EVALUATION OF THE RECTANGULAR RAPID FLASH BEACON AT A PINELLAS TRAIL CROSSING IN ST. PETERSBURG, FLORIDA

William W. Hunter
Senior Research Scientist

Raghavan Srinivasan
Senior Transportation Research Engineer

Carol A. Martell
Senior Applications Specialist

FDOT Contract BA784
Final Report

University of North Carolina
Highway Safety Research Center

October 2009

Technical Report Documentation Page

<table>
<tr><td>1. Report No.</td><td>2. Government Accession No.</td><td>3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Evaluation of the Rectangular Rapid Flash Beacon at a Pinellas Trail Crossing in St. Petersburg, Florida</td><td>5. Report Date
October 2009</td></tr>
<tr><td>6. Performing Organization Code</td></tr>
<tr><td colspan="2">7. Author(s)
William W. Hunter, Raghavan Srinivasan, and Carol A. Martell</td><td>8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Highway Safety Research Center
University of North Carolina
CB# 3430, 730 MLK Blvd.
Chapel Hill, NC 27599-3430</td><td>10. Work Unit No. (TRAIS)</td></tr>
<tr><td>11. Contract or Grant No.
BA784</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Florida Department of Transportation
605 Suwannee Street, MS-30
Tallahassee, FL 32399</td><td>13. Type of Report and Period Covered
Final Report
10/1/05-9/30/08</td></tr>
<tr><td>14. Sponsoring Agency Code</td></tr>
<tr><td colspan="3">15. Supplementary Notes</td></tr>
</table>

16. Abstract

This report is an evaluation of the installation of the rectangular rapid flash beacon (RRFB) where the Pinellas Trail crosses 22nd Avenue N, a busy four-lane, urban street in St. Petersburg, Florida. The unit has two rectangular yellow LED indicators which flash rapidly in a wig-wag sequence. It is solar-powered, radio controlled, and activated by trail users. The experimental design was to collect data of trail users before and after the installation of the RRFB. Videotape data were collected with a camera set up on a stepladder beside the trail and several hundred feet from the actual trail crossing. Supplemental data were also collected on scene by staff from the Neighborhood Transportation section, an office within the city government. From an analysis of the videotape data, trail user delay before starting to cross was reduced after installation of the RRFB. Bicyclists and pedestrians yielded considerably less, and motorists considerably more, after the installation. Overall, motorist yielding increased from 2% before to 35% after. When the flasher was activated, motorist yielding was 54%. In the before period, 82% of the trail users were able to cross all the way across the intersection, while 18% stopped in the middle. In the after period, 94% of the trail users were able to cross all the way across the intersection, while 6% stopped in the middle. Similar results were obtained from the on-scene data. Overall, the installation of the RRFB increased the safety of trail users at the crossing. However, the device is not fail safe, and communities employing the device, especially at trail crossings, should take note of this. Perhaps some additional education effort would be helpful in (1) increasing the percentage of trail users pushing the button, and (2) increasing motorists' knowledge about the requirement to yield to pedestrians in such crossings. Perhaps of more benefit would be periodic police enforcement operations, or the development of a passive system.

<table>
<tr><td colspan="2">17. Key Word
rectangular rapid flash beacon, trail crossing</td><td colspan="2">18. Distribution Statement
No restrictions</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages
30</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

The research was funded by the Florida Department of Transportation (Contract BA784), and the contract manager was Dennis Scott. From the City of St. Petersburg, Mike Frederick, Manager of the Neighborhood Transportation section within the city government; Cheryl Stacks, Bicycle and Pedestrian Coordinator; and Melody Stone, Traffic Engineering Assistant, were extremely helpful in all stages of the project.

EXECUTIVE SUMMARY

This report is an evaluation of the installation of the rectangular rapid flash beacon (RRFB) where the Pinellas Trail crosses 22nd Avenue N, a busy four-lane, urban street in St. Petersburg, Florida. The unit has two rectangular yellow LED indicators which flash rapidly in a wig-wag sequence. It is solar-powered, radio controlled, and activated by trail users. The RRFB had been previously evaluated at 19 uncontrolled pedestrian crosswalks in St. Petersburg, and the system wide average motorist yielding compliance rate improved from less than 1% to 82%. For the current study, it was felt that the RRFB would make the trail crossing safer by increasing the yielding of motorists to trail users. The RRFB system was installed on August 2, 2008 and included beacons and signs on the edge of the roadway and in the median, as well as a push button to activate.

The experimental design was to collect data of trail users before and after the installation of the RRFB. Videotape data were collected with a camera set up on a stepladder beside the trail and several hundred feet from the actual trail crossing. Videotape was collected from both directions of travel, at various times of the day on both weekdays and weekends when it was not raining. Supplemental data were also collected on scene by staff from the Neighborhood Transportation section, an office within the city government, on a form similar to the one used in the earlier evaluations of uncontrolled crosswalks in St. Petersburg.

Four hundred trail users in each of the before and after periods were viewed from the videotape and their interactions with motor vehicles coded. Chi square tests were used to compare the distributions. General findings from the videotape for trail user characteristics and equipment were as follows:

- 82% of the trail users were bicyclists, 13% walkers, 2% skaters, 1% joggers, 0.9% walkers pushing a cart or stroller, 0.6% skateboarders, and 0.4% persons in wheelchairs. Since the vast majority was bicyclists, the remainder of the text will generally refer to non-bike users as pedestrians. The percentage of bicyclists increased from 80% in the before period to nearly 85% in the after period, but the change in the distribution was not statistically significant.
- Female trail users decreased from 32% in the before period to 21% in the after period, and the change in the overall distribution was statistically significant (p.<.001). It is not felt that this change in the distribution was related to the experiment.
- The trail users approached the crosswalk equally from the near or far side relative to the position of the camera in before and after periods - not statistically significant.
- The trail users were going equally northbound or southbound relative to the position of the camera in before and after periods - not statistically significant.
- 91% of the trail users approached the crossing from the trail and 9% from the sidewalk in the before period compared to 93% from the trail and 7% from the sidewalk in the after period – not statistically significant.
- In the before period, 35% of trail users approached alone, 46% with others, and 20% with others nearby. In the after period, 52% of trail users approached alone, 36% with others, and 13% with others nearby. The differences were statistically significant (p<0001). It is not felt that this change in the distribution was related to the experiment.
- In the after period, 32% of the trail users pushed the button to activate the flashing beacons, 49% did not, and for 19% of the trail users the button had already been pushed.
- There were only a handful of cases where the button did not work when pushed. It was discovered that the solar charging equipment was sometimes inadequate to handle the number of trail users pushing the button. A few other problems occurred with the equipment, such as the flashers remaining on for an extended duration.

