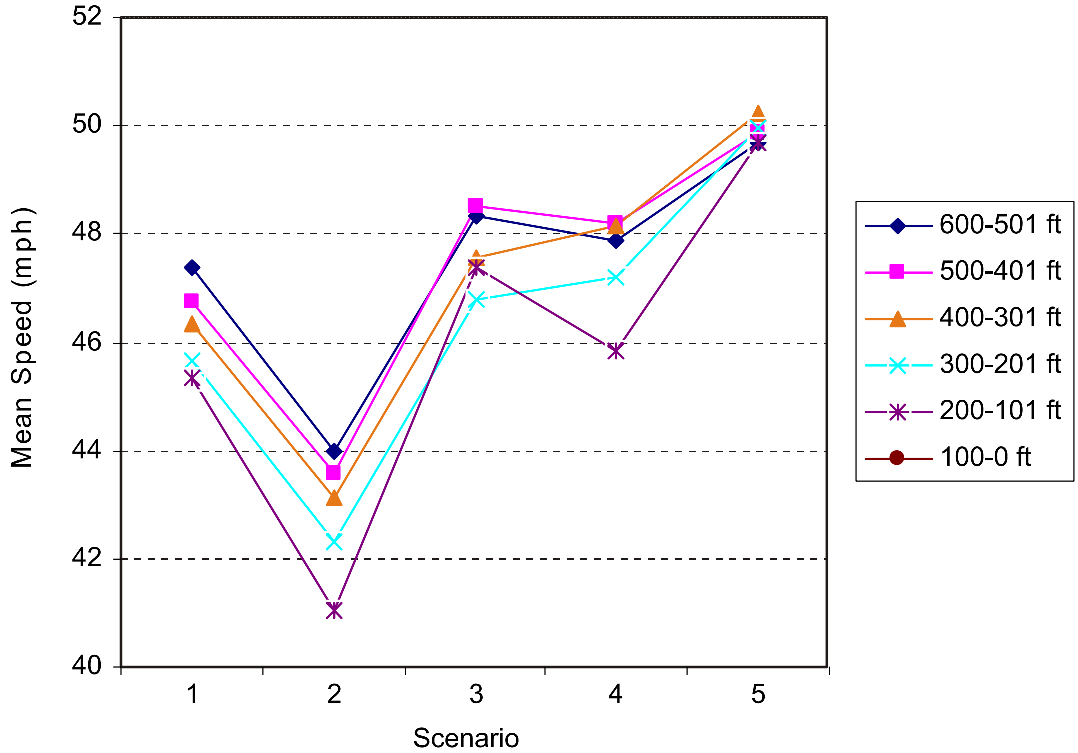

Figure 6. Mean Speed Profile for Each 100-ft Section for Eastbound Vehicles. *Scenarios are defined as follows: 1 = flashers on, biker present on north side; 2 = flashers on, biker present on south side; 3 = flashers off, biker present on north side; 4 = flashers off, biker present on south side; 5 = flashers off, no biker present.*

to when no biker was present (Scenario 5). However, the flashing beacons did not seem to have a significant impact on speed reduction across distances as evidenced by the relatively small speed differences between Scenarios 1 through 4.

To determine if mean speeds across the range of distances for each scenario were significantly different, multiple comparison tests for all pair-wise differences between the scenario means were conducted. The results are shown in Table 6.

Table 6. Statistical Comparisons Between Scenarios for Eastbound Vehicles

Scenario	Sample Size	Mean Speed (mph)	Standard Error (mph)	95% Confidence Interval	
				Lower Bound (mph)	Upper Bound (mph)
1 (flashers on , biker present north side)	37	46.2	0.85	44.6	47.9
2 (flashers on, biker present south side)	22	43.3	1.10	41.2	45.5
3 (flashers off, biker present north side)	25	48.5	1.03	46.4	50.5
4 (flashers off, biker present south side)	16	46.1	1.29	43.6	48.7
5 (flashers off, no biker present)	21	50.3	1.13	48.0	52.5

At a confidence level of 95 percent ($\alpha = 0.05$), the data in Table 6 show that all scenario mean speeds were significantly different from that in Scenario 5 except for Scenario 3, thus indicating, in general, that the condition of a biker present at the crossing may have had an effect on motorist reaction (in terms of speed). However, the impact of the flashing beacons was less evident. There were decreases in mean speeds of 2.3 and 1.8 mph when comparing flashers "on" vs. "off" in the northbound and southbound directions, respectively, but the differences were not significant. The relatively small sample sizes may have contributed to indistinct differences. There was a significant difference in mean speeds between Scenarios 1 and 2 (biker present, flashers on), indicating that the direction of a biker's approach was a factor in the speed differential. However, there were no significant speed differences between Scenarios 3 and 4 (biker present, flashers off), indicating that when flashers were off, the biker's approach was not a factor in the speed differential.

