EVALUATING THE EFFECTIVENESS OF SIGNAL-BASED COUNTERMEASURES ON PEDESTRIAN SAFETY

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Evaluating the Effectiveness of Signal-based Countermeasures on Pedestrian Safety

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ABSTRACT
This paper summarizes an evaluation of the effectiveness of signal-based countermeasures to enhance pedestrian safety. Two pedestrian-oriented countermeasures: pedestrian call buttons that light up and pedestrian countdown signals with animated eyes, and one motorist oriented countermeasure: pedestrian activated flashing yellow are evaluated in this paper. These countermeasures were deployed at three locations (two intersections and one mid-block location) in the Las Vegas metropolitan area in Nevada. The evaluations are based on field observations of pedestrian and motorist behaviors before and after the installation of the countermeasures. Their effectiveness was evaluated using the following measures of effectiveness: pedestrians trapped in the roadway, signal cycles in which call button was pushed, frequency of signal violation, pedestrians who look for vehicles before beginning to cross, pedestrians beginning their crossings during the WALK phase, pedestrians in crosswalk at the end of flashing DON’T WALK phase, pedestrians who look for vehicles before crossing 2nd half of street, captured pedestrians, diverted pedestrians (those who had to go out of their way to use the crosswalk or changed their course of action), drivers yielding to pedestrians, distance driver yields or stops before the crosswalk, driver blocking the crosswalk, and drivers making Right Turn On Red who come to complete stop. The results show improvements in pedestrians’ observational behavior for pedestrian-oriented countermeasures. However, motorist behavior did not show significant improvement at intersections with pedestrian-oriented countermeasures. On the other hand, motorist-oriented signal deployment improved yielding behavior of both drivers and pedestrians. The findings from this study could be used to enhance pedestrian safety on arterial roads in other cities with similar demographic characteristics and traffic conditions.

INTRODUCTION
Traffic control devices are used not only to facilitate safe and efficient movement of motorized vehicles, but also non-motorized road users such as pedestrians. Traffic control devices are being routinely evaluated and improved to address such needs. While the primary target of these

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devices may be one type of a road user, their impacts on the entire user community are considered. Safety is the main consideration in this regard.

World Health Organization (WHO) reports that more than a million people are killed on the world’s roads each year, and as many as 50 million people are injured in road crashes annually worldwide (1). By the year 2020, these figures are expected to increase by about 65 percent. Pedestrians are among the most vulnerable road users based on their characteristics relative to those of motorized vehicles. In the year 2006, there were 4,784 pedestrian fatalities reported in the U.S when compared to 4,901 fatalities reported in 2001. Additionally, over 61,000 pedestrians were injured in traffic crashes in 2006 (2, 3). On an average, a pedestrian is killed in a traffic crash every 108 minutes, and one is injured in a traffic crash every 8 minutes. Most pedestrian fatalities in 2005 occurred in urban areas (74%), at non-intersection locations (80%), under normal weather conditions (89%), and at night (67%) (4).

The 2005 Census American Community Survey estimated that 3,291,401 people used walking as their primary mode of travel for their journey to work each week. It is estimated that there are 56 million walking trips in the U.S. every day (7.2 percent of all trips). However pedestrian fatalities account for more than 11 percent of the total fatalities. Thus, the use of effective traffic control devices is an important consideration from a pedestrian safety and mobility perspective, although pedestrian injuries and fatalities are likely to occur despite appropriately deploying such devices.

**BACKGROUND**

Clark County has been the fastest-growing (in terms of population) county in Nevada and it is one of the fastest-growing counties in the country. According to the Southern Nevada Regional Planning Coalition (SNRPC), Clark County’s population as of July 2007 is just under 2 million, which reflects a 45 percent growth over the population in 2000 (5). A significant proportion of the population is elderly and they often choose public transportation systems and walking as their primary mode of transportation. This, along with the fact that Las Vegas is a popular tourist destination, with many tourists preferring to walk, makes pedestrian safety a serious concern for the local agencies.