From an analysis of the videotape data, the following operational results were statistically significant:

- Trail user delay before starting to cross was reduced.
- Bicyclists and pedestrians yielded considerably less, and motorists considerably more, after the installation of the RRFB. Overall, motorist yielding increased from 2% before to 35% after. When the flasher was activated, motorist yielding was 54%.
- The increased yielding by motorists was also reflected in the responses by bicyclists, pedestrians, and motorists when there were interactions.
- In the before period,82% of the trail users were able to cross all the way across the intersection, while 18% stopped in the middle. In the after period, 94% of the trail users were able to cross all the way across the intersection, while 6% stopped in the middle.

Supplemental data collected by an on-scene observer also showed statistically significant findings:

- Trail user delay was reduced.
- Overall, motorist yielding increased from 3% before to 52% after. When the flasher was activated, motorist yielding was 80%.
- In the after period, 95% of the trail users were able to cross all the way across the intersection, while 5% stopped in the middle.

The results pertaining to the trail users being able to cross completely after the installation of the RRFB are particularly gratifying, as this definitely indicates an improvement in safety. The findings for motorist yielding from the on-scene observer tend to closely approximate the findings from the earlier uncontrolled crosswalk studies in St. Petersburg. These earlier studies usually involved a staged crossing, where a pedestrian would place a foot in the crosswalk to set up the interaction with a motorist whose vehicle was outside of the dilemma zone. Florida statutes require motorist yielding when the pedestrian is in the crosswalk. Enforcement operations using police equipped with radios who posed as pedestrians also were used to reinforce that yielding was expected. None of the data gathered in the present study pertained to staged crossings, and no enforcement operations were employed. The videotape set up did not allow a determination of whether motorists were in the dilemma zone when the flasher was activated. Thus, any motorist proceeding through the crossing with the flasher activated was coded as not yielding. This procedure likely accounts for the difference in the motorist yielding rates between the videotape versus the observer results.

Overall, the installation of the RRFB increased the safety of trail users at the crossing. However, the device is not fail safe, and communities employing the device, especially at trail crossings, should take note of this. Perhaps some additional education effort would be helpful in (1) increasing the percentage of trail users pushing the button, and (2) increasing motorists' knowledge about the requirement to yield to pedestrians in such crossings. Perhaps of more benefit would be periodic police enforcement operations.

It has also been learned that the vendor is pursuing the development of a passive RRFB, where the associated radar would be used to detect those desiring to cross and no button would have to be pushed to activate the flashers. Certain situations would have to be worked out, such as approaching bicyclists who are able to cross in the available gap without need of the flashers, as well as some pedestrians who may stop and rest at the crossing and potentially extend the flashers unnecessarily. If such operational situations could be solved, one would expect the motorist yielding rate to increase with a passive device.

This page is intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The City of St. Petersburg is located about halfway down the western side of Florida and lies between Tampa Bay and the Gulf of Mexico. The population is approximately 250,000. Within the city government, the Neighborhood Transportation section, an office within city government, is involved in the planning and implementation of bicycle and pedestrian facilities. The city government should be commended for taking a variety of steps to increase bicycle and pedestrian safety in recent years. These steps follow adoption of the St. Petersburg CityTrails – Bicycle Pedestrian Master Plan in 2003. Improvements have included the installation of bike lanes, a green-colored bike lane weaving area, and upgrading of many uncontrolled pedestrian crosswalks throughout the city. (See Hunter, Srinivasan, and Martell, 2009, and Hunter, Srinivasan, and Martell, 2008, for bicycle-related evaluations.)

One countermeasure used at 19 of the St. Petersburg uncontrolled crosswalks is the rectangular rapid flash beacon (RRFB). The unit has two rectangular yellow LED indicators which flash rapidly in a wig-wag sequence. It is solar-powered, radio controlled, and activated by pedestrians (Figure 1). An evaluation of 18 of these 19 locations had been previously performed, and the system wide average motorist yielding compliance rate improved from less than 1% to 82% (Shurbutt, Van Houten, and Turner, 2008). For the current study, it was decided that the RRFB should be installed and evaluated at a location where the Pinellas Trail, a multi-use facility, crosses 22nd Avenue N, a busy four-lane, urban street with 15,000 vehicles per day, and posted speed limit of 40 mph. Depending on season, the Pinellas Trail has approximately 1,300-2,000 trail users per day. It was felt that this would make the trail crossing safer by increasing the yielding of motorists to trail users.

This study came about as part of a contract between the University of North Carolina Highway Safety Research Center (HSRC) and the Florida Department of Transportation (FDOT). The contract provides funding to evaluate innovative bicycling and pedestrian improvements in the State of Florida.

Figure 1. RRFB at an uncontrolled crosswalk.

LITERATURE REVIEW

The literature seems to be focused on the effects of different signing and marking countermeasures for pedestrians crossing roadways. However, these are relevant to the evaluation of the RRFB at the trail crossing in this study and will be reported.

The problem of pedestrians being struck while crossing the roadway is not new. Zegeer, Opiela, and Cynecki (1985) examined crashes from 15 cities and found that 43% were struck while crossing against the pedestrian signal. Hunter, Stutts, Pein, and Cox (1996) used data from six states to learn that as many as 26% of pedestrian-motor vehicle crashes occur at uncontrolled midblock locations. A more recent study by Zegeer, Stewart, Huang, Lagerway, Fegan, and Campbell (2005) showed that multilane roadways where crosswalks were marked tended to have more pedestrian crashes than comparable roadways without marked crossings. Recommendations indicated that roadways with high motor vehicle traffic volume should not be marked unless additional safety features were provided for pedestrians.