Yields

As noted in Table 2, there were 16 instances of vehicles yielding for a biker in the crossing during the almost 7 hours of data collected as defined previously; however, 14 of these were for the staged bikers in the study.

Biker and Pedestrian Data Collection

Counts

As noted in Table 2, the number of bikers on the trail averaged four per hour during the almost 7 hours of data collected as defined previously; there was only one pedestrian during the entire period of observation.

Table 7 provides summary counts from the automatic traffic recorders placed on the trail at the crossing. These were collected for a weekend in mid-October 2007 that started right before noon on Friday and ended mid-morning on Monday. The Monday counts are not reported as they were very low. During the 7 hours from 11 A.M. to 6 P.M. on Friday, there was an average of three bikers per hour. This compares closely with the average of four observed during the weekday periods captured by the video. As anticipated, bike traffic picked up considerably on the weekend, averaging six bikers per hour on Saturday and nine bikers per hour on Sunday.

Table 7. Biker Counts from Automatic Traffic Recorders

Data Collection Period	No. Bikers	Bikers per Hour
Friday, October 12, 2007 11 A.M.–6 P.M.	24	3
Saturday, October 13, 2007 7 A.M.–6 P.M.	77	6
Sunday, October 14, 2007 7 A.M.–6 P.M.	106	9

Biker and Pedestrian Survey

A total of 27 responses to the survey were obtained and analyzed. A response rate could not be determined because it is unknown how many of the 370 surveyed club members were trail users that did not respond to the survey. A summary of the results is presented in Table 8. A discussion of the results by question is provided here.

Table 8. Results of Survey of Bikers and Pedestrians Using the Virginia Capital Trail Crossing of Route 5 in James City County

Question	Response	Number	% (of 27 Respondents)
1. How many times have you used this crossing?	1 to 5 times	3	11.1
	6 to 15 times	8	29.6
	>15 times	16	59.3
2. Are you usually biking, walking, or both?	Biking	25	92.6
	Walking	0	0.0
	Both	2	7.4
3. Typically, do you have to wait to cross?	Yes	19	70.4
	No	8	29.6
4. If you wait, what is your average wait time?	<1/2 min	15	71.4
	1/2 to 1 min	4	19.0
	>1 min	2	9.5
5. If you wait, do you feel the wait is excessive?	Yes	0	0.0
	No	23	100.0
6. What is your overall feeling about safety at the crossing?	Safe	16	59.3
	Somewhat safe	8	29.6
	Not safe	3	11.1
7. What measure contributes most to the crossing's safety?	Flashing red and yellow lights	17	54.8
	Bike/Xing marking on road	7	22.6
	Rumble strips on Route 5	7	22.6
8. Do the flashing lights activate as you approach?	Most of the time	14	56.0
	Some of the time	6	24.0
	None of the time	5	20.0
9. Have the flashing lights improved safety at the crossing?	Yes	20	76.9
	No	6	23.1
10. Who has right-of-way at the crossing?	Motorist/vehicle	24	96.0
	Pedestrian	1	4.0
11. Do you rely on the flashing lights to stop vehicles?	Yes	1	3.7
	No	26	96.3

1. Approximately 60 percent of the respondents reported they had used the crossing more than 15 times; another 30 percent had used it 6 to 15 times. The remaining reported minimal use.

2. The respondents were mostly bikers (93 percent) with the remaining few being both bikers and pedestrians.

3. Seven of 10 respondents had to wait to cross.

4. Approximately 71 percent of the respondents reported that their wait to cross was less than 1/2 minute, 19 percent reported waits of 1/2 to 1 minute, and about 10 percent reported waits of more than 1 minute. None of the respondents thought the wait was excessive.

5. Approximately 89 percent of the respondents felt safe or somewhat safe at the crossing, with the percentage split 59 percent and 30 percent, respectively. Only 11 percent felt not safe at the crossing.

6. Approximately 55 percent of the respondents thought that the system of flashing red and yellow lights contributed most to the safety of the crossing. The bike crossing pavement markings on Route 5 and the rumble strips were each selected by about 23 percent of the respondents as the measure contributing most to safety. Several respondents selected more than one measure, with most of those noting all three worked together to make the crossing safe. One respondent selected none of the measures and noted that none of them work (to increase safety).