The National Highway Traffic Safety Administration (NHTSA) ranked Nevada as fifth in the nation in 2002 for its pedestrian fatality rates, with 52 pedestrians killed. Forty-five of those 52 deaths in 2002 occurred in Clark County where the Las Vegas metropolitan area is located. In addition, more than 600 pedestrian injuries occurred on the roads in the Las Vegas metropolitan area in the same year (6). Nevada has one of the worst pedestrian fatality rate since the early 1990s (7).

The mix of aggressive driving, a good network of multi-lane, high speed arterials, a high proportion of automobile based travel, and crosswalk markings that are often not clearly visible are thought to contribute to the pedestrian safety record in Las Vegas. There is a notion that, considering the nature of study area, driving or walking under the influence of alcohol or drugs could be major contributing factors of pedestrian and motor-vehicle crashes. While motor-vehicles use a significant part of the roadway space, the needs of pedestrians and other non-motorized users also should be considered in road design and operations. Of particular interest are strategies to improve pedestrian mobility and safety (9, 10, 11, 12, 13, 14, 15, 16, 17).

Efforts have been ongoing to enhance pedestrian safety in the Las Vegas metropolitan area. As a part of a Federal Highway Administration (FHWA) sponsored project, high pedestrian risk locations were selected based on geo-coded pedestrian crash data and crash rates (8, 18, 19).
Pedestrian crashes at these identified locations were analyzed in detail to identify the causes of crashes. Based on the pedestrian crash characteristics and the land use and demographics of the neighborhood, various traffic engineering countermeasures such as signs, signals, intelligent transportation systems (ITS) and other safety engineering pedestrian safety countermeasures were identified for deployment at these locations (8). This paper summarizes the evaluation of three signal-based countermeasures on enhancing pedestrian safety. The countermeasures evaluated in the paper are specifically related to traffic control devices. They are pedestrian call button that light up, pedestrian activated flashing yellow, and pedestrian countdown signals with animated eyes at three different locations. These devices were installed at three different sites, some individually and others in combination with other countermeasures. In order to evaluate the effectiveness of these devices, both pedestrian and motorist behavior were analyzed.

While the traffic control devices evaluated in this paper have been around for some time now, there is limited published literature on the evaluation of these treatments. A before and after study approach was adopted in the study reported herein to draw conclusions. It used field observations of pedestrian and motorist behaviors and statistical analysis of the data.

SITE DESCRIPTION AND PROBLEM IDENTIFICATION

Efforts reported herein are conducted as a part of Federal Highway Administration (FHWA) pedestrian safety program aimed at enhancing pedestrian safety and identifying suitable countermeasures for deployment in nationally. Features available in commercial Geographic Information Systems software were used to extract the number of pedestrian crashes in the vicinity of several high crash sites. Countermeasures were identified at each selected high crash site based on crash analysis to study contributing factors along with field observation of pedestrian and motorist behavior (8, 19). Signal-based countermeasures selected for installation at 3 sites are described in this paper. These sites are: Fremont Street/8th Street, Flamingo Road/Koval Lane, and Maryland Parkway/Dumont Street. The first site is a mid-block location and the others are intersection locations.

Site 1 - Fremont Street/8th Street: Land use adjacent to the corridor includes hotels, casinos and other commercial activities. The location is within the jurisdiction of the City of Las Vegas. Fremont Street is classified as a minor arterial and the posted speed limit is 25 mph. As per 2006 traffic count statistics, the ADT at Fremont Street is 13,800 along this corridor. Some of the problems identified at Fremont Street from 8th Street to 6th Street are pedestrians not using the crosswalks, a high percentage of elderly pedestrians involved in crashes, and pedestrians failing to yield. Speeding is a key observed problem along this corridor. In addition to other countermeasures aimed at changing driver behavior, an enhancement to the signal based countermeasure implemented at this site is installation of “pedestrian call button that confirm press.” Although it is used in several places, at the time of its implementation, it was relatively new.