Over time, a variety of signing and marking techniques have been employed to enable safer pedestrian crossings. Huang, Zegeer, and Nassi (2000) evaluated an overhead crossing sign in Seattle, Washington; pedestrian safety cones with the message “State Law: Yield to Pedestrians in Your Half of Road” in New York State and Portland, Oregon; and pedestrian-activated overhead signs with the message “Stop for Pedestrians in Crosswalk” in Tucson, Arizona. The safety cones and the overhead crosswalk sign in Seattle showed promise for pedestrian safety effects on low speed, two-lane roads by increasing yielding by motorists. The pedestrian-activated signs in Tucson showed less promise, perhaps because they were installed on four and six lane arterials with higher speeds.

Hughes, Huang, Zegeer, and Cynecki (2000) evaluated whether automated pedestrian detectors (both infrared and microwave), used along with standard pedestrian push buttons, would reduce crossing against the signal and pedestrian-motor vehicle conflicts. Results showed a significant reduction in both variables.

Huang, Hughes, Zegeer, and Nitzburg (1999) evaluated an in-roadway flashing crosswalk installed in Orlando, Florida in 1997. Small positive effects were shown for increasing motor vehicle yielding to pedestrians, reducing motor vehicle speeds, and reducing pedestrian-motor vehicle conflicts. The device was not very effective in getting pedestrians to use the crosswalk, and interviews showed that many pedestrians did not understand the working of the crosswalk. A few did not know that it was activated in daylight.

Turner, Fitzpatrick, Brewer, and Park (2006) undertook a national study to examine engineering treatments used to enhance pedestrian safety in marked crosswalks. Three categories of devices were studied: (1) red signal or beacon devices, (2) “active when present” devices, and (3) enhanced and high visibility treatments. The red signal or beacon devices included midblock signals, half signals, and high intensity activated crosswalk (HAWK) signal beacons, and these devices showed motorist yielding rates greater than 94% for all study sites, nearly all of which were on arterial streets. Pedestrian crossing flags and in-street crossing signs had 65% and 87% motorist yielding rates, with most of these treatments used on low-volume, two-lane streets. Yielding rates varied by study site, and speed of traffic and number of lanes were factors.

Fitzpatrick and Park (2009) used the empirical Bayes method to perform a before-after safety performance study of HAWK signals. Crash data was obtained for 21 HAWK sites and 71 reference sites. Results indicated that the HAWK signals were associated with a 28% reduction in all crashes and a 58% reduction in pedestrian crashes.

Several studies by Van Houten and others add knowledge to how pedestrians react to various signal systems and/or associated features. One study examined the effects of pedestrian push buttons that give audible and visual feedback (Van Houten, Ellis, Sanda, and Kim, 2006). The data were collected at two intersections in Miami Beach, Florida. Results showed that the push buttons were associated with a statistically significant increase (1) in the percentage of cycles where pedestrians pushed the buttons, and (2) in the percentage of pedestrians who waited for the walk indication. The latter result was also associated with fewer pedestrians trapped in the roadway.

Another Miami-Dade County study (Van Houten, Ellis, and Kim, 2007) examined various minimum green times and the effect on the pedestrians waiting for a midblock walk signal. Data were collected at two intersections, one on an arterial multilane roadway with two-way traffic, and the other a multilane roadway with one-way traffic. The minimum green time varied between 30 and 120 seconds at each location. When the minimum green time was increased, results indicated that (1) the rate of pedestrians complying with the walk signal decreased, and (2) the percentage of pedestrians trapped at the centerline increased. For the location with one-way traffic and a lower average daily traffic, the pedestrian compliance decreased more rapidly as minimum green time increased, most likely due to the ability to more easily find an acceptable gap in traffic.

Both the Huang et al. (2000) and the Turner et al. (2006) studies had shown increased motorist yielding compliance with in-roadway signs. Ellis, Van Houten, and Kim (2007) examined whether placing such signs at the crosswalk or 20 or 40 feet from the crosswalk would alter the effectiveness. Data were collected at three intersections on Collins Avenue, a two-way street with one lane in each direction, parking on both sides of the street, and an average daily traffic of 29,500 in Miami Beach, Florida. All three individual placements of the signs produced a significant increase in motorist yielding, and there were no differences in yielding depending on the sign placement. Using all three signs in combination was no more effective than the use of a single sign at the crosswalk. Significantly fewer pedestrians were trapped in the crosswalk at one of the intersections. Being trapped was rare at the other two locations.

Van Houten, Ellis, and Marmolejo (2008) conducted two experiments in Miami-Dade County, Florida involving the use of standard pedestrian warning signs accompanied with two LED flashers for each sign. The LED flashers were 6 inches wide and 2.5 inches high and configured 9 inches apart. The LED's operated in a wigwag flashing sequence and could be seen front and rear. The signs and flashers were used at multilane crosswalks at two test locations. Four signs with the flashers were used at each crosswalk. Radio transponders were used to link all signs and flashers, so that a call from any of the pedestrian push buttons activated all four signs and flashers. Once the push button was depressed, the pedestrian received an audible message indicating device operation and to wait for motorists to stop before crossing. Staged pedestrians were used in baseline, and yielding was scored once the pedestrian placed at least one foot in the crosswalk. Florida law requires motorists to yield under this condition. Resident pedestrians were scored after baseline. Results showed that motorist yielding increased significantly, from approximately 3% or less yielding in baseline to approximately 65% after the installation of the signs and flashers. The yielding rate was actually a bit higher for local pedestrians, perhaps because they were more assertive in their attempt to cross. Evasive conflicts and the proportion of pedestrians trapped in the center of the roadway also significantly decreased. A second experiment also employed LED white lighting to illuminate the departure curb and the first four feet of the crosswalk at another location. The addition of the LED lighting did not improve the effectiveness of the signs and flashers alone. Observers noted that the pad lighting was difficult to see when the flashers were in operation.