7. Fifty-six percent of the respondents reported that the flashing lights activated most of the time when they approached the crossing. Another 24 percent reported activation some of the time, and 20 percent reported activation none of the time.

8. Approximately 77 percent of the respondents thought that the flashing lights improved safety at the crossing.

9. On overwhelming majority of 96 percent of the respondents thought that motorists have the right of way at the crossing. Similarly, the same majority of respondents (96 percent) did not rely on the flashing lights to stop vehicles.

Respondent Comments

Twenty-one of the 27 respondents offered comments, and these were generally positive. Users thought the following:

- When working properly, the system prompts bikers to slow down/stop before the crossing and prompts motorists of the presence of bikers.

- VDOT has provided reasonable and adequate safety facilities for this location, and these systems should be incorporated at all at-grade crossings.

- Since the lights do not constantly flash, they seem to get motorists' attention when they do, even if the motorists do not slow down.

There were also negative comments. A couple of respondents were not aware that the lights were supposed to flash. Another saw no differences in speed and observed that there was a very sensitive detection zone. One respondent thought motorists were responding to the bridge construction and that once completed, the crossing would become far less safe. Finally, one respondent questioned the cost-effectiveness of the system.

In addition to the positive and negative comments, a couple of respondents suggested that basic safety rules at the crossing and instructional information about the system should be provided on the trail itself.

GENERAL OBSERVATIONS FROM FIELD EVALUATIONS

The following observations were made during several visits to the crossing for preliminary review and data collection.

- *Traffic volumes were relatively small, and gaps in the flow provided ample opportunities for bikers and pedestrians to cross.* There was a large number of dump trucks, assumed to be related to the bridge construction at the Chickahominy River. (Counts taken from the video showed the percentage of trucks was 21 percent, which is relatively high for a two-lane rural road.)

- *Many bikers did not have to wait to cross.* Of those waiting to cross, the wait was short.

- *Vehicles appeared to be slowing down more when the yellow beacons were flashing.*

- *Flashing of the beacons was erratic.* This applied to the red/yellow beacons at the crossing as well as the advance yellow beacons. There were many instances when the beacons at the crossing were flashing while the advance beacons were not. This suggests problems with the radio transmission between the crossing and the advance beacons.

- *Biker actuation of the flashing beacons was erratic.* Approaching bikers were most often successful in actuating the beacons; however, the cone of detection varied between approaches and often seemed to vary within an approach; i.e., staged bikers and pedestrians approaching the crossing activated the beacons at 35 ft on one approach and 60 ft on the other approach. Some of this difference may be explained by the fact that the cone of detection varied because of the geometry of the trail and location of adjacent vegetation. Staged bikers and pedestrians from either direction also had problems consistently locating the cone of detection in order to activate the flashers for speed measurements. In many cases the sensor detected the biker as he or she departed the crossing.

- *Timing of the flashing beacons was erratic.* According to a Cross Alert representative, the timing should be set to allow a pedestrian to cross safely, e.g., 10 seconds. Once the sensor detects motion, the beacons start flashing for a 10-second period; however, the 10 seconds can be reset if another detection is made (e.g., another biker arrives). Likewise, a single slow pedestrian or biker walking his or her bike may actuate the beacons more than once. Accordingly, timing of the flashing can vary. There was a number of instances observed in the field, however, when the beacons continued to flash after a biker had departed the crossing, sometimes up to 48 seconds.

- *There were several instances when a vehicle stopping for a biker in the crossing was almost rear-ended.* This may have been attributable to a general misunderstanding or confusion of whether the motorist or biker/pedestrian has the right of way.

CONCLUSIONS

- Since all the safety enhancements, including the Cross Alert system, were installed prior to initiation of this study effort, there can be no valid conclusions about the effectiveness of the series of safety measures installed at the crossing as no "before" data could be collected.

- There is ample opportunity for bikers and pedestrians to cross Route 5 safely at the designated crossing as both traffic and trail volumes are relatively low.

- The flashing yellow beacons increase motorist awareness of bikers and pedestrians at the crossing as approach speeds were lower when the beacons were flashing than when not flashing.

- The effectiveness of the flashing beacons may be reduced over time because of the erratic nature of the Cross Alert system.

- There is a potential for rear-end collisions as some motorists yield to bikers or pedestrians approaching the crossing.

