An Analysis of the Efficacy of Rectangular-shaped Rapid-Flash LED Beacons to Increase Yielding to Pedestrians Using Crosswalks on Multilane Roadways in the City of St. Petersburg, FL.

Dr. Ron Van Houten

&

Dr. J.E. Louis Malenfant

Center for Education and Research in Safety

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EXECUTIVE SUMMARY

This evaluation examined research in St. Petersburg, FL. on the efficacy of the rectangular LED stutter flash beacon and the efficacy of a rectangular side mounted stutter-flash LED beacon system to increase motorist yielding to pedestrians in St. Petersburg, FL. Because the percentage of drivers yielding to pedestrians during baseline was so low in the city of St. Petersburg this evaluation represented a rigorous test of the rectangular stutter flash crossing system. This study reports on the day and nighttime effects of these devices on several roads in the city of St. Petersburg as well as long term citywide follow-up citywide data collected at 18 sites. We also compared the efficacy of the rectangular stutter flash beacon with a standard overhead flashing yellow beacon and a side-mounted standard flashing yellow beacon. The results indicated that the device increased yielding levels from single digit or low levels up to 20% to 30% to between 80 and 90% at most sites, and that yielding levels persisted for up to two years and did not decline over time. At several multilane pedestrians crossings the device produced yielding levels that are equivalent to a traffic signal. No other device without a red indication has produced similar yielding data. It is our recommendation that this system replace the ITS crosswalks in the city crosswalk report. These data are similar to those obtained in the city of Miami, FL. Based on these findings and the relatively low cost of this device we have recommended changes to the installation warrant allowing installation at other sites where it can be beneficial to the community.

INTRODUCTION

Motorists often fail to yield right-of-way to pedestrians in crosswalks. Thus, being a pedestrian can be extremely dangerous. During the three-year period of 2004 through the end of 2006 there were a total of 14,340 pedestrian fatalities and 193,000 pedestrian injuries resulting from pedestrian-automobile crashes nation-wide (National Highway Traffic Safety Administration [NHTSA], 2008). Decreasing the occurrence of these crashes and increasing the incidence of drivers yielding right-of-way to pedestrians would increase both safety and the overall experience of walking. The majority of pedestrian crashes occur at mid-block crossings. Any alternative traffic control device that is not a traffic signal has historically had minimal effect on motorist yielding behavior on multilane roads. Because of the high cost of traffic signals their installation is restricted to intersections with high motor vehicle and pedestrian usage. The traffic signal warrant also limits the application of such devices to high pedestrian volume areas.

One alternative to a traffic signal is the use the ‘High Intensity Activated Crosswalk” (HAWK) signal to assist pedestrians in crossing major streets. The HAWK beacon signal consists of two RED signal indications above a YELLOW signal indication forming a beacon signal that remains dark until activated by a pedestrian. Once activated the signal initiates a flashing yellow indication to warn approaching drivers, followed by a solid yellow identical to a normal signal to warn of impending requirement to stop. The solid yellow is followed by a brief solid red indication, which is followed by a wig wag flashing red signal requiring drivers to stop before proceeding. Although this signal has proven very effective in the city of Tucson, AZ, it is considerably more expensive to install than the relatively inexpensive rectangular stutter flash beacons evaluated in this report.

Turner et al. (2006) evaluated multiple treatments in an effort to increase motorist yielding to pedestrians at uncontrolled crosswalk locations. The Turner study included 11 separate treatments at sites across the country. The treatments included red signal devices (e.g., mid-block signals), active when present devices (e.g., pedestrian crossing flags, in-roadway warning lights and overhead flashing yellow beacon both with push button activation), and enhanced and/or high-visibility devices (e.g., in-street crossing signs, high-visibility signs and median refuge islands). Turner et al. found the most effective treatment for increasing yielding were the red signal devices. The treatment type that was second best, that did not include a red beacon, were the in-street crossing signs (87%) compliance. It should be noted however that these devices were evaluated on smaller two-lane roadways and would not perform as well on larger arterial roadways. The least effect devices were the high visibility signs (17%).

Along with increased yielding compliance it is important to increase yielding distance on multilane roadways, particularly those with high vehicle traffic volumes. When a motorist yields close to the crosswalk on a multilane road they may block the ability of the pedestrian to see approaching traffic (Figures 1) in the lane adjacent to the yielding vehicle as well as blocking the ability of any approaching vehicle to see the crossing pedestrian. Crashes that result from this type of visual screening are referred to as multiple threat crashes (Van Houten et al., 2001). The probability of this occurring greatly increases on multi-lane roadways with a high ADT because as traffic volume increases, the chance that a vehicle will be approaching in a lane adjacent to the one in which a driver is yielding also increases. This increase in probability further stresses the need for yielding at increased distances at multilane crosswalks. With motorists yielding at further distances, the screening effect is reduced thereby decreasing the chance that a motorist may strike a pedestrian.

Van Houten (2001) explains two advantages, other than a decrease in the screening effect, produced by increased yielding distances. One additional advantage is a reduction in the chance of a vehicle approaching from behind the yielding vehicle that attempts to pass and go around the yielding vehicle will not see crossing pedestrian and not be able to stop. Second, there is a decrease in the chance that a yielding vehicle is struck from behind and propelled forward into the pedestrian.

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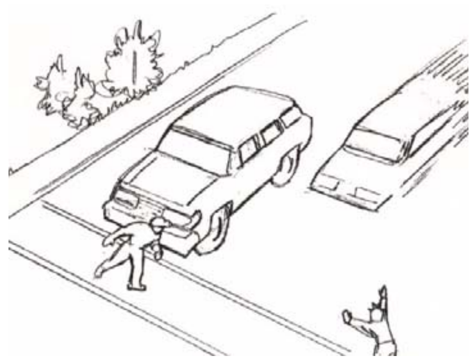
are needed to see this picture.



Figures 1. Multiple threat renderings

One method for increasing yielding distance is in-roadway is the use of advance yield markings and “Yield Here” signs placed in advance to the crosswalk (Figures 2, 5, & 6). Van Houten, R. McCusker, D. Huybers, S., Malenfant, J.E.L., & Rice-Smith, D. (2003) evaluated the separate and combined effects of in-roadway advance yield markings and sign prompts. The advance yield markings consisted of a row of large white triangles made of reflective material that were placed in advance of crosswalks. The sign prompts were “Yield Here to Pedestrian” signs with either a white or yellow-green background. These signs, when evaluated, were placed along side the in-roadway markings. The measures recorded were evasion conflicts and motorist yielding distances. The authors defined evasion conflicts as either the motorist swerving and/or braking abruptly to avoid striking a pedestrian or either the pedestrian running, lunging, and/or jumping to avoid being struck by a vehicle. During baseline, evasion conflicts occurred during 15.5% of the crossings. Either sign decreased evasion conflicts by about 10% when compared to baseline. When the white sign was evaluated along with the roadway markings, evasion conflicts decreased to about 2.5%. Either sign also increased yielding at 3 meters or greater by about 20% over baseline. The white sign and roadway markings combination increased yielding 33% over the baseline condition. In a second experiment, (Huybers, Van Houten & Malenfant, 2004) the authors reversed the order of treatment introduction. In this experiment the in-roadway markings were evaluated alone first followed by the addition of the white signs. The markings alone decreased the average number of conflicts from 17.3% during baseline to 5.4%. The addition of the white sign showed no change in evasion conflicts. The markings also increased those yielding at 6 meters or more from 14.2% during baseline to 51% during treatment. The addition of the white sign to the roadway markings showed little change. Because of the risk of multiple threat signs on multilane roads with a high ADT, advance yield markings should be used whenever crosswalks are marked on such roads. Although advance yield or stop markings can increase the safety of crosswalks on multilane roads, they only produce a small increase in driver yielding.