Shurbutt, Van Houten, and Turner (2008) continued with three more experiments of the RRFB's described above in St. Petersburg, Florida. The first experiment basically compared the operation of two sets of RRFB's (at the edge of the roadway) with four sets of beacons (at the edge of roadway and in the median island). Four locations with slightly varying attributes were used. Overall, motorist yielding showed a statistically significant increase from 18% at baseline to 81% with a two-beacon system to 88% with a four-beacon system. Yielding distance also increased, with the percentage of vehicles yielding at greater that 100 feet basically doubling. Passes or attempted passes of vehicles stopped for pedestrians also decreased. In the second experiment a standard round, overhead, yellow flashing beacon and a standard round, side-mounted, yellow beacon were compared with a two-beacon and then a four-beacon flash system at two different locations. Motorist yielding increased from 11% baseline to 16% with overhead standard beacon to 78% with two-beacon flash to 88% four-beacon flash at one location. The differences were comparable but not quite as large at the second location. The motorist yielding distance was not quite as clear cut as in the first experiment, but the percentage of vehicles yielding at greater than 100 feet more than doubled from the two-beacon system to the four-beacon system (5.6% to 12%). The third experiment compared two- or four-beacon systems to baseline at 18 separate locations over time. The average baseline yielding percentage for all 18 sites was 0.88%. The average yielding percentage for all 18 sites was 78% after seven days, 85% after 30 days, and approximately 80% a year later.

The Federal Highway Administration (FHWA) granted Interim Approval for the optional use of Rectangular Rapid Flashing Beacons (RRFB) as warning beacons under certain limited conditions in July 2008 (see http://mutcd.fhwa.dot.gov/resinterim_approvals.htm).

THE EXPERIMENT

The decision had been made by the Neighborhood Transportation section to install a safety treatment at a street crossing with the Pinellas Trail. A consultant examined candidate locations and recommended that a RRFB be installed at 22nd Avenue North and the trail. This was the device previously evaluated at uncontrolled pedestrian crosswalks in St. Petersburg and described in the introduction and literature review. The RRFB system was installed on August 2, 2008 (Figures 2 and 3) and included beacons and signs on the edge of the roadway and in the median, as well as a push button to activate. The vendor was Stop Experts, Inc., and the cost of the system was $26,050.

Figure 2. RRFB at the Pinellas Trail crossing.

Figure 3. Push button configuration at the trail crossing.

A more detailed description of the RRFB is provided below. The description is paraphrased from the various Van Houten studies in the literature:

> The treatment of primary interest in this experiment was two (2) rectangular LED flashing beacons. The LED flashers on the front and back were each six (6) inches wide, 2.5 inches high, and placed nine (9) inches apart. Each unit was dual indicated (LED's on front and back). Each side of the LED beacon flashed in a wig-wag flashing sequence (left light on, then right) - the two LED's in combination flashed 190 times in the wig-wag flashing sequence during a 30 second cycle. Of the two LED's, the left LED flashed two times (in a slower type of a rapid flash) each time it was energized followed by the right LED, which flashed in a very fast rapid three (3) flash volley when energized. Four (4) signs along with beacons were installed at each crosswalk. Radio frequency transmitters linked the devices so a depression of any of the pedestrian call buttons activated the flashers on all four signs. A separate LED facing the pedestrian flashed to indicate to pedestrians that the system was operating. The system also presented an audible message instructing pedestrians that the light flashing across the street indicates that the device was operating, and instructing them to wait for cars to stop before crossing.

The before condition of the trail crossing (Figures 4 and 5) at 22nd Avenue North did not have a median of any kind, and the consultant recommended that a striped, center refuge island be installed due to the numbers of interacting trail users and motor vehicles at the crossing.

Figure 4. View of roadway before RRFB.

Figure 5. View of trail before RRFB.

The experimental design was to collect data of trail users before and after the installation of the RRFB. Videotape data were collected by a staff person from HSRC during several time periods before and after installation. A camera was set up on a stepladder beside the trail and several hundred feet from the actual trail crossing, and videotape was collected from both directions of travel (Figure 6). Data were collected at various times of the day on both weekdays and weekends when it was not raining.

Figure 6. Videotape data set up.

Supplemental data were also collected by staff from the Neighborhood Transportation section on a form similar to the one used in the earlier evaluations of uncontrolled crosswalks in St. Petersburg. The data pertained to pedestrian and bicycle information, yielding compliance, and conflicts.

The actual installation of the RRFB took a long period of time as various procedural matters were agreed to by the city and county. Before videotape data were collected in conjunction with trips made for another study being conducted in St. Petersburg and occurred in September and October of 2006 and October of 2007. The after videotape data were collected in December of 2008. The before data from the Neighborhood Transportation section were collected in June, August, and December of 2007 and May of 2008. The after data were collected in September, October, and November of 2008 and February and June of 2009.

DATA REDUCTION

From the before and after video data, a number of measures of effectiveness and other attributes were coded. The bicycle or pedestrian or other trail user (e.g., skater) was the basic unit of analysis. For each trail user passing across the trail intersection, gender and helmet use (if applicable) were recorded, along with their approach position (vast majority on the trail), direction, some information about the flasher buttons in the after period, and delay to starting across the trail intersection. The vast majority of cyclists approached on the trail, although a few approached from the sidewalks.

The interactions between trail users and passing motor vehicles were also studied. As many as four interactions were coded for each trail user. On some occasions, a trail user proceeded through the intersection without any motorists present. These were coded as no interaction or “none.” When the trail user interacted with motorists at the crossing, an avoidance maneuver, conflict, or no interaction was coded. An avoidance maneuver was defined as a change in speed or direction by either the trail user or motorist to avoid the other (e.g., minor braking by the motor vehicle). A conflict was defined as a *sudden* change in speed or direction by either the trail user or motorist to avoid the other (e.g., major braking by the motor vehicle).

