

Comparative Evaluation of Flashing Beacon Devices in Santa Monica

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Abstract

The City of Santa Monica is conducting experiments with two new pedestrian warning devices at marked uncontrolled crosswalks. The goal of these new devices is to increase driver awareness at uncontrolled crosswalks and increase crosswalk compliance rates. Both devices are variations on the Rectangular Rapid Flashing Beacon (RRFB). These new devices have been highly successful in other states, and the State of California has approved Santa Monica's request to experiment with these new devices. The new devices will be evaluated over a period of one year at two intersections on Santa Monica Boulevard.

The objective of this experiment is to evaluate the effectiveness of the RRFB, and to evaluate the RRFB versus a circular rapid flashing beacon with 8" round beacons that has been modified with high intensity lights and a rapid flash pattern. The experiment will evaluate vehicle yield response rates at Santa Monica Blvd./Princeton St. before RRFB installation and after. At the intersection of Santa Monica Blvd./Stanford St., the experiment will evaluate vehicle yield response rates after installation of the circular rapid flashing beacon. The experiment will collect data for one year following installation of the two devices, and will include regular reporting of findings.

The experiment is in progress, and this paper will describe the experiment process in greater detail, as well as provide an update on the current results of the experiment.

Introduction

The City of Santa Monica is approximately 11 square miles and has a daytime population of close to 250,000. The City is relatively flat and therefore allows for ease of mobility via bicycle, walking, or automobile. The dense urban nature of the City, combined with high daily volumes of people traveling in various modes creates a need for diverse traffic control measures.

The City deploys various traffic control devices in order to improve pedestrian mobility, from basic signage and markings, to more capital-intensive solutions like curb extensions, bulb-outs, raised medians, offset crossings, and raised intersections. In more recent years, the City has deployed in-roadway warning light (IRWL) systems at 22 locations, utilized advanced flashing beacon systems, and provided signalized mid-block pedestrian crossings in the Downtown and other areas. The installation of traffic signals for pedestrian crossings is very effective in terms of driver yielding response, and is one of the more expensive measures that can be implemented. The IRWL systems have proven to be effective devices to improve pedestrian mobility and increase driver yielding response at pedestrian crossings, at a cost substantially less than the installation of new traffic signals. The major drawback for IRWL systems has been maintenance and upkeep, since all IRWL systems deployed in the City have been found to be susceptible to damage and malfunction. In 2009 and 2010 the City completed an evaluation of the various IRWL systems deployed City wide, and the study concluded that no single device was durable enough to withstand the constant wear and tear associated with being installed in the roadway. The study identified a number of recommended installation techniques and a preferred manufacturer for future IRWL system installations, recognizing that there will be ongoing maintenance costs for any system installed. The City, therefore, is actively looking for

similar devices that can be as effective as the IRWL systems while also provide better long-term performance in terms of maintenance and upkeep.

Background

While undertaking the evaluation of IRWL systems, City staff became aware of the Rectangular Rapid Flashing Beacon (RRFB) through the report titled Increasing Motorist Yielding Compliance at Pedestrian Crosswalks (Frederick and Van Houten). The report indicated that RRFB installations at pedestrian crossings had driver yielding response rates of approximately 82% percent, which was comparable to the yielding response rates of approximately 90% percent found in the City's evaluation of IRWL systems. Therefore, the RRFB was identified as a potential similar device to IRWL systems. Since the RRFB systems are installed on poles on the side of the roadway, the devices likely have much lower maintenance costs compared to IRWL systems. City staff further researched the device and contacted the Federal Highway Administration (FHWA) for more information on the interim approval issued in July 2008.

In September 2008 the California Traffic Control Devices Committee (CTCDC) discussed the RRFB and its potential application in the State of California. The CTCDC had reservations about the system, particularly related to the shape of the beacon and to the fact that the device was initially produced by only one manufacturer. Ultimately the CTCDC did not grant approval for use of the device in California, as they felt at that time additional experimentation was required.

In the fall of 2010, City staff were approached by Spot Devices, Inc. staff who were marketing RRFB devices for sale across the US. Through discussions with Spot Devices staff, the City identified a potential experiment in which two types of rapid flashing beacon systems could be tested and compared. City staff brought this idea to members of the CTCDC, who urged the City to submit a formal request for experimentation. In December 2010, the City officially submitted its request for experimentation to test both a rectangular rapid flashing beacon (RRFB) and circular rapid flashing beacon (CRFB). The request was sponsored by John Fisher, Deputy General Manager of the Los Angeles Department of Transportation and Chairman of the CTCDC at the time. The request for experimentation was discussed at the February 2011 CTCDC meeting. An additional request for experimentation was submitted to FHWA for the testing of the CRFB device. Both the CTCDC and FHWA requests for experimentation were approved in March 2011. The City's Fiscal Year 2011-2012 budget was approved in June 2011 and included funding for the purchase and installation of the new flashing beacon systems. Following the City's official purchasing guidelines, and working with the manufacturer to finalize specific details of both devices, the City received delivery of both devices in October 2011. The devices were installed in November 2011.