One inexpensive device to increase yielding rates on multilane roads is the use of pairs of rectangular yellow LED beacons that employ a stutter flash pattern similar to that used on emergency vehicles. This study evaluated the efficacy of the rectangular rapid-flash LED flash beacons (the housing is shown in Figure 2) mounted to pedestrian signs along with advance yield markings during daytime and nighttime operation with and without a median island or pedestrian refuge island (see Figure 3 for a photograph of the beacon system attached to the pedestrian sign).

Figure 2. A picture of the rectangular-shaped rapid flash LED beacon housing.

Figures 3 - A photograph of the rectangular-shaped rapid flash LED beacon system.

EXPERIMENTAL METHOD

Participants and Setting

Participants consisted of drivers traveling on 18 multilane roads in the city of St. Petersburg, Florida. More detailed evaluations were performed at the following locations: 1st Street south of 37th Avenue North; 58th Street south of 3rd Avenue North; 22nd Avenue North @ 7th Street; and 31st Street north 54th Avenue South.

The crosswalk at 1st Street traversed four lanes, had a posted speed limit of 35MPH, and an ADT (Average Daily Traffic Count) of 8,596. This location provided a crossing between two bus stops and included a pedestrian refuge island in the middle of the crosswalk. The 58th St. crosswalk traversed four lanes, had a posted speed limit of 35 MPH, and an ADT of 19,192. It also had a refuge island and provided a crossing for the residents of a near-by retirement center. The 22nd Avenue North crosswalk traversed four lanes, had a posted speed limit of 35 MPH, and an ADT of 18,367. It is equipped with a refuge island and provided crossing for neighborhood residents to and from a large dog park. The 31st St. crossing traversed three lanes at the crossing itself, had a posted speed limit of 35 MPH, and an ADT of 9,600. It had a refuge island and provided crossing between an over-flow parking lot and a large community sports complex. Each of the above sites is on roads carrying two-way traffic. Each site also had a “Yield Here to Pedestrian” advance yielding sign approximately 30 ft. in advance of the crosswalk along with the in-roadway advance yield markings. The data for these four sites will be presented first.

Apparatus

The treatment of primary interest in this experiment was two (2) rectangular LED flashing beacons as shown in Figure 2. 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 comparison device included a pre-existing traditional over-roadway incandescent yellow beacon. This beacon was located at the 58th St. site described above. The system was activated with a pedestrian call button. The standard traditional systems employed two 12-inch diameter yellow beacons facing each direction of traffic. The beacons flashed at a rate of 55 times per minute.

Measures

During each session, data were collected on a sample of 20 pedestrian crossings. These crossings occurred when vehicles were present that could influence crossing behavior. Data were collected during both day and nighttime hours at two of these sites. All data were collected on weekdays when it was not raining. Observers measured the following 6 behaviors: the number of drivers who did and did not yield to pedestrians in crosswalks, the percentage of drivers who yielded at <10ft., 10ft.-20ft., 20ft.-30ft., 30ft.-50ft., 50ft.-70ft., 70ft.-100ft., and >100ft, the number of cars that passed or attempted to pass a stopped/yielding vehicle, and the number of cars that demonstrated a sudden and heavy, use of brakes behind a stopped car.

Driver Yielding to Pedestrians

Observers scored the percentage of motorists yielding and not yielding to pedestrians. A motorist was scored as yielding if he or she stopped or slowed and allowed the pedestrian to cross. A motorist was scored as not yielding if he or she passed in front of the pedestrian but would have been able to stop when the pedestrian arrived at the crosswalk. The ITE signal timing formula was used to determine the duration of the yellow signal phase on traffic lights was used to determine whether a driver could safely stop. Calculating the distance before which a motorist can safely stop for a pedestrian is essentially the same problem as calculating the distance that a motorist can stop for a traffic signal that changes to red. Traffic engineers use the signal-timing formula (Institute of Transportation Engineers, 1985), which takes into account driver reaction time, safe deceleration rate, the posted speed, and the grade of the road. A landmark associated with this distance was identified for vehicle approach to the crosswalk. The landmark at three of the sites was the start of a solid line lane divider painted on the roadway in place of the dashed lane lines (Figure 3). A fourth location was marked with white “X’s” at the threshold point. Motorists who passed this landmark before the pedestrian started to cross could be scored as yielding to pedestrians but not for failing to yield because they may not have sufficient distance to safely stop. Motorists beyond the landmark when the pedestrian entered the crosswalk could be scored as yielding or not yielding because they had sufficient distance to safely stop. When the pedestrian first started to cross, only drivers in the first half of the roadway were scored for yielding (e.g., approaching vehicles). Once the pedestrian reached the median, the yielding behaviors of motorists in the remaining two lanes were scored. This procedure was followed because it conformed to the obligation of motorists specified in the Florida Statutes.

Staged crossings always followed a specific crossing protocol. First, the pedestrian placed one foot in the crosswalk when an approaching vehicle was just beyond the ITE dilemma zone. If the vehicle made no attempt to stop, the pedestrian did not proceed to cross and scored the vehicle as not yielding. If the vehicle clearly began to yield and the next lane was free, the staged pedestrian would begin crossing. The staged pedestrian always stopped just before the lane-dividing line and made sure the next lane was clear before proceeding. If a large gap appeared the staged pedestrian continued crossing to the median island where this protocol was continued until the crossing was complete. This is essentially the protocol followed by police officers when they conduct pedestrian crossing enforcement “sting” operations. This protocol ensures the safety of the staged pedestrians. Residents were only scored if they initiated a crossing in the same manner as the staged pedestrian by placing at least one foot in the crosswalk. Pedestrians that did not place a foot into the crosswalk were not scored because according to the Florida Statutes, drivers are not required to yield unless the pedestrian is in the crosswalk.

Yielding distance

The distances yielding motorists yielded in advance of the crosswalk was recorded. Each yielding motorist generated a yielding distance. The yielding distance was recorded by observing which of several colored flags the motorist yielded behind (see Figure 4).

Figure 4. The yellow arrow marks the dilemma zone calculated using the ITE signal timing formula. This Figure also shows the flags used to judge how far the motorists yielded in advance of the crosswalk.

A series of different colored small utility-like flags were placed along side of the curb in each direction of traffic at the distances of 10ft., 20ft., 30ft., 50ft., 70ft., and 100ft. The colors of the flags were red, orange, yellow, green, blue, and red, respectively. This provided a simplified system for recording the distance motorists yielded in advance of the crosswalk within the following distance categories: <10ft., 10ft.-20ft., 20ft.-30ft., 30ft.-50ft., 50ft.-70ft., 70ft.-100ft., and >100ft. The distance a motorist yielded in advance of the crosswalk was recorded only after the pedestrian had completely cleared the lane, was no longer in the path of the vehicle and, thus, the vehicle posed no threat. Yielding vehicles and their distances were recorded only on the front vehicles in each lane. That is to say that if the first car in each of four lanes yielded, only their yielding, distance, and other data were recorded. No data were recorded on the vehicles stopped behind the front cars due to the fact that it is impossible to discriminate whether the back vehicles stopped in order to yield to a pedestrian, to avoid striking the yielded vehicle in front of it, or both.