RECOMMENDATIONS

1. *The Regional Operational Director in VDOT's Southeast Regional Office should immediately investigate the erratic operation of the Cross Alert system at the Virginia Capital's Trail crossing of Route 5 in James City County*. A number of operational problems were observed by the researchers while conducting the evaluation of the system. Specifically, motorists were often confronted with a flashing beacon with no biker or pedestrian in sight, trail users were often not detected by the system, and the beacon's flashing times were inconsistent. Survey respondents also noted operational problems. Twenty percent reported that the flashing lights *never* activated when they approached the crossing, and another 24 percent reported activation *some* of the time. Further details about the problems were described previously.

2. *Regional operations directors in all of VDOT's regional offices should not deploy the Cross Alert system as a safety countermeasure at any other locations in Virginia until the operational problems described in Recommendation 1 are resolved.*

3. *If these operational problems are resolved satisfactorily or are determined to be site specific and thus not applicable at other crossings, regional operations directors in all of VDOT's regional offices should consider the deployment of an activated flashing beacon system as a safety countermeasure at bike and/or pedestrian crossings where a greater than average number of accidents or severe accidents has occurred, including along the Virginia Capital Trail.* The flashing yellow beacons increased motorist awareness of bikers and pedestrians at the crossing as approach speeds were lower when the beacons were flashing than when not flashing. From the biker and pedestrian perspective, results from a limited sample of trail users indicated that 89 percent felt safe or somewhat safe at the crossing and 77 percent felt that the Cross Alert system improved safety. Other specific considerations regarding deployment include the following:

    - *Rural versus urban site.* The study location was in a rural area with a 55 mph speed limit. It is not known if the speed reductions will be as significant in an urban area where the speed limit is lower.

    - *Roadway geometry.* The roadway at the study location was a cross section of a two-lane roadway. It is not known if the speed reductions will be as significant for a different cross section.

    - *Benefit/cost ratios.* The system at the study location represented a significant majority of the costs of the VDOT-installed safety enhancements at the crossing and, since the crossing was new, there was no accident history to evaluate. Accordingly, the benefits and costs listed in Tables 9 and 10 should be reviewed to determine the level of risk acceptable to VDOT.

COSTS AND BENEFITS ASSESSMENT

The research found that the Cross Alert system enhanced safety at the crossing by increasing motorist awareness of pedestrians and bicyclists. This was evidenced by greater motorist speed reductions in general when the beacons were flashing than when not flashing.

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 Cross Alert 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 there will be crashes prevented or avoided with the system installed.

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 all the safety enhancements made at the crossing. These are shown in Table 9; as can be seen,

Table 9. Costs Associated with Capital Trail Crossing of Route 5

Item	Unit Cost ($)	Total Cost ($)	Notes
Cross Alert system		36,401	Includes 2 post-mounted advance warning bicycle crossing ahead signs (W11-1) with a single flashing yellow beacon, an advisory plate "when flashing" and an advisory plate "45 mph"; 2 post-mounted advance warning bicycle crossing ahead signs (W11-1) with a single flashing yellow beacon, an advisory plate "when flashing," a single flashing red beacon, a stop sign, a sensor, and a solar panel; and miscellaneous pavement markings and signs on the trail itself. (All signs and plates are fluorescent yellow-green.)
4 sets of transverse rumble strips	100	400	
2 post-mounted advance warning bicycle crossing ahead signs (W11-1) in fluorescent yellow-green	503	2,006	
2 sets of pavement markings in the travel lane of a bicycle symbol followed by the word "X-ING"	300	600	
Pavement markings at crossing		325	
Total cost		$39,732	

the cost of the Cross Alert system represented about 92 percent of the total costs. Since the purpose of the research was to evaluate the effectiveness of the Cross Alert system, and since it can be assumed that the other enhancements would be installed regardless of its installation, it is appropriate to base the economic analysis on the cost of the Cross Alert system, i.e., $36,401.

Table 10 compares the cost of installing each pilot with the estimated costs of motor vehicle crashes of varying severity.

A benefit/cost (b/c) ratio greater than 1.0 is desirable as it shows that the savings resulting from the benefits of a countermeasure exceeds its costs. Based on the b/c ratios shown in Table 10 it can be said (with two exceptions) that if even one crash is prevented by installing the Cross Alert system, the resulting savings exceed the cost of implementation. In those cases where a fatality or severe injury is prevented, the resulting savings can be sizeable. The exceptions involve crashes that result in a possible injury or property damage only (no injuries).