Additional information associated with each interaction was coded. The type of interaction was coded as bicycle-motor vehicle or pedestrian-motor vehicle, depending on the interacting parties. The main dependent variable coded was whether the trail user or motorist yielded to the other. Yielding was defined as slowing or stopping to give way to the other party at the trail crossing. Finally, when an avoidance maneuver or conflict occurred, the responses of the trail user and the motorist were coded. Bicyclist response categories were did not start, kept moving safely, kept moving recklessly, no change, slows or stops pedaling, slight direction change, brakes, major direction change, full stop, or unsure. Other trail user responses (vast majority walkers) were did not start, kept going safely, kept going recklessly, no change, slows, stops walking or running, stops quickly, steps back, jumps out of way, runs, other, or unsure. Motorist response categories were no change, slows, slight direction change, brakes, major direction change, full stop, or unsure.

ANALYSIS AND RESULTS

Videotape Data

Trail Users and Equipment Operation

Four hundred trail users in each of the before and after periods were viewed and their interactions with motor vehicles coded. Chi square tests were used to compare the distributions. General findings from the videotape data for trail user characteristics and equipment were as follows:

- 82% of the trail users were bicyclists, 13% walkers, 2% skaters, 1% joggers, 0.9% walkers pushing a cart or stroller, 0.6% skateboarders, and 0.4% persons in wheelchairs. Since the vast majority was bicyclists, the remainder of the text will generally refer to non-bike users as pedestrians. The percentage of bicyclists increased from 80% in the before period to nearly 85% in the after period, but the change in the distribution was not statistically significant.
- Female trail users decreased from 32% in the before period to 21% in the after period, and the change in the overall distribution was statistically significant ($p<.001$). It is not felt that this change in the distribution was related to the experiment.
- The trail users approached the crosswalk equally from the near or far side relative to the position of the camera in before and after periods - not statistically significant.
- The trail users were going equally northbound or southbound relative to the position of the camera in before and after periods - not statistically significant.
- 91% of the trail users approached the crossing from the trail and 9% from the sidewalk in the before period compared to 93% from the trail and 7% from the sidewalk in the after period – not statistically significant.
- In the before period, 35% of trail users approached alone, 46% with others, and 20% with others nearby. In the after period, 52% of trail users approached alone, 36% with others, and 13% with others nearby. The differences were statistically

significant (p<0001). It is not felt that this change in the distribution was related to the experiment.

- In the after period, 32% of the trail users pushed the button to activate the flashing signals, 49% did not, and for 19% of the trail users the button had already been pushed.
- There were only a handful of cases where the button did not work when pushed. It was discovered that the solar charging equipment was sometimes inadequate to handle the number of trail users pushing the button. A few other problems occurred with the equipment, such as the flashers remaining on for an extended duration.

Trail User Delay

Delay was timed using a stopwatch for those users who stopped at the intersection. Delay began when either the bicyclist or pedestrian stopped for traffic and ended when they started across. This represents the initial start delay and does not include any time spent when the user had to wait in the middle of the intersection. Before the implementation of the RRFB, the average delay for pedestrians and bicyclists was 10.1 seconds with a standard deviation of 15.6 seconds. After the implementation of the RRFB, the average delay was 5.2 seconds with a standard deviation of 6.2 seconds. Thus, the implementation of the RRFB seems to have not only reduced the average delay but also the variation in the delay.

Table 1 shows the delay to trail users before and after installation of the RRFB. Shorter delays from 0-5 and 6-10 seconds increased from before to after, while longer delays were more frequent in the before period. The differences were statistically significant (p<.0001). The longest delay recorded was 89 seconds in the before period. In the after period, there were no delays more than 40 seconds, and these occurred because the trail user chose not to push the button to activate the flashers.

Interactions between Trail Users and Motorists

In the before period, 80% of the interactions were between bicyclists and motorists compared to 83% in the after period. In like fashion, 20% of the interactions were between pedestrians and motorists in the before period compared to 17% in the after period. The differences were not statistically significant.

Table 1. Delay to start of crossing by period.

Delay to start (sec)	Before	After	Total
0-5	220 (55.0) [1]	254 (63.5)	474 (59.3)
6-10	59 (14.8)	79 (19.8)	138 (17.3)
11-20	53 (13.3)	55 (13.8)	108 (13.5)
21-30	28 (7.0)	9 (2.3)	37 (4.6)
31-40	8 (2.0)	3 (0.8)	11 (1.4)
41-50	19 (4.8)	0 (0)	19 (2.4)
51+	13 (3.3)	0 (0)	13 (1.6)
Total	400 (50.0)[2]	400 (50.0)	800 (100.0)

[1]Column percent
[2]Row percent

Yielding Behavior

Table 2 shows the number of times bicyclists, pedestrians, and motorists yielded in the before and after periods while interacting with each other. Only those situations where either the motorist or the bicycle yielded were considered for this analysis. The table includes counts of up to four interactions between a bicyclist and pedestrian with a motorist.

Table 2. Yielding behavior.

Yielder	Before	After	Total
Bicyclist	881 (78.4)[1]	449 (56.4)	1330 (69.3)
Pedestrian	214 (19.0)	69 (8.7)	283 (14.7)
Motorist	26 (2.3)	277 (34.8)	303 (15.8)
Unsure	3 (0.3)	1 (0.1)	4 (0.2)
Total	1124 (58.50)[2]	796 (41.5)	1920 (100.0)

[1]Column percent
[2]Row percent

Bicyclists yielded in 78% of the interactions in the before period and 56% in the after period. Pedestrians yielded in 19% of the interactions in the before period and 9% in the after period. Motorists yielded in 2% of the interactions in the before period and 35% in the after period. Thus, bicyclists and pedestrians yielded considerably less, and motorists considerably more, after the installation of the RRFB. A chi square test revealed the differences to be statistically significant ($p<.0001$).

Table 3 shows the yielding behavior in the after period depending on whether the button was pushed, had already been pushed, or was not pushed to activate the beacon. This table takes into account all the interactions (up to four) between motorists and trail users. Sometimes a motorist would not yield to the trail user when the button was pushed because of their traveling speed. A subsequent motorist might yield. When the button was pushed (yes), bicyclists yielded in 23% of the interactions, motorists in 54%, and pedestrians in 38%. When the button was not pushed (no), bicyclists yielded in 68% of the interactions, motorists in 14%, and pedestrians in 48%. The differences were statistically significant ($p<.0001$).