Driver passed or attempted to pass stopped vehicle

A driver was recorded as passing a stopped vehicle if they passed a vehicle that was yielding to the pedestrian. A driver was recorded as attempting to pass a stopped vehicle if they did not yield until after they were along side, or past, a yielding vehicle or if the driver behind a yielding vehicle changed lanes to go around but then yielded. This action is an offense under the Florida Statutes.

Car behind yielding car jams on brakes

A car was recorded as jamming on brakes if they were behind a yielding car and the front-end of the car was observed taking a sudden movement toward the ground.

Design of Experiment

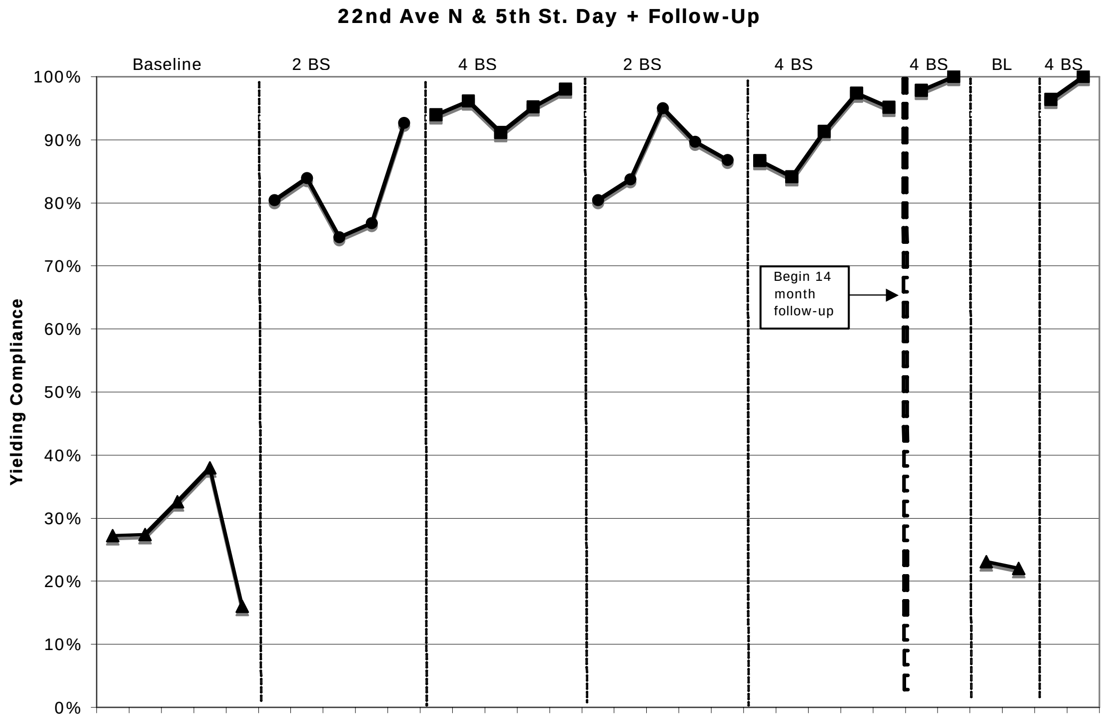
Each session consisted of 20 crossings each. After collecting baseline data on all four roads the rectangular LED beacons were installed in a staggered fashion following a multiple baseline across sites design. The traditional overhead beacon was evaluated prior to the stutter flash beacon at the 58th Street site. Because this treatment only produced a small increase in yielding a return to baseline was not implemented prior to the introduction of the rectangular LED beacon at this site. The rectangular LED beacon was first only installed on each side of the road for a total of two beacon systems per site. Next two additional beacons were added to the pedestrian refuge island for a total of four beacon systems per site. This condition was followed by a return to the two-beacon system followed by the reinstatement of the four-beacon system. Each alternation of two and four systems received five data sheets of observation. This produced a total of 112 data sheets comprised of 2,240 crossings.

Data were also collected at night (after civil twilight) at the 1st Street site. Baseline data were collected for nine (9) data sheets with each alternating phase being collected for five (5) data sheets each. This produced a total of 29 sheets of data and 580 crossings. Night data were collected between the hours of 7:00PM through 11:30PM.

RESULTS

Yielding Right-of-way to Pedestrians.

The percentage drivers yielding right-of-way to pedestrians during each session is presented on the next two pages in Figures 5. At the 22nd Avenue N. at the 5th St. site, the introduction of the rapid-flash beacon produced a marked increase in drivers yielding right-of-way to pedestrians from a baseline level of 28% to a two-beacon treatment level average of 84% and an average of 93% for the four-beacon treatment. Crossing 14 months latter with the beacon was associated with yielding of between 97 and 100% while crossing 14 months latter without the beacon lead to yielding of 23%.



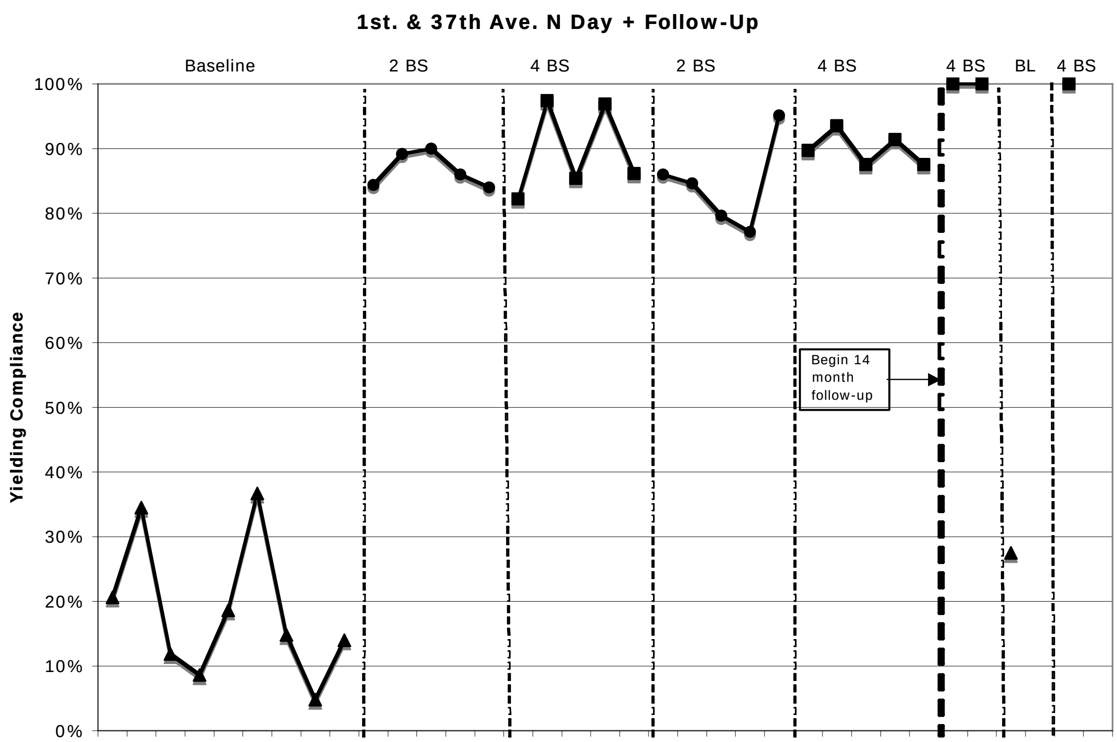
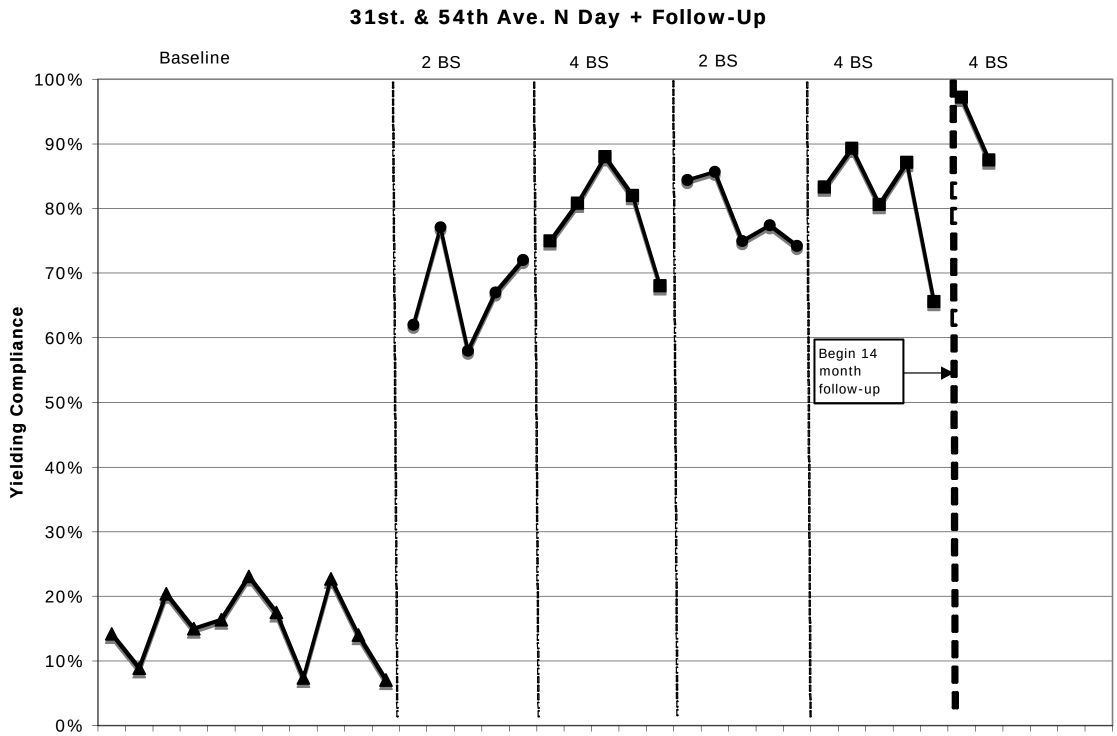