Evaluation Locations

The locations for testing the flashing beacons were identified based on the previous evaluation of IRWL systems. The intersection of Santa Monica Boulevard/Princeton Street previously had an IRWL system installed, and this location was included in the City's IRWL evaluation. After the initial evaluation, the City resurfaced Santa Monica Boulevard, and the City used this opportunity to remove the existing IRWL system and prepare the location for the testing of an alternative device.

Both the CTCDC and FHWA approvals for the City's request to experiment with the new flashing beacons provided for one year of device testing. In order to shorten the testing time

frame, the City identified a similar location on Santa Monica Boulevard. With verbal approval from CTCDC members, the City decided to test both devices concurrently at two intersections on Santa Monica Boulevard. Those locations are described in detail below.

Santa Monica Boulevard/Princeton Street



The Santa Monica Boulevard/Princeton Street test site consists of a marked crosswalk on Santa Monica Boulevard across the uncontrolled eastern leg of the intersection. Santa Monica Boulevard is a Principal Arterial. Stop controls are provided on Princeton Street, the minor side street approaches to Santa Monica Boulevard. The intersection is offset, with the segment of Princeton Street south of Santa Monica Boulevard located approximately 30 feet west of the segment to the north.

Lane Geometrics, Width, and Striping – In the vicinity of the test site, Santa Monica

Boulevard has a curb-to-curb width of approximately 68 feet, with five travel lanes (two travel lanes in each direction and a center two-way left turn lane) and two eight-foot parking lanes.

Crossing Enhancements – A high visibility “continental” pattern crosswalk is marked across Santa Monica Boulevard. There are advance “Ped Xing” pavement markings to the east and west of the crossing as well as advance stop bars on both approaches to the crosswalk. On the eastbound approach, the stop bar is located approximately ten feet from the crosswalk. On the westbound approach, due to the offset configuration of the intersection, the stop bar is located approximately 65 feet from the crosswalk. Overhead street lights located on each side of the crosswalk, provide illumination of the crossing at night.

Posted and Prevailing Speeds – The posted speed limit on Santa Monica Boulevard is 30 mph. Observed traffic speeds were considerably higher, in the 35-40 mph range, when traffic streams permitted. The most recent speed survey data indicates the following measured 85th percentile speeds: 32.0 mph eastbound and 31.4 mph westbound.

Sight Distance – Sight distance from the crosswalk was evaluated based on stopping sight distance criteria contained in the Caltrans *Highway Design Manual*, 6th Edition. For the posted 30 mph speed limit, 200 feet is required. Available sight distance for vehicles approaching the crosswalk is adequate in both directions; however, pedestrians standing at the curb waiting to cross the street may be shielded from approaching motorists’ view by parked cars, street signs, and light poles on the eastbound approach. Similarly, on the westbound approach, pedestrians standing at the curb waiting to cross the street may be shielded from motorists’ view by light poles, street trees, and traffic signs.

Traffic Volumes – Traffic counts collected by the City in 2006 indicate Santa Monica Boulevard has an Average Daily Traffic Volume (ADT) of about 28,200 vehicles, with a PM peak hour count of approximately 2,030 vehicles.

Proximity of Existing Traffic Control Devices – Traffic signals are located approximately 725 feet east of the site at Santa Monica Boulevard/Yale Street, and approximately 300 feet west of the site at Santa Monica Boulevard/26th Street.

Adjacent Land Use – Land use in the vicinity of the test site includes strip commercial uses mixed with medium- to high-density multi-family housing developments. Individual land uses include a McDonalds on the southeast corner of the intersection, an auto shop on the northwest corner, auto sales on the northeast corner, and ground floor retail with second story residential on the southwest corner. Steady activity was observed at the automotive site on the northwest corner of the intersection. On several occasions, driveway operations at the site queued into the crosswalk.

Santa Monica Boulevard/Stanford Street

The Santa Monica Boulevard/Stanford Street test site originally consisted of unmarked uncontrolled crosswalks on Santa Monica Boulevard. Santa Monica Boulevard is a Principal Arterial. Stop controls are provided on Stanford Street, the minor side street approaches to Santa Monica Boulevard.

Lane Geometrics, Width, and Striping – In the vicinity of the test site, Santa Monica Boulevard has a curb-to-curb width of approximately 68 feet, with five travel lanes (two travel lanes in each direction and a center two-way left turn lane) and two eight-foot parking lanes.