Site 2 - Flamingo Road / Koval Lane: This site is within the jurisdiction of Clark County. The land use pattern is a mixed type with shopping complexes and apartments. Flamingo Road is classified as a major arterial and Koval Lane as a minor arterial. Crash data show a total of 29 crashes from January 1996 to December 2000 with 76 percent of them occurring at the intersection. Forty one percent of the total crashes are due to the motorists’ failure to yield. The 2006 traffic count show the estimated ADT on Flamingo Road near Koval Lane to be 40,500.
Some of the observed problems at this site are motorists’ failure to yield and a significant number of nighttime crashes, inconspicuous crosswalks, high percent of elderly pedestrian involved in crashes, motorist failure to yield, pedestrians do NOT wait for signals/acceptable gaps and high pedestrian/right turning vehicle conflicts. Based on the field observation and analysis of crash data, countermeasures are selected. These countermeasures aim at addressing both pedestrians and drivers behavior to improve safety. A Signal-based countermeasure, “Pedestrian Countdown Timer with Animated Eyes” is implemented to alert the pedestrians to look for the oncoming traffic or turning traffic before they start crossing the road.

**Site 3 - Maryland Parkway/Dumont Street:** The unsignalized intersection, considered as mid-block location because of its nature, at Maryland Parkway/Dumont Street comes under the jurisdiction of Clark County. Land use around this site is primarily commercial with shopping complexes and a shopping mall (Boulevard mall). Maryland Parkway is classified as a major arterial in the north-south direction. It has a posted speed limit of 30 mph. Dumont Street is a minor arterial with a posted speed limit of 25 mph. The average daily traffic (ADT) on Maryland Parkway near the intersection of Maryland Parkway/Dumont Street is 43,000 in the year 2006. The traffic on the eastbound direction of the Dumont Street leads to the Boulevard mall. The problems identified at Maryland Parkway/Dumont Street from field observation and from crash data include pedestrians not waiting for acceptable gaps before crossing the streets, drivers failing to yield, pedestrians trapped in the middle of the roadway, and conflicts between vehicles and pedestrians. Since the safety issues are result of both pedestrian and driver behaviors, the selected countermeasures are aimed at altering those. At this site, signal-based countermeasure of pedestrian activated flashing yellow is implemented to improve mainly motorist behavior.

Table 1 shows information regarding countermeasures, location, and implementation strategy at each of the sites.

**DESCRIPTION OF COUNTERMEASURES**

As illustrated in the previous section, out of three signal-based countermeasures implemented, two are focused on improving pedestrian behavior, whereas the pedestrian activated flashing yellow is focused on changing driver yielding behavior. Each of the countermeasures are described in detail.

**Pedestrian call buttons that confirm press**
This countermeasure is one of the accessible pedestrian signals (APS). APS is a device that communicates information about pedestrian timing in non-visual format such as audible tones, verbal messages, and/or vibrating surfaces (MUTCD 2003, Section 4A.01). The LED light up button which is installed with this countermeasure also gives information to pedestrians that the sign is activated after they push the button.

Problems addressed
- High percent of elderly pedestrian involved in crashes

**Pedestrian countdown signals (animated eyes)**
The animated eyes ITS warning sign is installed together with pedestrian countdown signal and walk man pictogram. The main purpose of the “animated eyes” is to remind pedestrian to look left and right for the vehicles before crossing the street. The sign could be activated by a pedestrian call button or using pedestrian detection on devices.
Problems addressed

- Pedestrian trapped in the middle of street
- High percent of elderly pedestrian involved in crashes
- Pedestrian do NOT wait for signals/ acceptable gaps

**Pedestrian activated flashing yellow**

Pedestrian activated flashing yellow is pedestrian-activated overhead flashing yellow lights and downward lighting installed above the crosswalk. The flashing yellow lights could be either activated by a pedestrian pushing a button at the curb or activated by “ITS automatic pedestrian detection devices”. These flashing lights are timed to stay on long enough to allow pedestrians to cross the street. This countermeasure has the objective of drawing the attention of drivers to the presence of a crosswalk ahead, and encouraging pedestrians in crossing the street.