Figure 5 – Yielding Compliance



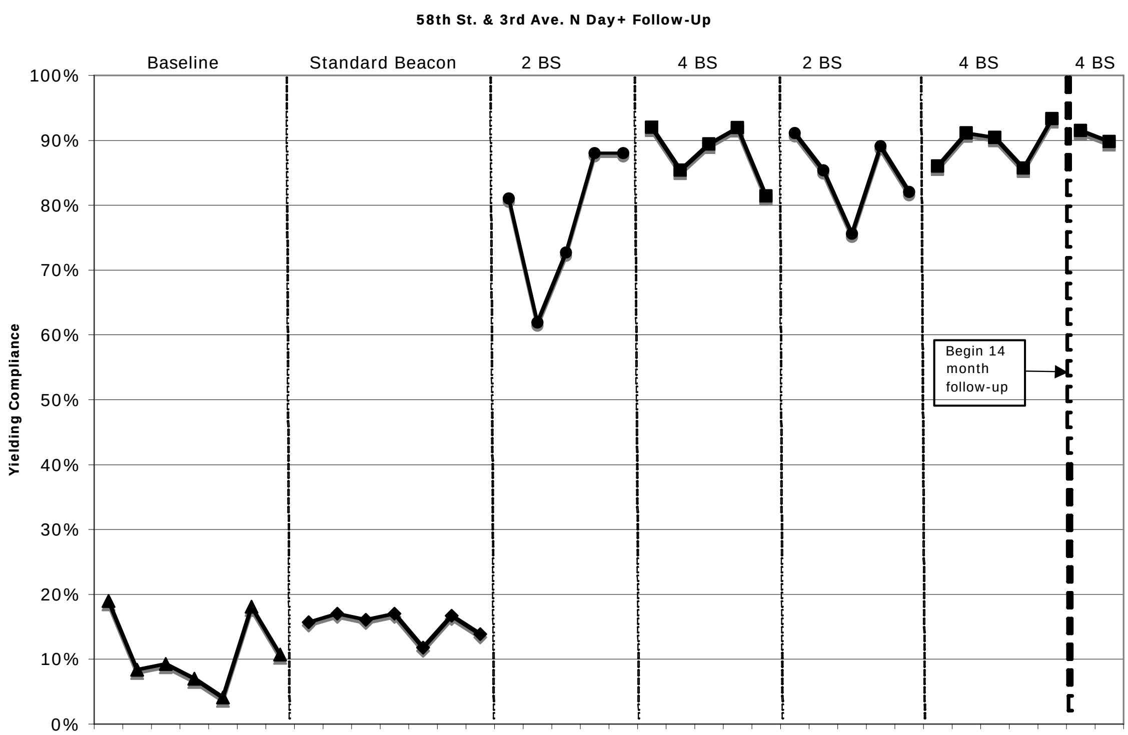


Figure 5 – Yielding Compliance

At the 1st Street at 37th Ave site the introduction of the rapid-flash beacon produced a marked increase in drivers yielding right-of-way to pedestrians from a baseline level of 18% to averages of 86% and 90% for the two- and four-beacon treatments, respectively. Data collected 14 months later was associated with yielding of 100% with the beacon and 27% without the beacon.

At the 31st St. at 54th Ave. South site the introduction of the rapid-flash beacon produced a marked increase in drivers yielding right-of-way to pedestrians from a baseline level 15% to 73% and 80% for the two and four beacons treatments respectively. Data collected 14 months latter with the beacon was associated with 93% yielding.

At the 58th Street site the introduction of the standard overhead beacon produced a small increase in driver yielding to pedestrians from 10.9% to 15.5%. The introduction of the rapid-flash beacon at this site lead to a marked increase in yielding to 81.5% and the introduction of the four beacons system was associated with a further increase to 88.7%. Fourteen-month follow-up data at this site averaged 91%.

Yielding Distance

The majority of yielding across all four sites during each condition occurred between 30ft and 50ft intervals, which is behind the advance yield markings and signs. There were increases in yielding at >30ft. over baseline for the two and four light treatments of 8.3% and 9%, respectively. Yielding at >100ft. more than doubled over baseline for the two-beacon system and showed an even greater increase with the introduction of the four-beacon system. The absence of the standard beacon at the 58th Street location produced a better effect on yielding distance than the standard overhead beacon. There were 48 motorists yielding at less than 30 feet during standard treatment with only 27 during baseline. These numbers are representative of 34% and 33% of the yielding for this that occurred during baseline and standard treatment conditions, respectively. There were also only one more car yielding at >100ft. during the standard beacon treatment, 8 vehicles, when compared to baseline, 7 vehicles.

Driver Passed or Attempted to Pass Stopped Vehicle

During baseline across all four sites, there were a total of 48 passes or attempted passes. There were only 8 of these occurrences during treatment phases, three occurred during the two-beacon treatment and five occurrences during four-beacon treatment. It is also worth noting that at the 58th Street location there were 14 occurrences during the standard beacon treatment but only 10 of these instances recorded during baseline.