Crossing Enhancements – A high visibility “continental” pattern crosswalk was installed across Santa Monica Boulevard for the purposes of this experiment. Advance stop bars are provided on both approaches to the crosswalk. On the eastbound approach, the stop bar is located approximately on the adjacent side of the intersection from the crosswalk. On the westbound approach the stop bar is located approximately 10 feet from the crosswalk. Overhead street lights located on each side of the crosswalk, provide illumination of the crossing in the dark.

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Traffic Volumes – Traffic counts collected by the City in 2006 indicate Santa Monica Boulevard has an Average Daily Traffic Volume (ADT) of about 28,200 vehicles, with a PM peak hour count of approximately 2,030 vehicles.

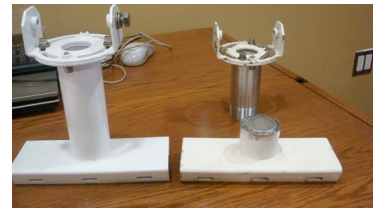
Proximity of Existing Traffic Control Devices – Traffic signals are located approximately 300 feet west of the site at Santa Monica Boulevard/Yale Street, and approximately 725 feet east of the site at Santa Monica Boulevard/Berkeley Street.

Adjacent Land Use – Land use in the vicinity of the test site includes strip commercial uses mixed with medium- to high-density multi-family housing developments. Individual land uses include a medical equipment vendor on the southeast corner of the intersection, a small commercial shopping plaza on the northwest corner, a hotel on the northeast corner, and an automotive sales facility on the southwest corner.

Pre-Deployment Device Preparation

Following delivery of the new devices in October 2011, staff from the City's Traffic Signals Section made a number of modifications to the beacon mounting systems. These modifications were made to ensure that the devices would be fully adjustable once installed on traffic signal poles. The modifications allowed for each beacon device to be adjusted so that the beacons would face the desired path of travel. The modifications were made using available equipment in the Traffic Signal Shop, and were documented for future applications.

The City of Santa Monica made many after-market modifications to the RRFB device as provided by Spot Devices, Inc. The RRFB housings were initially designed to be attached to a pole directly. City staff created modified mounts for the housing using video detection equipment mounts.



The modified mounts are affixed to a standard terminal block, and allow the RRFB housings to be angled towards or away from the roadway, and rotated from top to bottom.

Here is another view of the RRFB housing mounts, showing the adjustable angle of the RRFB. This mounting ensures that once the RRFB is affixed to the pole, the RRFB housing can be angled to point directly at the path of travel of oncoming vehicles.



To the left is an image of the finished modification, with the terminal block holding two RRFB housings, to face each direction of oncoming traffic.

Last is an image of the finished devices mounted to a pole. Once mounted, the fully adjustable mounting allowed for optimal adjustment to aim the flashing beacons at oncoming traffic.



Similar modifications were made to the Circular Rapid Flashing Beacon (CRFB) devices. Each of the circular indications was mounted on standard traffic signal installation housings, and attached to the pole via a terminal block.

The modifications allowed each of the circular indications of the CRFB to be directed towards oncoming traffic.



Deployment

The photos below show the flashing beacon systems as installed. The first photo shows the RRFB at the intersection of Santa Monica Boulevard/Princeton Street, while the second photo shows the CRFB at the intersection of Santa Monica Boulevard/Stanford Street.



Evaluation

Data collection was conducted to determine driver reactions to a pedestrian showing an intention to cross the street. The purpose of the tests was to document behavior exhibited by motorists approaching crosswalks both with and without the R/CRFB in operation to determine if the devices are effective in increasing the awareness of drivers. Data collection for the with R/CRFB conditions began in January 2012 and is scheduled to continue through January 2013.

A team of two technicians was utilized to record the observations with one technician acting as the “staged pedestrian.” To be inconspicuous to motorists during the testing process, the pair wore plain clothes, communicated via hand held radios, and the observer recorded test data from a vantage point outside of the driver’s peripheral vision. Evaluations were performed during weekday conditions only. Five test sessions were performed at each location, including three during daylight hours, one at dusk, and one at night. The day sessions were conducted in the morning between 9:00 AM and 11:00 AM, mid-afternoon between 12:00 PM and 2:00 PM, and late afternoon between 2:30 PM and 4:00 PM. Dusk sessions were recorded during the lighting transition from daytime to nighttime, which typically occurred between 4:30 PM and 6:00 PM. Night sessions were recorded when there was no ambient sunlight, between 6:30 PM and 8:00 PM. Each testing session consisted of a minimum of 40 pedestrian crossings, including 20 observations of traffic in each direction. For each of the 20 directional crossings, testing was further broken down with ten observations recorded with the R/CRFB system on, and ten observations with the R/CRFB system off.