Problems addressed

- Motorist failure to yield

Figure 1 shows pictures of these countermeasures.

**STUDY METHODOLOGY**

An observational study approach was used to evaluate the effectiveness of the subject countermeasures. The evaluation focused on pedestrian behavior and motorist compliance (yielding or stopping) at marked crosswalks. Field observations were conducted by trained observers who manually recorded data needed to quantify the desired measures of effectiveness (MOEs). The data collected include pedestrians who look for vehicles before beginning to cross and also before crossing 2nd half of the street, number of diverted pedestrians, and motorist’s yielding or stopping behavior. In terms of context, as indicated in the previous section, these efforts were part of a pedestrian safety program funded by the FHWA. The goals of this program were to identify, develop, deploy, and evaluate pedestrian safety countermeasures to help improve pedestrian safety (minimize risk) and walkability. So, the MOEs were designed from a broader perspective so as to permit comparisons with other efforts supported by FHWA, and to facilitate potential implementation of successful strategies at other locations.

**DATA COLLECTION/EXPERIMENT DESIGN**

Trained observers collected data for both before and after scenario on weekdays during morning and evening peak hours between 7:00 to 9:00 a.m. and 4:00 to 7:00 p.m. respectively. For the “after” condition, data were collected no earlier than three weeks after installation of the countermeasures. This was to eliminate any novelty effects. The observers were located close to the crosswalk in order to have a good view of the pedestrians and motorists. Observations were made to record the following data and the data were used to quantify the corresponding MOEs:

A. Pedestrians trapped in the roadway
B. Signal cycles in which call button was pushed
C. Frequency of signal violation
D. Pedestrians who look for vehicles before beginning to cross
E. Pedestrians beginning their crossings during the WALK phase
F. Pedestrians in crosswalk at the end of flashing DON’T WALK
G. Pedestrians who look for vehicles before crossing 2nd half of street
H. Captured pedestrians
I. Diverted pedestrians (those who had to go out of their way to use the crosswalk or changed their course of action)
J. Drivers yielding to pedestrians
K. Distance driver yields or stops before the crosswalk
L. Driver blocking the crosswalk
M. Drivers making Right Turn On Red who come to complete stop

Table 2 summarizes MoEs applicable to each of the countermeasures that is analyzed in this paper. Each of these MoEs is explained next.

A. Pedestrians Trapped in the Roadway
The number of pedestrians who are trapped in the middle of uncontrolled locations for at least 5 seconds is counted. This is generally the result of a pedestrian selecting a gap that is too small for them to completely cross the road before encountering approaching traffic. Pedestrians are scored as trapped in the middle at the centerline or between lanes if they have to wait to finish crossing. These pedestrians are converted into the percentage of total observed pedestrians.

B. Signal Cycles in Which Call Button was Pushed
To record this MOE, every signal cycle for a given data collection period in which a pedestrian is present is observed as to whether or not the call button is pushed (cycles where no pedestrians are present are ignored in the percentage calculation). This MOE is recorded separately for each treated crosswalk at the intersection. Pedestrians are scored if they push the call button and the recorded data are converted to the percent of the total pedestrians crossing at a signalized intersection. Also, the percent of cycles where the call button is pushed is considered.

C. Pedestrian Signal Violations (Crossing during the DON’T WALK Phase)
A pedestrian is considered to be a signal violator if the pedestrian steps in or near the crosswalk from the curb when the solid DON’T WALK sign is displayed on the pedestrian signal head. Such violators are reported as a percent of the total pedestrians observed during the study period.

D. Percent of Pedestrians Who Look for Vehicles before Beginning to Cross
The percent of pedestrians who look for vehicles before beginning to cross is the percent of pedestrians who visually looked in the direction of a potential threat before stepping off the curb into the roadway. A noticeable scan must be observed for a “look” to be scored. Pedestrians should noticeably look to the left before starting to cross at a mid-block location.