Abrupt Braking

There were a total of only five occurrences of a vehicle braking hard behind another vehicle. There were two of these occurrences during the standard beacon treatment at the 58th Street location and three of these occurrences during the two-beacon treatment combined from all sites. There were no reports of hard braking during the four-beacon treatments at any location.

Night Evaluation of Rapid-Flash Devices

Data for nighttime yielding is presented in Figure 6. Baseline yielding compliance at night was 4.8% during nighttime data collection at the 1st at 37th Ave. North location. The introduction of the treatment was associated with an increase in nighttime yielding to 86.7% for the two-beacon system and 99.4% for the four-beacon system. These changes represent increases of 81.9% and 94.46% over baseline levels respectively. Nighttime yielding remained high during the 14 month follow-up.

During baseline conditions, the majority of yielding occurred at the 30ft.-50ft. range (47.1%). The same is true for the two-beacon system and four-beacon system, 31.05% and 35.9%, respectively. During baseline there was no yielding recorded at either the 70ft.-100ft. or >100ft. intervals. However, with system activation there was a large increase in yielding at, or greater than, this distance. During the two-beacon system treatment, 70% of the yielding occurred at or greater than 30 feet. Over 74% of yielding occurred at these distances during the four-beacon treatment. Additional data for this location is provided in Figure 5 on the following page. Although we only have a complete set of night data for one site we have probe data for three other sites that show similar results.

Inter-Observer Agreement.

Inter-observer agreement on the occurrence of a yielding behavior averaged 92% with a range of 80% to 98%. Inter-observer agreement on yielding distance averaged 97.5%. Inter-observer agreement on evasive conflicts was 100%. Inter-observer agreement on whether the pedestrian was trapped in the center of the road averaged 100%; inter-observer agreement on vehicle passes or pass attempt averaged 100%, inter-observer agreement on vehicles that jam on brakes averaged 100%.

Statistical Analysis

The results show average daytime yielding for baseline across all four sites to be 18%, two systems 78%, and four systems 88%. These represent increases of 60% more yielding over baseline for the two-system treatment and a 70% increase from baseline to the four-system treatment. A two-sample t-test for independent (uncorrelated) samples was performed to test the significance between the averages of the reported yielding percentages between the two- and four-beacon systems. The test showed significance at the .05 level (Table 1).

Figure 6. - Nighttime driver yielding compliance for 1st Street location

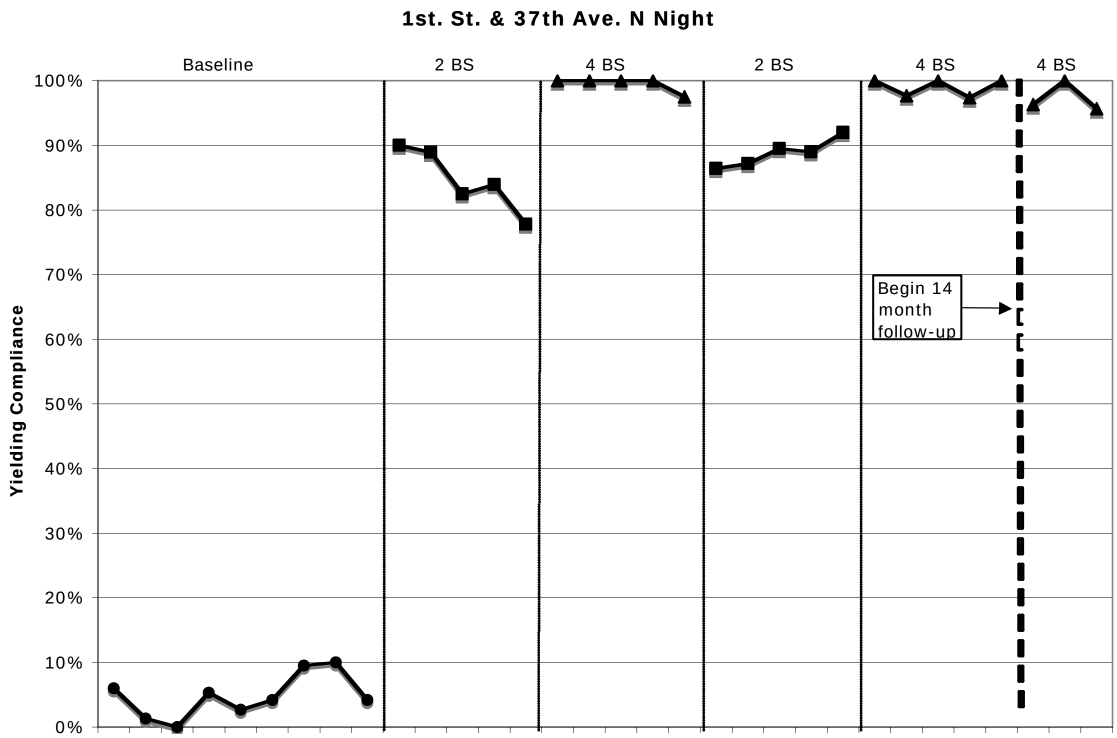


Table 1. Test of significance between two- and four-beacon yielding percentages

Two-sample T-test

	T-Value	P-Value	df
Obtained	|-3.68|	0.008	78
Critical	2		

The daytime combined average yielding of all four sites during baseline are as follows: 0-10ft. = 3.6%; 10ft.-20-ft.= 10.3%; 20ft.-30ft.=16.8%; 30ft.-50ft.=36.6%; 50ft.-70-ft.=14.9%; 70ft.-100ft.=10.6%; and >100ft.=7.2%. Once the two-beacon system treatments were activated, the combined average yielding per distance was: 0-10ft.= 3.1%; 10ft.-20ft.= 7%; 20ft.-30ft.=12.3%; 30ft.-50ft.= 31%; 50ft.-70ft.=17.8%; 70ft.-100ft.=13.7%; >100ft.=15.1%. The combined average yielding distance for the four-beacon was: 0-10ft.= 2.3%; 10ft.-20ft.= 6.2%; 20ft.-30ft.=13.3%; 30ft.-50ft.=31.6%;

50ft.-70ft.=18%; 70ft.-100ft.=11.6%; and >100ft.=17.1%. The total average yielding distances for all four sites (>30ft.) is provided in Table 2.

Table 2. Average yielding distances per condition greater than 30ft.

	30ft-50ft	50ft-70ft	70ft-100ft	>100ft
Baseline	36.60%	14.90%	10.60%	7.20%
2 RF Beacons	31%	17.80%	13.70%	15.10%
4 RF Beacons	31.60%	18%	11.60%	17.10%

COMPARISON WITH OVERHEAD AND SIDE MOUNTED BEACON

Participants and Setting

Participants consisted of drivers traveling on 58th St. N s/of 3rd Avenue and the crossing pedestrians. The location at 58th St. N s/of 3rd Avenue traversed four lanes of traffic, a posted speed limit of 35 MPH and an ADT of 19,192. It also had a median island and provided a crossing for the residents of a near-by retirement center. The second location was at 4th St. S & 18th Avenue. This location was equipped with a side-mounted system. This roadway traversed four lanes, has an ADT of 9,600, and a posted speed of 35 MPH.

Apparatus

The treatment in this experiment was the standard over-head yellow flashing beacon and a standard side-mounted yellow beacon (see Figure 7). These systems are activated with a pedestrian call button. The system employed two 12-inch diameter yellow beacons facing each direction. The beacons were flashed at a rate of 55 times per minute and the illumination period of the beacon was 50 percent of the time.