The following behaviors for the primary vehicle (closest vehicle to the crosswalk) were observed and recorded:

- Drivers that yielded or did not yield to pedestrians
- The distance in advance of the crosswalk at which drivers first applied their brakes
- The location at which drivers stopped to yield to pedestrians
- The number of drivers that attempted to pass a stopped or yielding vehicle
- The number of drivers that braked abruptly

Behaviors were also observed for secondary vehicles approaching in the adjacent lane, including whether or not the driver of the secondary vehicle yielded, braked abruptly, and the distance at which this occurred.

Yielding Observations

An approaching motorist was recorded as yielding to a pedestrian if he or she slowed or stopped and allowed the pedestrian to cross. Motorists were recorded as not yielding if he or she passed in front of the pedestrian but would have been able to stop for the pedestrian based on the signal timing parameters published by the Institute of Transportation Engineers (ITE). The ITE formula used to determine the duration of the yellow clearance phase for traffic signals was applied as this formula takes into account driver reaction time, deceleration rates, posted speed limit, and roadway grade in order to determine the distance that is required for a driver to stop safely for a traffic signal that turns red. This concept can similarly be applied to that of a driver yielding to a pedestrian in a crosswalk.

In order to observe yielding distances, measurement markings were applied to the roadway in advance of the test crosswalks. Measurement markings were painted at 50-foot intervals

beginning at the stop bar (referred to as 0 feet) and extending to the distance determined through use of the ITE signal timing formula. The recorded data also included the lane the driver was traveling in. For data collection purposes, the lane closest to the sidewalk was designated as Lane #2, while Lane #1 was closest to the centerline/median. The data collected and used for analysis only refers to the reaction of the driver of the primary vehicle.

Pedestrian crossings were staged utilizing specific protocol to ensure the consistency of collected data. Hand held radios were used by the observer and the acting, or 'staged,' pedestrian to communicate when a vehicle was approaching the dilemma zone threshold, which was demarcated by a line painted across the travel lanes. At the instant the vehicle crossed this mark the staged pedestrian entered the crosswalk and/or activated the system. If other vehicles pulled out of side driveways, maneuvered to make a turn, or if an unforeseen condition occurred that could alter driver behavior, the staged crossing was voided and no data was collected. Once the intersection was cleared and conditions fit the protocol, the team would resume the data collection process. Drivers that entered the dilemma zone under ideal conditions had adequate time to stop safely, so were counted and scored as either yielding or not yielding.

Yielding Distance

Two measurements were recorded for vehicle yielding distances. First, the observer recorded the distance at which drivers reacted to the activated IRWL system and/or the test pedestrian by applying their brakes. Second, the test pedestrian noted the actual distance at which the motorist yielded in advance of the crosswalk. The primary measurement used for this evaluation was the initial breaking reaction by drivers, which demonstrated a response to either the crosswalk warning system or the test pedestrian. While the ultimate distance from the crosswalk at which drivers yielded is meaningful and has safety implications, motorists' initial braking reaction was utilized for this evaluation as the primary distance measure since it is a definitive occurrence compared to the more subjective 'yield' distance.