E. Percent of Pedestrians Beginning Their Crossings During the WALK Phase
This MOE is scored if a pedestrian steps from the curb into the crosswalk when the WALK signal is displayed on the pedestrian signal head. These data are converted into the percent of total observed pedestrians.
F. Percent of Pedestrians in Crosswalk at the End of Flashing DON’T WALK
The number of pedestrians in or near the crosswalk, who initiate their crossing before the solid
DON’T WALK pedestrian signal who are still in a traffic lane after the cross street traffic
receive the green signal, is counted. These data are reported in terms of the percent of total
observed pedestrians.

G. Percent of Pedestrians Who Look for Vehicles before Crossing 2nd Half of Street
This MOE is the percent of pedestrians who, at the centerline/center of the roadway, visibly
scanned for vehicles before continuing to cross the 2nd half of the street. A noticeable scan must
be observed for a “look” to be scored. To look for a vehicle, the pedestrian must noticeably look
to the right before beginning to cross the second half of the street.

H. Percent Captured Pedestrians
The percent of captured pedestrians is the percent of pedestrians who modified their paths to use
a safety countermeasure, but who do not go out of their way to do so.

I. Percent of Diverted Pedestrians
The percent of diverted pedestrians is the percent of pedestrians who modified their paths or
changed their course of action to use a safety countermeasure, and who walk out of their way to
do so. These pedestrians would walk some additional distance to reach their destination, since
the subject crossing would not in their shortest path.

J. Percent of Motorists Yielding to Pedestrians
The percent of motorists yielding to pedestrians is the percent of motorists who stopped or
slowed to allow pedestrians crossing in the crosswalk to proceed in front of the motorist before
the motorist proceeded to travel across the crosswalk. At mid-block locations, it is the percent of
through vehicles that yield.

K. Distance Motorist Yields or Stops Before the Crosswalk
The distance a motorist stops upstream of (before) a crosswalk at an intersection is the distance
between the front bumper of the stopped vehicle and the painted crosswalk. The distance a
motorist yields at a mid-block crosswalk is the distance between the vehicle and the crosswalk
when the motorist first begins to brake in advance of the mid-block crossing. To score the
distance the motorist yielded to a pedestrian, both a vehicle and a crossing pedestrian need to be
present at the same time. A crossing pedestrian must be present (either on the curb about to cross
or already crossing in the crosswalk). A vehicle with the opportunity to cross the pedestrian’s
path must also be present. Only the yielding distance of the first vehicle in a queue of vehicles
was recorded (the distances of any vehicles queued behind the yielding vehicle were not scored
nor were they counted as a vehicle present in the percent calculation). To measure the distance a
motorist yields upstream of a mid-block crosswalk, marks were placed on the curb or in the
roadway at 10-foot intervals upstream of the crosswalk. The distance of the furthest mark behind
which the motorist begins stopped was recorded.

L. Motorists Blocking the Crosswalk
The data for the frequency of motorists blocking the crosswalk at the intersections and mid-block
locations are collected. A vehicle is scored as "blocking the crosswalk” when it encroaches the
crosswalk. These data on the motor vehicles that block the crosswalk are converted into the percentage of total observed motor vehicles during the study period.

M. Motorists Making Right Turn On Red Who Come to Complete Stop

Drivers are scored as coming to a complete stop if their wheels stopped turning before they enter the crosswalk. Drivers are scored as RTOR coming to rolling stop if the vehicles slow considerably, but the wheels do not stop turning before entering the crosswalk. If drivers turn without appreciably slowing, they are scored as RTOR without slowing. This MOE is reported in terms of the percent of total observed vehicles during the study period.