Experimental Design

An ABCD design was employed at the 58th St. N s/of 3rd Avenue site to measure the efficacy of standard over-head beacons. This design was comprised of collecting baseline data in the absence of activation of the standard system. The system was activated during treatment. Collecting seven data sheets of data comprised of 20 crossings each. Following the standard beacon treatment, a rapid-flash two-beacon system was implemented followed by the four-beacon system. The rapid-flash treatments were repeated. Each rapid-flash treatment was observed for five data sheets each. This gave a total of 680 crossings.

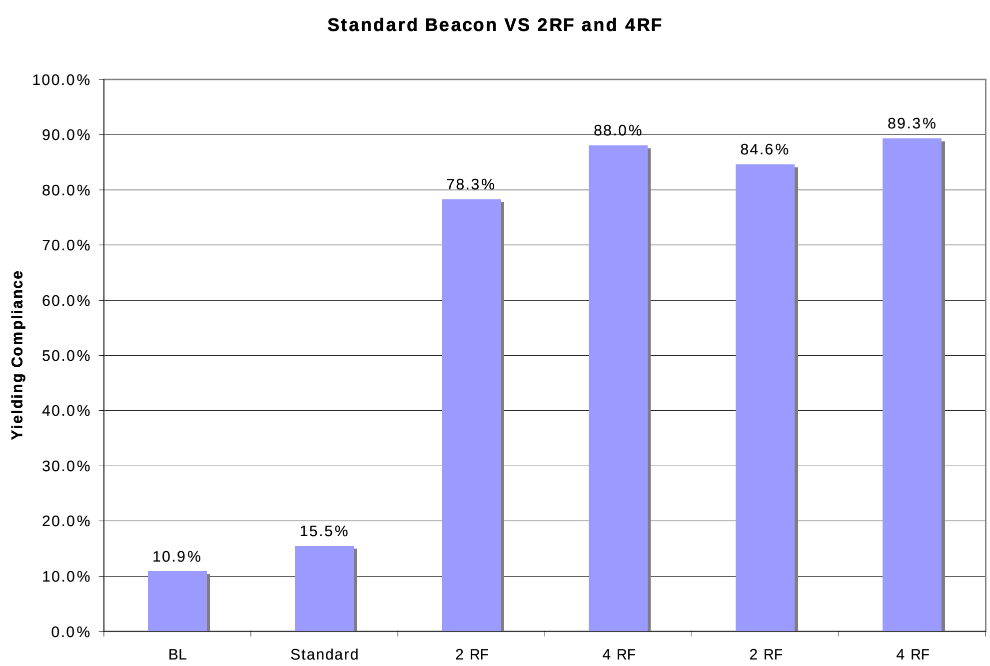
Figure 7 – Standard Over-head and Side-mount Round Flashing Beacons

An ABC design was used at the 4th St. S @ 18th Avenue location. Baseline consisted of 46 crossings. After baseline, a side-mounted standard beacon system was evaluated for 70 crosses at seven and 30-day intervals. Following the B phase of treatment, a two-beacon rapid-flash system was installed and evaluated at the seven and 30-day intervals after rapid-flash installation. The standard and rapid-flash evaluations each consisted of 70 crossings.

Statistical Analysis

Driver Yielding Behavior

The average yielding compliance at the 58th St. N s/of 3rd Avenue site during baseline recording was 10.9%. The activation of the over-head standard beacon produced an average yielding compliance of 15.5%. This is an average increase of only 4.6% above baseline. The introduction of a two-beacon, rapid-flash, system produced an increase in yielding to 78.3%. A four-beacon system followed giving 88% yielding compliance. Reversal back to two beacons yielded 84.6% compliance followed by 89.3% yielding for the second four-beacon system treatment. The average yielding percentage for a two-beacon system was 81.5%. The average yielding compliance for the four-beacon system was 88.7%. With the introduction of a two- and four-beacon system came increases of 70.6% and 77.8% increases over baseline, respectively, and increases of 66% and 73.2% over the standard-beacon efficacy. (See figure 8).



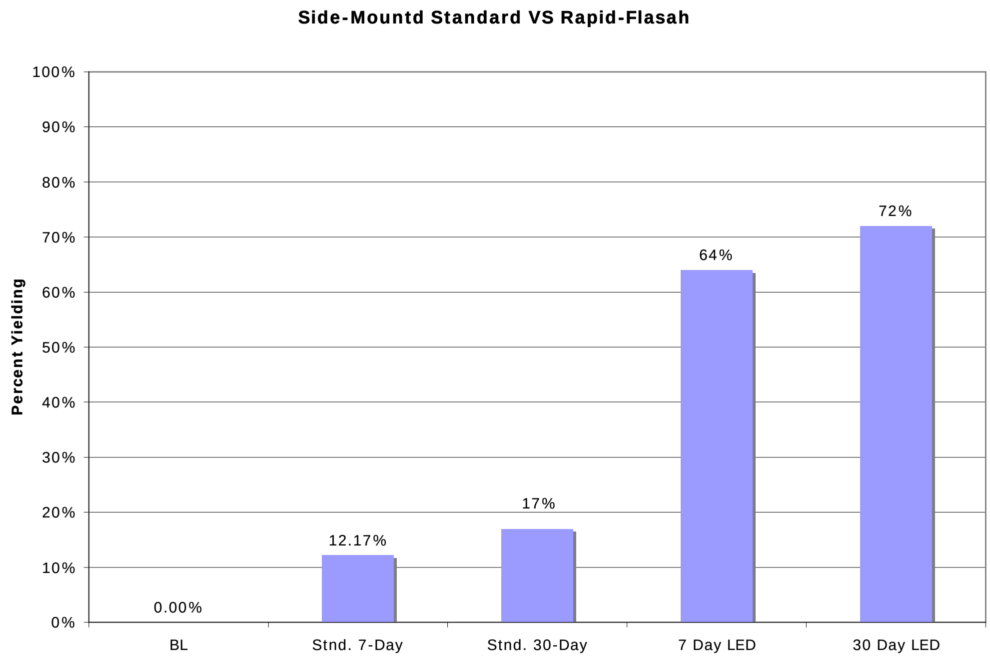


Figure 8 – Yielding Comparison between Standard and Rectangular-shaped

Baseline data at the 4th St. & 18th Avenue site showed a 0.0% yielding compliance. Activating the side-mounted standard beacon produced a 12.2% yielding compliance after seven days. A 30-day analysis of the standard side-mounted system yielded 17% compliance. The rapid-flash produced 63.4% yielding compliance after 7 days and the 30-day analysis showed 72% yielding. The rapid-flash percentages are representative a two-beacon system only. The average yielding percentage for each of the two-beacon analysis is 67.7%. This number is 55.5% more yielding over the 12.2% observed during the standard beacon treatment.

Driver Yielding Distance Behavior (58th St. N s/of 3rd Avenue only)

The absence of the standard beacon actually produced a better effect on yielding distance than during standard overhead beacon. During treatment, light on, a higher percentage (one percent more) of the vehicles yielded at less than 30ft. However, there are more cars yielding during treatment and this produces a larger number of cars that yielding at closer distance than in the absence of the light. There were 48 cars yielding at less than 30 feet during treatment with only 27 during baseline. There were also a smaller percentage of cars yielding at >100ft. during treatment, 5.6%, as opposed to 8.4% of vehicles yielding at >100ft. during baseline. The majority of yielding during both conditions occurred at the same distance, 30ft.-50ft. During baseline, 41% of motorists yielded at this distance and 42.7% during the standard beacon treatment. The majority of yielding during the two-beacon system occurred at the 30ft.-50ft. interval (43.5%). During the four-beacon system, the majority was at the same interval with 41.7%. The percentage of motorists yielding greater than 100ft. more than doubled from the two-beacon system to the four-beacon system with an increase from 5.6% to 12%.