Driver Passed or Attempted to Pass Stopped Vehicle

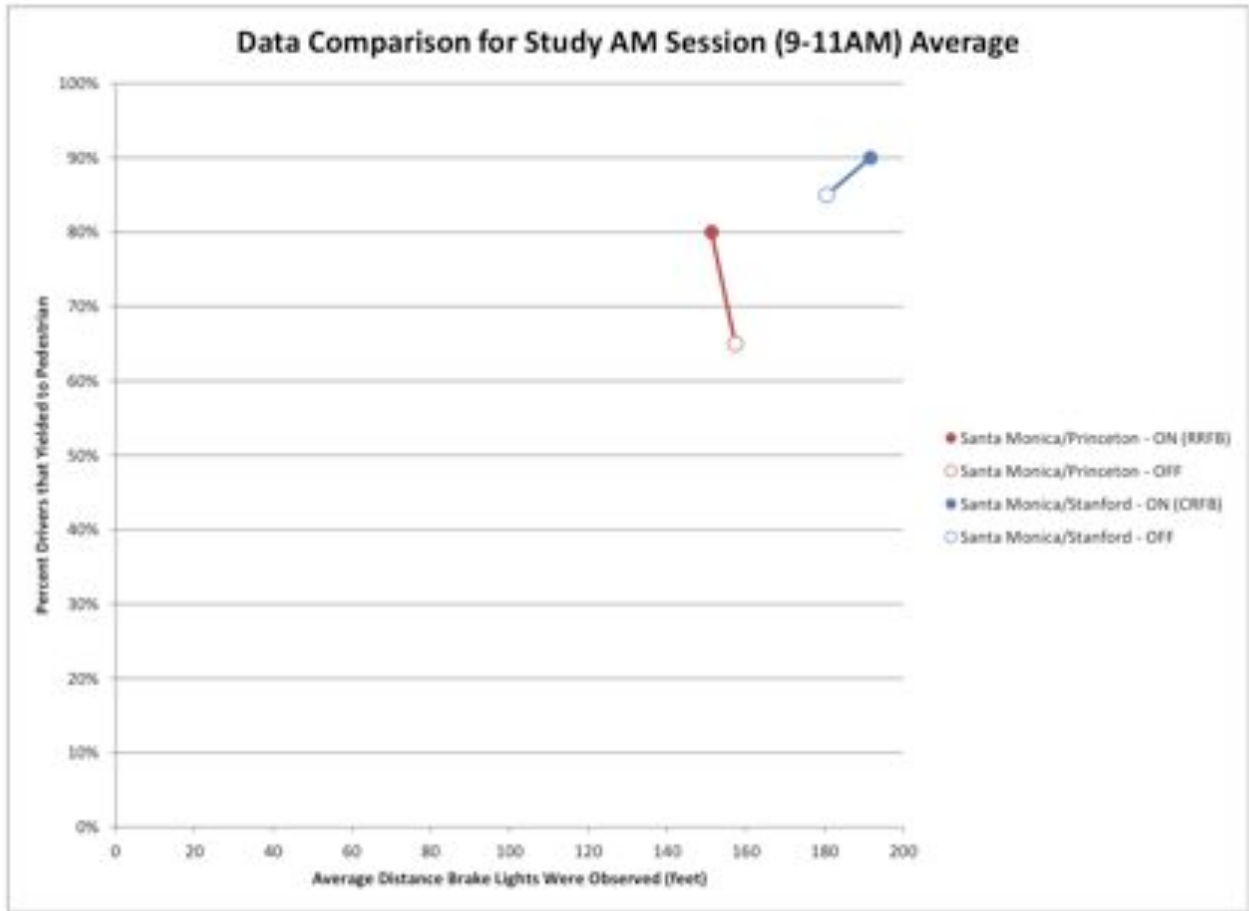
A vehicle was recorded as passing, or attempting to pass, if the driver changed lanes to pass a vehicle that was yielding to a pedestrian in the crosswalk. This action is an offense under the California Vehicle Code which states in Section 21951: "Whenever any vehicle has stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway the driver of any other vehicle approaching from the rear shall not overtake and pass the stopped vehicle."

Sudden Braking

A driver was recorded as braking suddenly if the front-end of the vehicle was observed dipping sharply toward the ground.

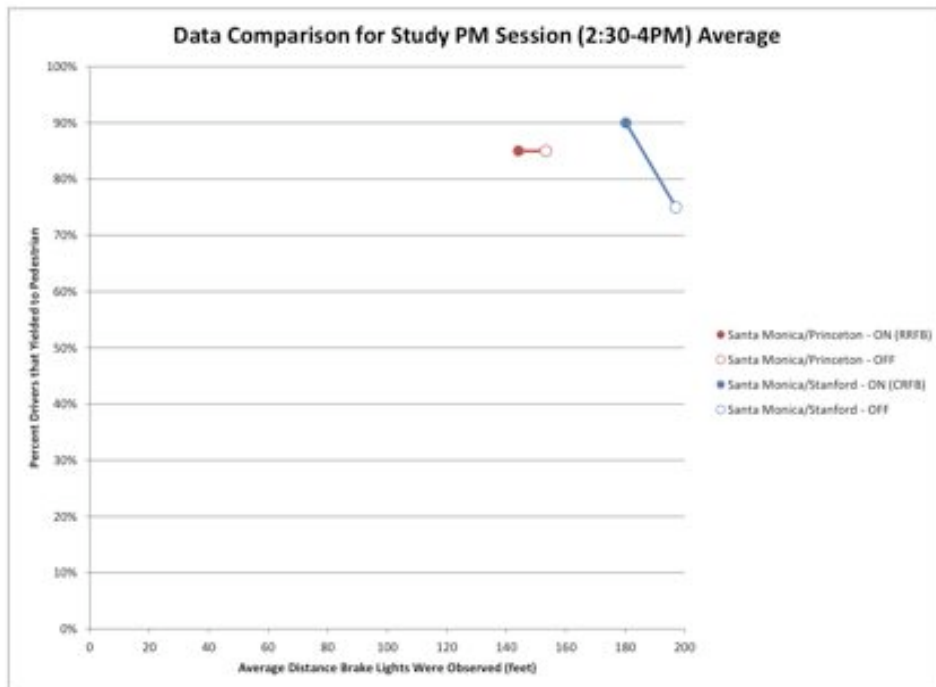
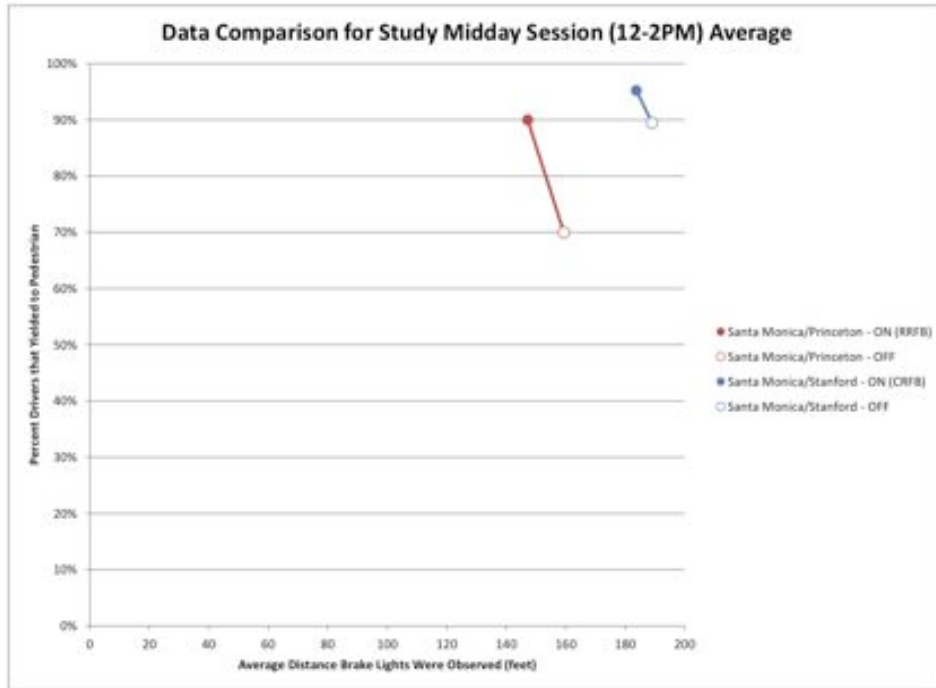
Initial Evaluation Findings