Table 3. Yielding behavior as a function of whether the button was pushed.

Pushed button	**Yielder**			
	Bicyclist	Motorist	Pedestrian	Total
Already pushed	43 (9.6)[1]	91 (32.7)	10 (14.5)	144 (18.1)
No	304 (67.9)	38 (13.7)	33 (47.8)	375 (47.2)
Yes	101 (22.5)	149 (53.6)	26 (37.7)	276 (34.7)
Total	448 (56.4)[2]	278 (35.0)	69 (8.7)	795 (100.0)

[1]Column percent
[2]Row percent

Avoidance Maneuvers and Conflicts

Interactions and maneuvers were defined as either avoidance maneuvers or the more severe conflicts. Virtually all of the interactions were avoidance maneuvers. There were only two conflicts, and both occurred in the after period. There were no differences in the distributions.

Bicycle and Motor Vehicle Responses while Interacting

Tables 4, 5, and 6 show the bicyclist, pedestrian, and motorist responses during their interaction with each other in the before and after periods. It is clear from Table 4 that bicycles kept moving safely more often and slowed or stopped pedaling less often during the after period. In addition, bicyclists did not start (i.e., yielded) considerably more often in the before period. A chi square test revealed the differences to be statistically significant (p<.0001).

Table 4. Bicycle responses during bicycle-motor vehicle interactions.

Bicyclist response	**Before**	**After**	**Total**
Did not start	575 (64.0)[1]	335 (50.7)	910 (58.4)
Kept moving safely	22 (2.5)	185 (28.0)	207 (13.3)
Slows, stops pedaling	269 (30.0)	120 (18.2)	389 (25.0)
All others	32 (3.6)	21 (3.2)	53 (3.4)
Total	898 (57.6)[2]	661 (42.4)	1559 (100.0)

[1]Column percent
[2]Row percent

Table 5 shows the same tendencies for the pedestrian responses. A chi square test revealed the differences to be statistically significant (p<.0001).

Table 5. Pedestrian responses during pedestrian-motor vehicle interactions.

Pedestrian response	**Before**	**After**	**Total**
Did not start	148 (66.7)[1]	57 (38.8)	205 (55.6)
Kept going safely	38 (17.1)	59 (40.1)	97 (26.3)
Slows	24 (10.8)	2 (1.4)	26 (7.1)
All others	12 (5.4)	29 (19.7)	41 (11.1)
Total	222 (60.2)[2]	147 (39.8)	369 (100.1)

[1]Column percent
[2]Row percent

Table 6 shows that motorists had considerably more full stops and slowing when responding to bicyclists and pedestrians from before to after periods. The motorists had no change (i.e., kept moving without yielding) in 98% of the interactions in the before period and in 64% of the interactions in the after period. A chi square test revealed the differences to be statistically significant (p<.0001).

Table 6. Motorist responses during interactions with bicyclists and pedestrians.

Motorist response	Before	After	Total
Full stop	21 (1.9)[1]	217 (27.3)	238 (12.4)
Major direction change	0 (0.0)	5 (0.6)	5 (0.3)
Slows	5 (0.5)	65 (8.2)	70 (3.7)
No change	1096 (97.7)	508 (63.9)	1604 (83.7)
Total	1122 (58.5)[2]	795 (41.5)	1917 (100.0)

[1]Column percent
[2]Row percent

Complete Crossings versus Stranded in the Middle

Table 7 shows the number of occasions when pedestrians or bicyclists were stranded in the middle of the crossing before and after the implementation of the RRFB. In the before period 82% of the trail users were able to cross all the way across the intersection while 18% stopped in the middle. In the after period 94% of the trail users were able to cross all the way across the intersection while 6% stopped in the middle. These differences were statistically significant ($p<.0001$).

Table 7. Bicyclists or pedestrians stranded in the crossing before and after the implementation of RRFB.

Stranded condition	Before	After	Total
Stranded	71 (17.8)[1]	25 (6.3)	96 (12.0)
Not stranded	329 (82.3)	375 (93.8)	704 (88.0)
Total	400 (50.0)[2]	400 (50.0)	800 (100.0)

[1]Column percent
[2]Row percent

Data Collected by Observer at the Trail Crossing

Several studies by Van Houten and others pertaining to the RRFB at uncontrolled midblock crossings are described in the literature. The data collection procedure was to use an observer to collect data on a form. To supplement the videotape data, this procedure was also used at the trail crossing, with only minor modification of the form necessary. The data were collected by staff from the Neighborhood Transportation section in both the before and after periods.

Trail User Delay

Before the implementation of the RRFB, the average delay for pedestrians and bicyclists was 5.9 seconds with a standard deviation of 9.6 seconds. After the implementation of RRFB, the average delay was 3.1 seconds with a standard deviation of 4.7 seconds. Thus, the implementation of the RRFB seems to have not only reduced the average delay but also reduced the variation in the delay. Table 8 shows the distribution of delay before and after implementation of the RRFB. It is clear that in the after period, a much higher percentage of delay was between 0 and 5 seconds, and a much smaller percentage of delay exceeded 11 seconds. A chi-square test was conducted after combining the last four rows of the table (starting from 11-20 seconds) into one category. The chi-square tests indicated that the differences in the distribution of delay between the two periods was statistically significant ($p = 0.007$).

Table 8: Delay before and after the implementation of RRFB.