There were no significant results reported for Evasive action: pedestrian/vehicle, Pedestrian trapped in median or Car behind yielding or drivers jamming on brakes.

Inter-observer agreement

Inter-observer agreement on the occurrence of a yielding behavior averaged 92% with a range of 80% to 98%. Inter-observer agreement on evasive conflicts was 100%. Inter-observer agreement on whether the pedestrian was trapped in the center of the road averaged 100%, inter-observer agreement on vehicle passes or pass attempt averaged 100%, inter-observer agreement on vehicles that jammed on brakes averaged 100%, and inter-observer agreement on stopping distance averaged 99%.

DATA FOR ALL 18 SITES

The average yielding data for all sites for the first year are presented below in Figure 9. The data in Figure 9 shows that the device produces sustained yielding behavior over time. It should be noted that because all 18 devices were not installed simultaneously not all data point represent the average data for all 18 sites. The baseline, 7 day, 30 day, 60 day and 90 day data represent data for all 18 sites. The 180 day data only represents data for 17 sites, while the 270 day data represent data for 15 sites, and the 360 day data only represent data for 10 sites. The 730 day data point is only based on the first site to be installed.

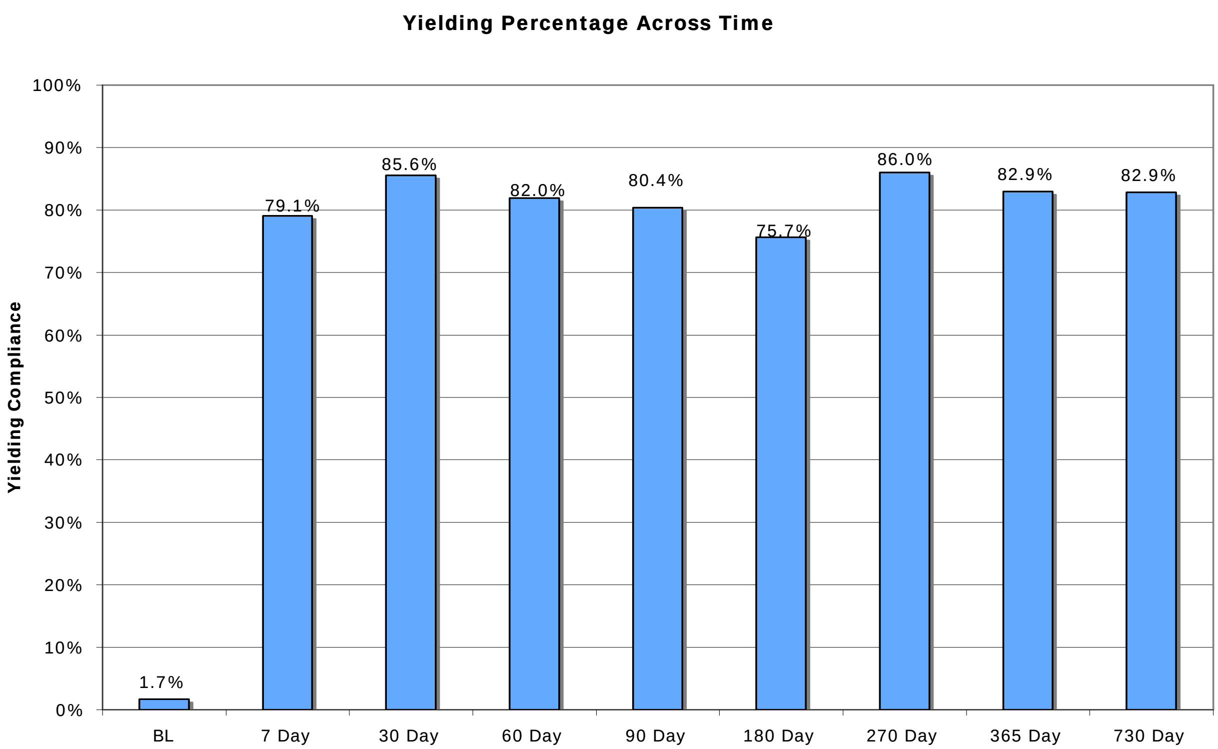


Figure 9 – Effectiveness of the Rectangular-shaped Rapid Flashing LED Beacon

DATA FROM OTHER SITES

To date only Miami Dade County have reported data on the installation of these beacons. This month rectangular stutter flash system was installed in Washington, D.C. and systems will be installed at three sites in Illinois this month. The site in Los Cruses NM has not been evaluated because of construction. We only have baseline and 7 day data for the D.C. site.

The Miami research was particularly important because it studied both staged crossing and crossing by local residents. Baseline levels were similar for both, but the treatment results obtained observing yielding to local residents crossing was somewhat better than the results obtained from staged crossings. These data suggest that the data collected in St. Petersburg might somewhat under represent the magnitude of the effects produced by the rectangular LED stutter flash system. A picture of a Miami site is shown below.

Figure 10 - One of the two installations in Miami Dade County.

The results obtained in Miami were very similar to the results obtained in St. Petersburg in a number of important regards. First, baseline-yielding behavior was as low at the Miami sites as it was at the St. Petersburg sites. Second, the effects of the rectangular stutter flash system were as striking in Miami as they were in St. Petersburg. Third, the night results obtained at both Miami sites were very similar to the night effect size obtained at several St. Petersburg sites. Preliminary data from Washington, D.C. communicated by their local engineer suggest that the device is producing a similar effect in D.C. at 7 days. These data suggest that the device may be expected to work in a similar manner across the U.S. However, additional data are needed to confirm this hypothesis.

DISCUSSION

It is interesting that the average increase in yielding from baseline to a two-beacon system was 18.2% to 81.2%. The introduction of the four-beacon system was also associated with an average increase in yielding to 87.8%. This increase from two to four was found to be statistically significant (Table 1). It may be that these increases from two to four systems are due to the rapid-flash sequences and their visibility to the motorists occupying the inside lanes. That is, the middle lanes in which the motorists are more likely to see the median devices rather than those placed near the curb.

The increase in yielding distances is also an important effect. With motorists yielding at further distances, the chance that a pedestrian may be struck by a motorists due to the inability to see the pedestrian and vice-versa due to a yielding vehicle is greatly reduced. An increase in yielding distance decreases the probability of a multiple threat. The amount of yielding occurring at >100ft. more than doubled over baseline during the four-system treatment. It was often observed that many of the motorists yielded at distances much greater than 100 feet upon activation of the rapid-flash devices. Since the research sites were only marked up to 100 feet, there was not a way to accurately record such distances. It was reported that it sometimes appeared that motorists were yielding at twice the distance as from the crosswalk to the 100ft. flag. This would be distances up to, and possibly in excessive of, 200 feet. It is suggested that this also occurs due to the visibility of the lights at such great distances. These distances were also reported during the two-system treatments, but not as often.

The increases in yielding percentages and the yielding distances are, as should be, associated with a decrease in the number of vehicle passes, or attempts. This may also be due to the fact that, when activated, the signs are visible to all motorists and not only those in the direct field of vision to the pedestrian. However, it may sometimes be the case that a larger vehicle, such as a panel or delivery truck, blocks the view of a driver in a smaller vehicle.