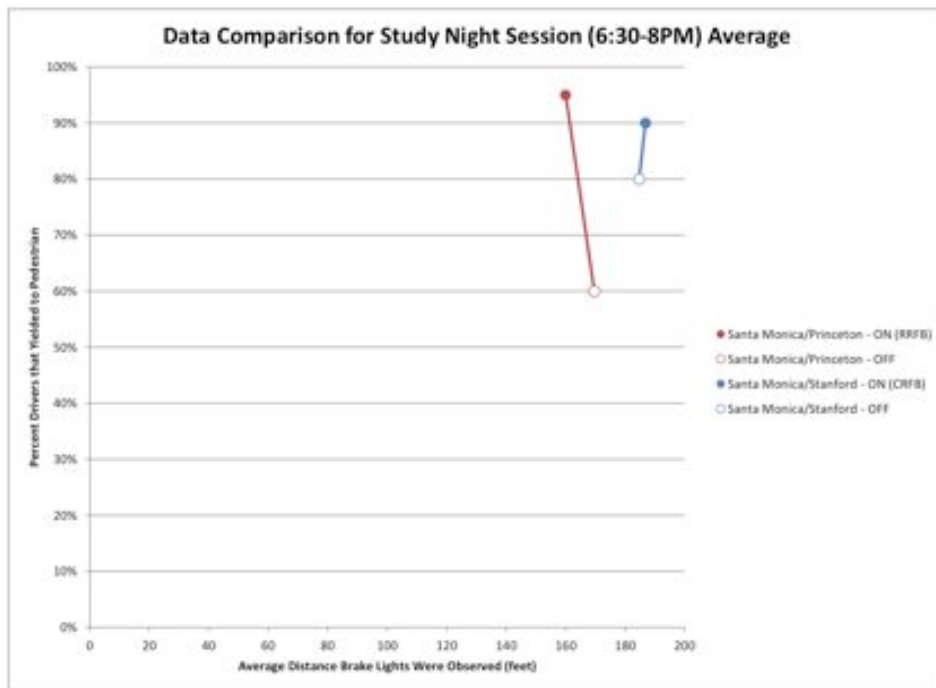
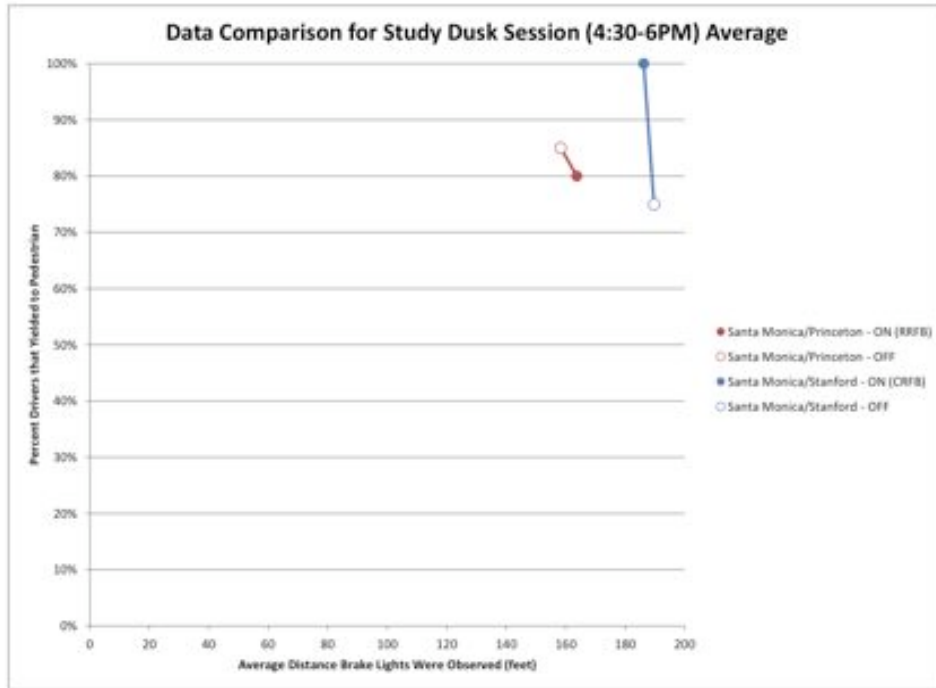
The first of the planned evaluations occurred in January 2012. The chart below shows the results of the morning evaluation for both the RRFB at Santa Monica Boulevard/Princeton Street and the CRFB at Santa Monica Boulevard/Stanford Street. On the chart, the solid dots represent driver yielding response rates when the flashing beacon is activated, while the unfilled dots represent driver yielding response when the flashing beacon is inactive.