Delay category	Before	After	Total
0-5 seconds	133 (70.4%)[1]	185 (80.8%)	318 (76.1)
6-10 seconds	21 (11.1%)	25 (10.9%)	46 (11.0)
11-20 seconds	19 (10.1%)	17 (7.4%)	36 (8.6)
21-30 seconds	9 (4.8%)	1 (0.4%)	10 (2.4)
31-40 seconds	4 (2.1%)	1 (0.4%)	5 (1.2)
41 seconds and higher	3 (1.6%)	0 (0.00%)	3 (0.7)
Total	189 (45.2)[2]	229 (54.8)	418 (100.0)

[1]Column percent
[2]Row percent

Yielding Behavior

In this analysis of yielding data collected by the observer, the behavior of all the motorists that interacted with the pedestrians and bicycles in the before period were included, unlike the analysis of videotape data where only the first four interactions were considered. In the after period, a maximum of four vehicles could be coded as yielding (one in each of the four lanes). Motorists within the dilemma zone were not coded with respect to their yielding behavior. Table 9 shows the number of motorists who yielded and the number of motorists who did not yield at the trail crossing before and after the implementation of the RRFB. Before the implementation of the RRFB, about 3% of motorists yielded to pedestrians and bicyclists waiting to cross or in the process of crossing the trail crossing. After the implementation of the RRFB, about 52% yielded. A chi-square test revealed that this difference was statistically significant ($p < 0.001$). It is important to note that whenever motorists yielded to bicyclists or pedestrians, they yielded at least 30 feet from the trail crossing.

Table 9: Yielding behavior before and after the implementation of RRFB.

Motorist Action	**Before**	**After**	**Total**
Motorists Yielded	10 (2.9%)[1]	169 (51.5%)	179 (26.5)
Motorists did not Yield	337 (97.1%)	159 (48.5%)	496 (73.5)
Total	347 (51.4)[2]	328 (48.6)	675 (100.0)

[1]Column percent
[2]Row percent

After the RRFB was activated, 229 groups of pedestrians and bicyclists used the trail crossing, out of which 83 groups of pedestrians and bicyclists pushed the button (i.e., about 36.2% of pedestrian and bicycle groups pushed the button). The 229 groups of pedestrians and bicyclists included a total of 290 pedestrians and bicyclists, out of which 120 bicyclists and pedestrians either pushed the button or had someone else in the group who pushed the button (i.e., about 41.3% of pedestrians and bicyclists pushed the button or had someone in their group who pushed the button).

Table 10 shows the number and percentage of motorists who yielded to pedestrians and bicyclists depending on whether the button was pushed to activate the RRFB. When the button was pushed, about 80% of motorists yielded. However, when the button was not pushed, only 20% of the motorists yielded. Again, a chi-square test revealed that this difference was statistically significant ($p < 0.001$)

Table 10: Yielding behavior depending on whether the button was pushed.

Motorist Action	**Pushed the Button**	**Did not Push the Button**	**Total**
Motorists Yielded	138 (79.8%)[1]	31 (20.0%)	169 (51.5)
Motorists did not Yield	35 (20.2%)	124 (80.0%)	159 (48.5)
Total	173 (52.7)[2]	155 (47.3)	328 (100.0)

[1]Column percent
[2]Row percent

Complete Crossings versus Stranded in the Middle

Table 11 shows the number of occasions when pedestrians or bicyclists were stranded in the crossing before and after the implementation of the RRFB. Before the implementation of the RRFB, pedestrians and bicyclists were stranded about 21% of the time. After the implementation, they were stranded about 5% of the time. A chi-square test revealed that this difference was statistically significant ($p < 0.001$).

Table 11: Bicyclists or pedestrians stranded in the crossing before and after the implementation of RRFB.

Stranded Condition	Before	After	Total
Stranded	40 (21.2%)[1]	11 (4.8%)	51 (12.2)
Not Stranded	149 (78.8%)	218 (95.2%)	367 (87.8)
Total	189 (45.2)[2]	229 (54.8)	418 (100.0)

[1]Column percent
[2]Row percent

SUMMARY AND DISCUSSION

The installation of the RRFB at the Pinellas Trail crossing with 22 Avenue N was associated with a variety of results. From an analysis of the videotape data, the following operational results were statistically significant:

- Trail user delay before starting to cross was reduced.
- Bicyclists and pedestrians yielded considerably less, and motorists considerably more, after the installation of the RRFB. Overall, motorist yielding increased from 2% before to 35% after. When the flasher was activated, motorist yielding was 54%.
- The increased yielding by motorists was also reflected in the responses by bicyclists, pedestrians, and motorists when there were interactions.
- In the before period, 82% of the trail users were able to cross all the way across the intersection, while 18% stopped in the middle. In the after period, 94% of the trail users were able to cross all the way across the intersection, while 6% stopped in the middle.

Supplemental data collected by an on-scene observer also showed statistically significant findings:

- Trail user delay was reduced.
- Overall, motorist yielding increased from 3% before to 52% after. When the flasher was activated, motorist yielding was 80%.
- In the after period, 95% of the trail users were able to cross all the way across the intersection, while 5% stopped in the middle.

The results pertaining to the trail users being able to cross completely after the installation of the RRFB are particularly gratifying, as this definitely indicates an improvement in safety. The percentage of motorist yielding from the data collected by the on-scene observer are greater than the percentage seen from the videotape data and tend to closely approximate the findings from the earlier uncontrolled crosswalk studies in St. Petersburg. These earlier studies usually involved a staged crossing, where a pedestrian would place a foot in the crosswalk to set up the interaction with a motorist whose vehicle was outside of the dilemma zone. Florida statutes require motorist yielding when the pedestrian is in the crosswalk. Enforcement operations using police equipped with radios who posed as pedestrians also were used to reinforce that yielding was expected. None of the data gathered in the present study pertained to staged crossings, and no enforcement operations were employed. The videotape set up did not allow a determination of whether motorists were in the dilemma zone when the flasher was activated. Thus, any motorist proceeding through the crossing with the flasher activated was coded as not yielding. This procedure likely accounts for the difference in the motorist yielding rates between the videotape versus the observer results.

While motorist yielding improved significantly after installation of the RRFB, an issue from the findings is why the motorist yielding was not greater. One factor is whether the button was pushed to activate the flashers. Based on the videotape analysis in the after period, it is interesting to note that 32% of the trail users pushed the button, 49% did not, and for 19% of the trail users the button had already been pushed. An examination of the on-scene observer after data indicated that many trail users were not pushing the button, and the city installed a sign to see if this would help (Figure 7.) However, not pushing the button remained a problem.

Figure 7. Sign to remind users to push the button.