STATISTICAL ANALYSES

The z-test for two proportions, a statistical analysis tool, was used to determine if the proportions obtained during the two study periods are significantly different. For example, let

- \( P_B \) = proportion (percent as a fraction) of vehicles yielding during the “before” period
- \( P_A \) = proportion (percent as a fraction) of vehicles yielding during the “after” period

The null hypothesis (\( H_0 \)) is that the percent of motorists yielding during the “before” period (\( P_B \)) is the same as that during the “after” period (\( P_A \)). The alternative hypothesis (\( H_a \)) is the percent of motorists yielding during “after” (\( P_A \)) period is greater than the percent of motorists yielding during “before” period (\( P_B \)). They are expressed as follows:

- \( H_0: P_A - P_B = 0 \)
- \( H_a: P_A - P_B > 0 \)

Let \( X_B \) = number of vehicles yielding in the “before” period, out of a total of \( n_B \) vehicles
- \( X_A \) = number of vehicles yielding in the “after” period, out of a total of \( n_A \) vehicles

The population proportions \( P_A^* \) and \( P_B^* \) are estimated by the sample proportions:

\[ \hat{P}_A = \frac{X_A}{n_A} \quad \text{and} \quad \hat{P}_B = \frac{X_B}{n_B} \]

For large sample sizes, the two sample proportions are approximately and normally distributed, and the z-test for testing the equality of the two proportions vs. the 1-sided alternative can be used. The test statistic used is \( Z_0 \), and is defined as follows:

\[ Z_0 = \frac{\hat{P}_B - \hat{P}_A}{\sqrt{\hat{P}(1-\hat{P}) \left( \frac{1}{n_B} + \frac{1}{n_A} \right)}} \]

where, \( \hat{P} = \frac{X_B + X_A}{n_B + n_A} \)

\( Z_0 \) is distributed approximately N (0, 1) when \( H_0 \) is true.

The significance probability, or P-value, for equality of proportions vs. the 1-sided alternative is calculated by:

\[ P\text{-value} = P(Z < Z_0) \]

The null hypothesis is rejected if the P-value < 0.05 (for 95 percent confidence level).

A one-tailed test was used to test the null hypothesis at a 95 percent confidence level (Probability, \( P < 0.05 \)).
RESULTS AND DISCUSSION
The results of the analyses of the data from field observations and the statistical tests are reported in this section. The results are analyzed for safety MOEs. Safety MOEs include pedestrian and motorist behavior related MOEs. Tables 3 and 4 summarize statistical analyses of pedestrian and motorist MOEs, respectively. Discussions of the analyses of these MOEs by countermeasure follow.

Pedestrian Safety MOEs

**Pedestrian Call Button that Light Up**
Pedestrian call button that light up, installed at Fremont Street/8th Street intersection, improved pedestrian yielding behavior, especially for elderly pedestrians, by informing them that the system has scored their pushing of button. The results show that the behaviors of pedestrians have changed significantly. There is a significant decrease in the percent of pedestrians trapped in the roadway, indicating that pedestrians are making better judgment in crossing. It might be due to the fact that since they realize that their requests (pushing the button) have been scored, they get the confirmation that the crossing is working. Percent of pedestrians doing signal violation has shown a significant decrease. This also could be attributed to the pedestrians’ better understanding of the system. The results also show a significant increase in percent of signal cycles in which call button has been pushed. This also could be attributed to the fact that pedestrians trust the system, which provides a feedback.

**Pedestrian Countdown Signals (with Animated Eyes)**
Results obtained at Flamingo Road / Koval Lane intersection after installation of pedestrian countdown signals with animated eyes show that there is a significant increase in percent of signal cycles in which call button was pushed. The result also shows that percent of pedestrians who look for vehicles before beginning to cross and percent of pedestrians beginning their crossing during WALK phase also increased significantly. Overall, pedestrian countdown signals with animated eyes improved pedestrian crossing behavior at the intersection.

**Pedestrian Activated Flashing Yellow**
Statistical Analyses of the data collected show that implementation of pedestrian activated flashing yellow improved pedestrian crossing behavior at Maryland Parkway / Dumont Street mid-block location. Observations indicate an increase number of pedestrians who look for vehicles before crossing the street. In addition, there was an increase in number of pedestrian who look before crossing the 2nd half of the street. In addition, pedestrians to walk additional distance (diverted) to reach out and use the crossing location with pedestrian activated flashing yellow signal.