Table 10. Cost and Benefit Assessment of Installing Cross Alert System

Cost of Cross Alert System	Crash Type[a]	Cost per Crash Type[a] Avoided (Benefit)	Benefit/Cost Ratio
$36,401	Fatality	$3,760,000	103.29
$36,401	Incapacitating Injury	$188,000	5.16
$36,401	Evident Injury	$48,200	1.32
$36,401	Possible Injury	$22,900	0.63
$36,401	Property Damage Only	$6,500	0.18

[a]Source: *Highway Safety Project (HSP) FY2008-09 Application (Rev 05/30/07).* Highway Safety Improvement Program. Virginia Department of Transportation, Richmond, 2007.

This simplistic assessment does not address either the service life of the Cross Alert system or the exposure (number of trail users) during the service life. The following information was obtained from a Cross Alert system representative.[6]

- The battery is the shortest lived element of the system, with an anticipated life of between 5 and 7 years. The system is shipped with a $150 solar specific battery; however, less expensive replacements have been used satisfactorily.

- The LEDs will probably last 15 years or more, with replacement bulbs running $75 for the 12-in LEDs and $50 for the 8-in LEDs.

- The solar panel is warranted for 10 years with an expected life of 15 years or more. Replacement panels are approximately $200.

- The circuit board (replacement cost not provided) should last 15 years or more.

If the circuit board is considered the first major maintenance cost, then a practical service life can be defined as 15 years.

Based on the bicycle counts reported earlier for a couple of weekdays and a weekend in mid-October, and assuming 10 hours of daylight per day, it is calculated that the trail has 350 bikers per week. Further, if it assumed that the trail is used approximately 8 months of the year (mid-March to mid-November), it can then be calculated that about 12,100 bikers use the trail in 1 year. This number is likely to be a low estimate as (1) the available counts were obtained in October and higher recreational usage can be expected in the late spring, summer, and early fall; (2) more than 10 hours of daylight are available in the late spring, summer, and early fall; and (3) usage will grow as the sections of the trail leading to Richmond are opened.

Thus, it can be estimated that during the 15-year practical service life of the Cross Alert system, the Route 5 crossing will be used by a conservative estimate of 181,500 bikers. This usage provides context to the previous statement that if even one crash is prevented by installing the Cross Alert system, then the resulting savings exceed the cost of implementation.

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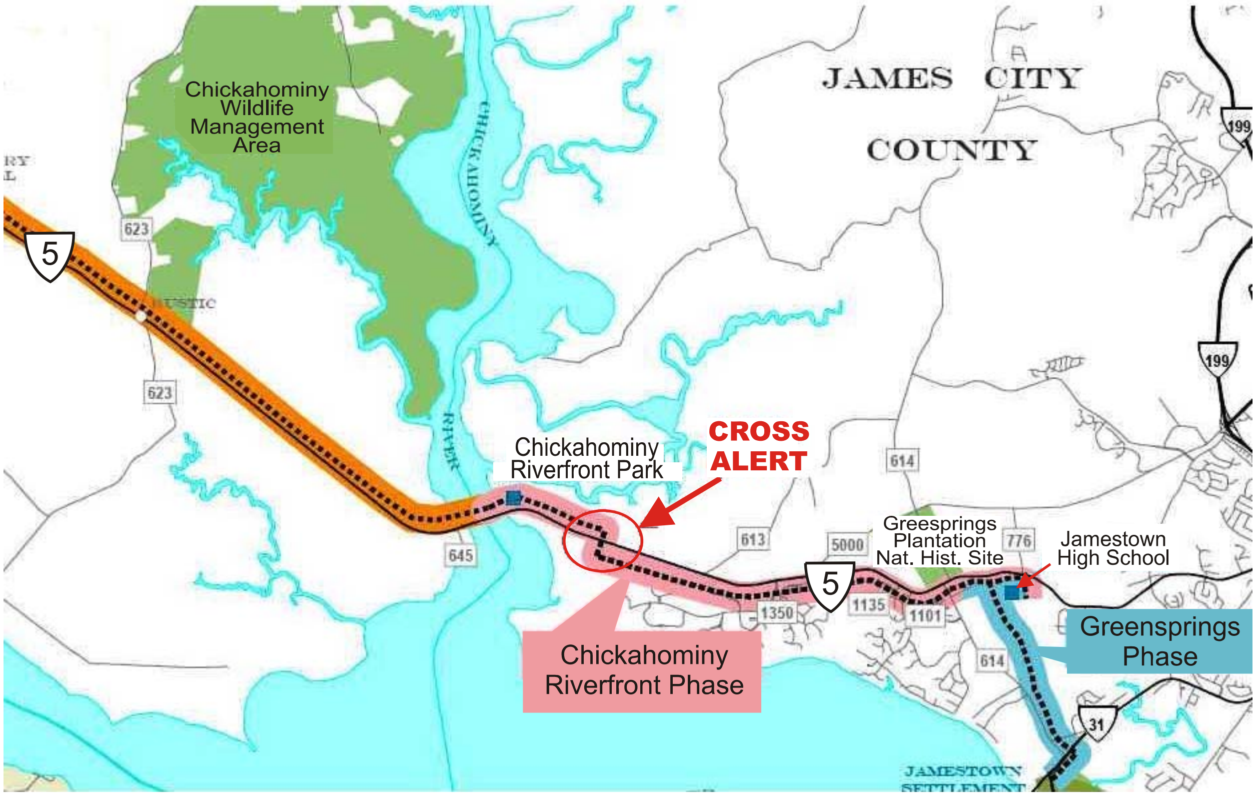
APPENDIX A