Viewing the videotapes showed that bicyclists liked to keep their bicycle moving, rather than stopping next to the push button to activate the flasher. Usually a bicyclist approaching the crossing would slow, observe traffic on the street, and determine if the gap was suitable for crossing. Sometimes the bicyclists would ride in a circling fashion until a gap in traffic appeared. However, when there were long lines of traffic, some of the bicyclists would move over to the push button and activate the flasher. Pedestrians were more likely to push the button than bicyclists.

Another factor relating both to delay and motorist yielding was the way the crossing functioned. In times of busy traffic in the before period, a trail user might have to wait for more than 50 motor vehicles to pass before a suitable gap would be available. Thus, motorists seemed to be in the habit of not yielding. Although this event was not coded, it seemed that more multiple threat situations took place in the before period, where a trail user would cross the first lane with a motorist stopped and then encounter a motorist in the adjacent lane not yielding. Sometimes there was considerable delay after the trail user had reached the middle of the crossing. On one occasion a senior pedestrian crossing in a motorized wheelchair reached the middle of the crossing and a motorist did not yield.

When the button was pushed in the after period, the flashers were activated immediately. However, motor vehicles traveling along the street might be close enough to the crossing (i.e., in the dilemma zone) where stopping to yield would be difficult. These vehicles tended to pass through the crossing while the flashers were operational. Sometimes it appeared that trailing motor vehicles would simply “follow the leader,” even though it appeared they had adequate time to stop safely. In many cases it would take 5-10 seconds after the flashers were activated to get motorists to a complete stop, and this is reflected in the delay for the after period. It also appeared that motorists came to recognize that the flasher might be on after trail users had cleared the crossing, and the motorists would proceed on through the crossing without stopping if no users were present. This is a legal maneuver.

Figure 8. Motorists yielding to trail user.

Overall, the installation of the RRFB increased the safety of trail users at the crossing. However, the device is not fail safe, and communities employing the device, especially at trail crossings, should take note of this. Perhaps some additional education effort would be helpful in (1) increasing the percentage of trail users pushing the button, and (2) increasing motorists’ knowledge about the requirement to yield to pedestrians in such crossings. Perhaps of more benefit would be periodic police enforcement operations.

It has also been learned that the vendor is pursuing the development of a passive RRFB, where the associated radar would be used to detect those desiring to cross and no button would have to be pushed to activate the flashers. Certain situations would have to be worked out, such as approaching bicyclists who are able to cross within the available gap without need of the flashers, as well as some pedestrians who may stop and rest at the crossing and potentially extend the flashers unnecessarily. If such operational situations could be solved, one would expect the motorist yielding rate to increase with a passive device.

REFERENCES

CityTrails bicycle pedestrian master plan. (2003). St. Petersburg, FL: City of St. Petersburg.

Ellis, R., Van Houten, R., and Kim, J. (2007). In-roadway "yield to pedestrian" signs: placement distance and motorist yielding. *Transportation Research Record No. 2002,* 84-89.

Fitzpatrick, K. and Park, E. (2009). *Safety effectiveness of the HAWK pedestrian treatment.* Paper presented at the 88th Annual Meeting of the Transportation Research Board, Washington, DC. (Paper #09-1652).

Huang, H.F., Hughes, R.G., Zegeer, C.V., and Nitzburg, M. (1999). *An evaluation of the LightGuard pedestrian crosswalk warning system.* Tallahassee, FL: Florida Department of Transportation.

Huang, H.F., Zegeer, C.V., and Nassi, R. (2000). Effects of innovative traffic signs at unsignalized intersections: three treatments. *Transportation Research Record No. 1705,* 43-52.

Hughes, R.G., Huang, H.F., Zegeer, C.V., and Cynecki, M. (2000). Automated detection of pedestrians in conjunction with standard pedestrian push buttons at signalized intersections. *Transportation Research Record No. 1705*, 32-39.

Hunter, W.W., Srinivasan, R., and Martell, C.A. (2008). *Evaluation of a green bike lane weaving area in St. Petersburg, Florida.* Tallahassee, FL: Florida Department of Transportation.

Hunter, W.W., Srinivasan, R., and Martell, C.A. (2009). *An examination of bicycle counts and speeds associated with the installation of bike lanes in St. Petersburg, Florida.* Tallahassee, FL: Florida Department of Transportation.

Hunter, W.W., Stutts, J.C., Pein, W.E., and Cox., C. (1996). *Pedestrian and bicycle crash types of the early 1990's.* (Report No. FHWA-RD-95-163). McLean, VA: Federal Highway Administration.

Shurbutt, J., Van Houten, R., and Turner, S. (2008). *An analysis of the effects of stutter flash LED beacons to increase yielding to pedestrians using multilane crosswalks.* Paper presented at the 87th Annual Meeting of the Transportation Research Board, Washington, DC. (Paper #08-1406).

Turner, S., Fitzpatrick, K., Brewer, M., and Park, E. (2006). Motorist yielding to pedestrians at unsignalized intersections. *Transportation Research Record 1982,* 1-12.

Van Houten, R., Ellis, R., and Kim, J. (2007). Effects of various minimum green times on percentage of pedestrians waiting for midblock "walk" signal. *Transportation Research Record 2002*, 78-83.

Van Houten, R., Ellis, R., Sanda, J., and Kim, J. (2006). Pedestrian push-button confirmation increases call button usage and compliance. *Transportation Research Record 1982*, 99-103.

Van Houten, R., Ellis, R., and Marmolejo, E. (2008). Stutter-flash light-emitting diode beacons to increase yielding to pedestrians at crosswalks. *Transportation Research Record 2073*, 69-78.

Zegeer, C.V., Opiela, K.S., and Cynecki, M.J. (1985). *Pedestrian signalization alternatives.* (Report FHWA-RD-83-102). Washington, DC: Federal Highway Administration.

Zegeer, C.V., Stewart, J.R., Huang, H.F., Lagerway, P.A., Fegan, J., and Campbell, B.J. (2005). *Safety effects of marked versus unmarked crosswalks at uncontrolled locations: final report and recommended guidelines.* (Report No. HRT-04-100). Washington, DC: Federal Highway Administration.