Motorist MOEs

**Pedestrian Call Button that Light Up**
The installation of pedestrian call button that light up at Fremont Street/8th Street did not improve most of MOEs that relate to motorist behavior. The only MOE that showed statistically significant improvement after installation is drivers blocking the crosswalk. The number of drivers blocking crosswalk has decreased after installation of pedestrian call button that light up signal.
**Pedestrian Countdown Signals (with Animated Eyes)**
As this countermeasure was primarily aimed at pedestrians, drivers’ behaviors are not reported.

**Pedestrian Activated Flashing Yellow**
Results obtained show that there is a significant decrease in percent of drivers blocking the crosswalks. Also there is a significant improvement in yielding distance at which drivers stopping for pedestrians. An increase in proportion of drivers yielding to pedestrians was observed in <10 ft, 10-20 ft and >20 ft yielding distance categories. The proportion of drivers tend be high in <10 ft followed 10-20 ft yielding distance categories. On the other hand, percent of drivers yielding to pedestrians, failed to make any valid conclusion.

**SUMMARY**
Three signal-based countermeasures were installed at three different locations to evaluate their effectiveness in enhancing pedestrian safety. Two countermeasures focused on improving pedestrian behavior, while the third was primarily to improve motorist behavior. The results from field observations and statistical analysis show that the implementation of pedestrian call button that light up, which is aimed at improving pedestrian yielding behavior helped improve pedestrian safety as quantified by several measures of effectiveness, including reducing frequency of signal violation, percent trapped in the roadway, and percent signal cycles in which call button has been pushed. Although it reduced the percent of pedestrians who begin their crossing during WALK phase, the change was not statistically significant. As expected, this countermeasure did not improve driver behavior, except for reduction in percent of drivers blocking the crosswalk. This change in driver yielding behavior could be because of pedestrians’ improvement in yielding, which reduces driver delays, hence encouraging them to accommodate crossing pedestrians.

The pedestrian countdown signal countermeasure also led to improvements in pedestrian crossing behavior as quantified by several measures of effectiveness, except for the percent of pedestrians in a crosswalk at the end of flashing DON’T WALK and at the end of All-Red, which showed increase in violations. This could be because of a false sense of security that the animated eyes offer to the pedestrians. Motorist yielding behavior was not assessed for this countermeasure.

Pedestrian activated flashing yellow is the only signal-based countermeasure that was deployed to change drivers’ yielding behavior. This countermeasure improved pedestrian behavior significantly as indicated by several MOEs, including the percent of pedestrians looking for vehicles before beginning to cross and before crossing 2nd half of the street and increase in percent of diverted pedestrians. Although it improved the percent of captured pedestrians, the improvement is not statistically significant. The only pedestrian oriented MOE which did not show an improvement is the percent of pedestrians trapped in the middle. While evaluating motorist yielding, this countermeasure showed significant improvements in yielding distance and a decrease in the percent of drivers blocking the crosswalk. However, after deploying the pedestrian activated flashing yellow signal, the percent of drivers yielding to pedestrians showed a decrease in value.

The observations and analyses indicate that although pedestrian oriented signal treatments improve pedestrian yielding and hence safety, they do not change driver yielding behavior. However, it is important to have some other improvements to change driver yielding behavior.
along with these countermeasures. If that issue is not addressed, the improvements made in the pedestrian behavior could become unnoticeable. On the other hand, driver oriented signal treatments improve the yielding behavior of both drivers and pedestrians, hence improving the safety of the location much better. Overall, the results indicate that signal-based countermeasures are successful in addressing safety issues as they intended to be. A comparison of the crashes before and after the installation of the countermeasures to further support the safety improvements and a cost-benefit analysis merit further investigation.