The efficacy of the standard overhead beacon system appears to be minimal at best. There was only a small increase in yielding compliance over baseline with the activation of the standard lighting system. The rapid-flash system was installed and evaluated at the same location. The rapid-flash system produced yielding percentages of 81.5% (two beacon-system) and 88.7% (four beacon-systems). Since these numbers were recorded at the same site with the only differences being the device used, it is assumed that this is due to the rapid-flash system being more visible and in the line-of-site to the motorists, as opposed to being highly elevated.

The strongest data recorded for the effectiveness of the rapid-flash system were the data collected during nighttime observations. These data came closest to approaching a full 100% yielding compliance. During some observation periods, 100% was recorded. In fact, it was recorded during four straight observation periods during four-beacon treatment. That is 80 consecutive street crossings in the presence of automobiles with total yielding compliance. The higher yielding compliance can probably be contributed to the fact that the LED lights become much more visible and salient at night.

The LED lights offer advantages, other than those produced in this study, when used instead of the conventional lighting sources (i.e., halogens or strobes). For one, LED lights require a very small amount of power to operate when compared to other forms of lighting. Second, LED’s can be activated and deactivated very quickly, referred to as their “ramping” speed, within their lighting sequences. This means that there is no carry-over effect from one flash to the other. This eliminates stop motion action and allows for greater conspicuity. Stop motion action is often encountered when one is in the presence of a strobe light.

The Society of Automotive Engineers (SAE) has researched the different uses of ground vehicle LED lighting and their effects for over 20 years. They have suggested that an optimum flash rate is between 60-120 flashes per minutes. This suggested flash rate is an attempt to have the lighting as perceivable as possible. The LED lighting sequence of the rapid-flash systems in this study produced a combined 390 flashes per minute for each set of forward facing lights. Since each set included two light sources flashing in a wigwag pattern, this means that there were actually only 190 flashes per minute, 60 flashes more than suggested by SAE. However, it should be noted that a flashing light is only perceived as being a steady lamp as they approach 1200 flashes per minute. It may be assumed that the separation between the lights allows for a slower perception of the flash rate of each individual light, thus, allowing a slightly higher than recommended flash rate to be effective. However it is also suggested that a study should be conducted with a slower, SAE recommended, flash rate. The Society of Automotive Engineers, in their extensive past, has conducted and concluded on several other properties of lighting and human perception.[1]

It is suggested that a major factor in the increases in yielding compliance is due to the combination of the rapid-flash lights and the signage they are attached to. If the lights were installed alone, the yielding percentages would be expected to decrease. Without a message attached to the lights (pedestrian silhouette), the lights themselves convey no

[1] Blue Advancing-Red Receding phenomenon. At night, the eye perceives high frequencies (blue/violet) as moving towards the observer while lower frequency colors (red) appears to be moving away. This aids in support of amber because there is no confusion of the placement of the lights relative to the automobile's speed. Also, nearly eight (8) percent of males have one of the three most common forms of color blindness while only about .5 percent of females exhibit the same.

useful information. It is often the case with emergency vehicles especially, that too many lights are used with too little direction (i.e., information) and that this may actually be counterproductive (Wells, 2006).

The type of textual prompt associated with the flashing beacons should be analyzed. The message is explainable in that the sign serves as a visual stimulus for, basically, a generic representation of a crossing pedestrian. It can be assumed that the majority of drivers have all had some past exposure and reinforcement history with this type of sign. That is, drivers have learned that the signs are usually placed at pedestrian crosswalks and that yielding occurs at these places. Once the sign is attended to, there are then a set of contingencies that define the desired behavior and possible outcomes. It may be that seeing the sign is then associated with regulations requiring the yielding of motorists to pedestrians. Therefore, the sign may be serving as a rule/law to yield for pedestrians. It should be noted that during the approach some of the drivers are exposed to the “Yield Here…” and “State Law” signs (Figure 2). These signs state the rule. Kudadjie-Gyamfi and Rachlin (2002) state that “When rules signal current contingencies behavior usually adjusts faster to those contingencies than when no rules are provided.” The signs do not directly state any outcome for yielding, or not, this could provide some explanation for lower yielding if the attached pedestrian signage and/or “Yield Here…” signs were removed. There would be no stimulus associated with or explaining what behavior is expected and the desired behavior would eventually be a result of multiple trials. “When provided as information about contingencies, rules work as verbal prompts that abbreviate the time and effort that are required by a full shaping process” (Ribes-Inesta, 2000).

DETERMINING A WARRANT FOR THE RAPID - FLASH SYSTEM

The results of this study clearly demonstrate the rapid-flash pedestrian crossing aids greatly increase driver-yielding behavior, as there were marked increases in yielding above the percentages reported during both baseline and the standard yellow flashing beacon. These are also the highest yielding levels reported for any crosswalk system that does not include a red indication. As a result of these findings, and the reduced cost of this type of system I have adjusted the warrant for the ITS crosswalk in the Pedestrian Crossing Task Order produced for the city of St. Petersburg. Because the cost of the system is a third to a quarter that of competing systems that include a mast arm I have revised the warrant numbers conservatively by half. The revised warrant document is included in Appendix 1.

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Appendix 1

Pedestrian Crosswalk Installation Criteria

Warrant Worksheet for Installation of a Crosswalk at an Uncontrolled Location.

All of the following 5 criteria must be met before marking a crosswalk at an uncontrolled location.

1. Does the pedestrian count exceed 24 pedestrians per hour during any two hours of the day **or** is it used by 12 or more children under 16, seniors, or persons with reduced mobility during any two hours of the day? Yes ___ No ___

2. Are vehicle traffic counts over 300 vehicles per hour during times when most pedestrians are present **or** pedestrian motor vehicle conflicts exceed 5% of crossing when vehicles are present (see Appendix 3), or more than one pedestrian has been struck at that location in the past 10 years. Yes ___ No ___

3. Is the next protected crossing more than 300 ft away. Yes ___ No ___

4. Is the stopping distance for vehicles traveling at the mode speed less than 235 feet? Yes ___ No ___

Note: This distance should be calculated using the signal timing formula. This corresponds to a mean or mode speed of 40 mph with no grade. Crosswalks should not be installed at uncontrolled locations if the stopping distance for vehicles traveling at the mean or mode speed is greater than 234 feet. Options include slowing vehicle speeds through traffic calming measures or speed enforcement.

5. Is the 85th percentile speed less than 45 mph? Yes ___ No ___

Enhancement Installation Criteria

Warrant Worksheet for Installation of an Intelligent Transportation System at a Crosswalk at an Uncontrolled Location.

If any two of the following questions are answered yes the Intelligent Transportation System Crosswalk Installation is warranted. The data and questions are ordered in terms of ease of data collection.

Number or lanes carrying through traffic in each direction.

First direction ______________

Second direction (not relevant if one-way) ______________

1. Does the pedestrian need to cross more than two lanes of traffic? Yes ___ No ___

Daytime ADT (between 8:00 AM and 6: PM) ______________

2. Does the hourly daytime two way traffic volume exceed 400 vehicles per hour? Yes ___ No ___

   Mode vehicle speed ______________

3. Is the mode vehicle speed greater than 35 mph? Yes ___ No ___

Percentage of pedestrians that are involved in a motor vehicle-pedestrian conflict per 100 crossings with vehicles present that involved an evasive action by the driver, the pedestrian or both. ______________

Percentage of pedestrians crossing while vehicles were present who were *trapped* in the center of the roadway for more than 6 seconds. ______________

4. Is the percentage of motor vehicle pedestrians conflicts greater than 2.5% ? Yes ___ No ___

   Is the percentage of pedestrians trapped in the roadway greater than 5%? Yes ___ No ___