As shown in the figure above, driver yielding responses when the devices were inactive were approximately 65% and approximately 85% at the intersections on Santa Monica Boulevard with Princeton and Stanford Streets, respectively. When the beacons were activated, the RRFB increased driver yielding responses by about 15%, to approximately 80%, while the CRFB increased driver yielding response by about 5%, to approximately 90%.

Similar results were found during the other evaluation periods. The charts for midday, afternoon, dusk, and nighttime evaluations are presented on the following pages below.





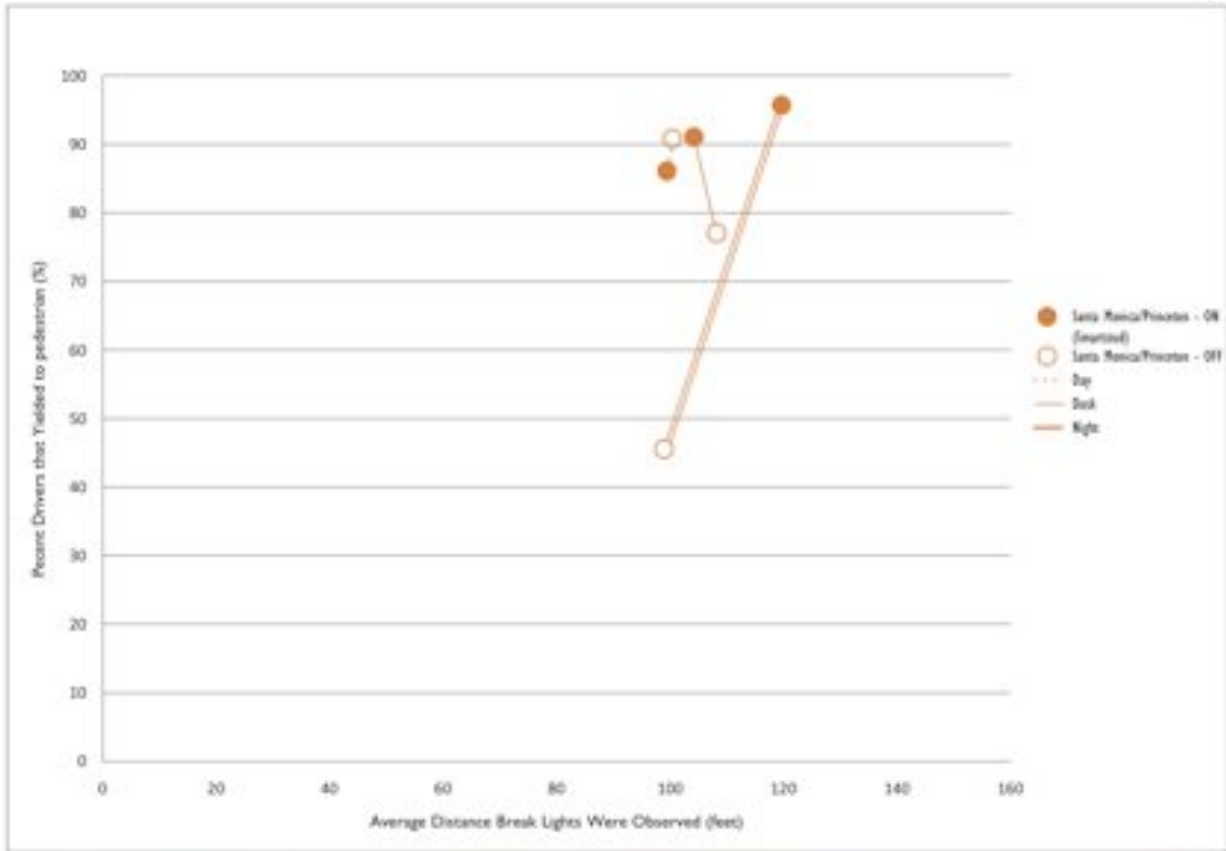
In general both devices showed increases in driver yielding response rates when activated, except in one situation. The table below presents a summary of the changes to driver yielding response rates when the devices are activated.