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REFERENCES


### TABLE 1 Summary of Countermeasure Deployment

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<td>HVCT</td>
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<td>Mar 7, 2007</td>
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PST Portable Speed Trailers
IRKS In-Roadway Knockdown Signs
HVCT High Visibility Crosswalk Treatment
DO Danish Offset
MR Median Refuge
AYM Advance Yield Markings
TABLE 2 Countermeasures and Corresponding MoEs

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<th>MoEs</th>
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<tbody>
<tr>
<td>Pedestrian Call Buttons that Light Up</td>
<td>A, B, C, D, E, J, K, L</td>
</tr>
<tr>
<td>Pedestrian Countdown Signals (animated eyes)</td>
<td>A, D, G, H, I, J, K, L</td>
</tr>
<tr>
<td>Pedestrian Activated Flashing Yellow</td>
<td>B, C, D, E, F, H, I, J, K, L, M</td>
</tr>
</tbody>
</table>
### TABLE 3 Results of Pedestrian Safety MOEs

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>Pedestrian Call Button that Confirm Press</th>
<th>Pedestrian Countdown Signals (animated eyes)</th>
<th>Pedestrian Activated Flashing Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measures of Effectiveness</strong></td>
<td><strong>Stage 2</strong></td>
<td><strong>Stage 3</strong></td>
<td><strong>Statistical Results</strong></td>
</tr>
<tr>
<td>Percent of pedestrians trapped in the roadway</td>
<td>437</td>
<td>9</td>
<td>275</td>
</tr>
<tr>
<td>Percent of pedestrians who look for vehicles before beginning to cross</td>
<td>437</td>
<td>437</td>
<td>275</td>
</tr>
<tr>
<td>Percent of pedestrians who look for vehicles before crossing 2nd half of street</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of pedestrian signal violation</td>
<td>437</td>
<td>63</td>
<td>275</td>
</tr>
<tr>
<td>Percent of pedestrians who begin their crossing during WALK phase</td>
<td>202</td>
<td>159</td>
<td>248</td>
</tr>
<tr>
<td>Percent of pedestrians in crosswalk at the end of flashing DON’T WALK</td>
<td>455</td>
<td>140</td>
<td>544</td>
</tr>
<tr>
<td>Percent of pedestrians in crosswalk at the end of All-Red</td>
<td>455</td>
<td>14</td>
<td>544</td>
</tr>
<tr>
<td>Percent signal cycles in which call button has been pushed</td>
<td>202</td>
<td>36</td>
<td>174</td>
</tr>
<tr>
<td>Percent of captured pedestrians</td>
<td>455</td>
<td>455</td>
<td>-</td>
</tr>
<tr>
<td>Percent of diverted pedestrians</td>
<td>455</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>
### TABLE 4 Results of Motorist MOEs

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>Measures of Effectiveness</th>
<th>Pedestrian Call Button that Confirm Press</th>
<th>Measures of Effectiveness</th>
<th>Pedestrian Activated Flashing Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stage 2</td>
<td>Stage 3</td>
<td>Statistical Results</td>
<td>Stage 2</td>
</tr>
<tr>
<td></td>
<td>NB</td>
<td>X_B</td>
<td>X_A</td>
<td>P_B – P_A</td>
</tr>
<tr>
<td>Percent of drivers yielding to pedestrians</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location driver stops/yields before crosswalk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at crosswalk</td>
<td>26</td>
<td>25</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>between crosswalk and stop bar</td>
<td>25</td>
<td>13</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>away from stop bar</td>
<td>25</td>
<td>5</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Percent of drivers blocking crosswalk</td>
<td>25</td>
<td>4</td>
<td>22</td>
<td>0</td>
</tr>
</tbody>
</table>

Distance driver stops/yields before crosswalk:
- < 10 ft: 246 188 1633 227 0.62 >0.05 Do not Reject
- 10-20 ft: 188 87 227 154 -0.21 <0.001 Reject
- >20 ft: 188 16 227 39 -0.08 <0.05 Reject

Percent of drivers blocking crosswalk:
- 246 8 1633 6 0.02 <0.05 Reject
a. Pedestrian Call Button that Light up

b. Pedestrian Countdown Signals with Animated Eyes

c. Pedestrian Activated Flashing Yellow

FIGURE 1 Signal Based Countermeasures Evaluated.