Map of Cross Alert Crossing on Route 5



Source: http://www.virginiadot.org/projects/resources/CAPTR121206chopped.pdf.
(Cross Alert system marker was added.)

APPENDIX B

PHOTOGRAPHS OF JAMES CITY COUNTY CROSSING

Figure B1. Capital Trail Users Crossing Route 5

Figure B2. Advance Warning Sign

Figure B3. Route 5 Eastbound Approach to Crossing

Figure B4. Route 5 Westbound Approach to Crossing

Figure B5. Capital Trail Northbound Approach to Route 5

Figure B6. Capital Trail Southbound Approach to Route 5

APPENDIX C

BIKER AND PEDESTRIAN SURVEY ON THE VIRGINIA CAPITAL TRAIL ROUTE 5 CROSSING IN JAMES CITY COUNTY

Have you ever used the Virginia Capital Trail's marked crossing of Route 5 that is just east of the Chickahominy Riverfront Park? If no, please discard this survey. If yes, please continue.

1. Approximately how many times have you used this crossing?
   1 to 5 times   6 to 15 times   More than 15 times

2. When using the crossing, were you   biking or   walking or   both?

3. Typically, did you have to wait to cross?
   Yes   No

4. If you typically had to wait to cross, what was your approximate average wait time?
   Less than ½ minute   ½ minute to 1 minute   More than 1 minute

5. Do you feel this wait time was excessive?
   Yes   No

6. In terms of safety, what was your overall feeling about crossing at this location?
   Safe   Somewhat safe   Not safe

7. In terms of safety, what safety measure do you feel contributed most to the crossing's safety?
   System of flashing red and yellow lights   Rumble strips on Route 5

   Bicycle and Xing markings on the pavement

8. Did the system of flashing red lights on the trail and flashing yellow lights on Route 5 activate as you approached the crossing?
   Yes, most of the times   Yes, some of the times   No, none of the times

9. Did you feel the system of flashing red and yellow lights improved the safety of the crossing?
   Yes   No

10. Who did you feel had the right-of-way at the crossing?
    Motorist (i.e. cars/trucks)   Trail user (i.e. biker/walker)

11. Did you rely on the flashing lights to stop vehicles so you could cross?
    Yes   No

Please provide additional comments you have about the crossing.

APPENDIX D

RAW COUNTS FROM VIDEO

Table D1. Vehicle, Biker, and Pedestrian Counts from Video

Date and Time of Data Collection Period	**10/17/2007 (Wednesday) 10:43 A.M.–12:51 P.M. 2 hr 8 min**	**11/1/2007 (Thursday) 11:32 A.M.–12:58 P.M. 1 hr 26 min**	**11/13/2007 (Tuesday) 11:23 A.M.–2:40 P.M. 3 hr 17 min**
Westbound Volume			
Total vehicles	214	183	364
Number of trucks[a]	44	43	74
Eastbound Volume			
Total vehicles	251	168	365
Number of trucks[a]	50	48	70
Number of Bikers	14	4	7
Number of Walkers	1	0	0
Instances of Vehicles Yielding			
Westbound	2	0	11[b]
Eastbound	0	0	5[b]

[a]Tractor trailers, dump trucks, box trucks, recreational vehicles, vehicles pulling trailers.
[b]All yields were for staged bikers.