Location:		Santa Monica/Princeton	Santa Monica/Stanford
Device:		RRFB	CRFB
Time of Day	State of Operation	Yielding Response (Approx.)	
AM	Off	65%	85%
	On	80%	90%
	Change	+15%	+5%
Midday	Off	70%	90%
	On	90%	95%
	Change	+20%	+5%
PM	Off	85%	75%
	On	85%	90%
	Change	0%	+15%
Dusk	Off	85%	75%
	On	80%	100%
	Change	-5%	+25%
Night	Off	60%	80%
	On	95%	90%
	Change	+35%	+10%

From the field evaluations, it is unclear what caused the decrease in driver yielding response rates for the RRFB during the dusk evaluation. The detailed evaluation data shows that the decrease in yielding response rates occurred only in the westbound direction on Santa Monica Boulevard, and the eastbound direction actually showed no change in yielding response rates whether the RRFB was activated or not (90% for both states of operation). Therefore, it is the opinion of the author that glare from the sunset at dusk was perhaps a factor in the reduction in driver yielding responses. Further testing will be conducted to determine if this is a factor.

It is interesting to observe that yielding response rates are generally higher at the intersection of Santa Monica Boulevard/Stanford Street than at the intersection of Santa Monica Boulevard/Princeton Street. This may be due in part to the sidewalk width near Princeton Street and the adjacent land uses. Although both locations are similar in cross-sectional roadway width, traffic volumes, and proximate traffic signals, the intersection with Princeton Street has a proximate signal to the west while the intersection with Stanford Street has a proximate signal to the east. Traffic flows are generally higher in the westbound direction, particularly during the afternoons, and this results in substantial queues of traffic backing up into the intersection with Princeton Street. These factors – sidewalk width and heavy traffic volumes – may cause a reduced ability for motorists to see pedestrians attempting to use the crossing. Further testing will be conducted to determine if this is a factor.

For comparison, the chart below shows a summary of the evaluation results for the intersection of Santa Monica Boulevard/Princeton Street when an IRWL system was in-place.



As shown above, the IRWL system increased driver yield response rates at Santa Monica Boulevard/Princeton Street by approximately 5%, 13%, and 50% during daytime, dusk, and evening conditions, respectively. Overall driver yielding response rates for the IRWL system were between approximately 87% and 95%. The initial evaluations of the RRFB system at the same location show driver yielding response rates between approximately 80% and 95%. Based on these initial evaluation results, it appears that both types of flashing beacons, RRFB and CRFB, appear to be as effective as IRWL systems.

Initial Conclusions

The initial evaluation results generally show that both flashing beacon systems increase driver yielding response rates. The RRFB seems to result in a greater increase in driver yielding response than the CRFB, with about a 13% average increase for the RRFB versus an about 10% increase for the CRFB. The reports from the data collection team indicate that amongst drivers who saw the pedestrian attempting the crossing, the flashing beacons seemed to legitimize the pedestrian crossing, and that drivers seemed to feel more compelled to let the pedestrian cross when the flashing beacons were activated rather when they were not activated.

Compared to IRWL systems, both the RRFB and CRFB flashing beacons appear to be as effective as IRWL systems. Given the high cost of ongoing maintenance and repair for IRWL systems, initial evaluation results indicate that the RRFB and CRFB systems may be viable alternatives with reduced lifecycle costs. As the evaluations continue through 2013, the City will continue to update the CTCDC and monitor both systems.

In August 2011, the CTCDC adopted the FHWA's interim approval of the RRFB devices statewide. Other cities are currently deploying RRFB devices, subject to the requirements of the interim approval. After consultation with CTCDC members, the City of Santa Monica is continuing its experiment in order to determine if there are measureable differences in the effectiveness of rectangular versus circular rapid flashing beacons.

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