EVALUATING ITS-BASED COUNTERMEASURES - HOW EFFECTIVE ARE THEY IN ENHANCING PEDESTRIAN SAFETY?

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Evaluating ITS-Based Countermeasures - How Effective Are They In Enhancing Pedestrian Safety?

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ABSTRACT

This paper summarizes an evaluation of the effectiveness of Intelligent Transportation Systems (ITS) based countermeasures installed in Las Vegas, Nevada as part of a Federal Highway Administration sponsored pedestrian safety project. ITS related countermeasures considered for evaluation include “ITS No Turn on Red” sign, automatic pedestrian detection devices and smart lighting, and portable speed trailer. The evaluations are based on field observations of pedestrian and driver behaviors “before” and “after” installation of countermeasures at selected locations in Las Vegas, Nevada. The effectiveness of “No Turn on Red” sign at intersections was evaluated using percent of signal cycles in which call button has been pushed, percent of drivers making right turn on red (RTOR) that come to a complete stop, percent of drivers violating the no RTOR (when pedestrians present), percent of drivers violating the no RTOR (when pedestrians NOT present), average pedestrian delay and average vehicle delay. On the other hand, the effectiveness of automatic pedestrian detection device and smart lighting at midblock locations was evaluated using pedestrians who looked for vehicles before beginning to cross, pedestrians who looked for vehicles before crossing 2nd half of the street, drivers yielding to pedestrians, distance driver stops/yields before the crosswalk, pedestrian delay and vehicle speed as measures of effectiveness. Results show statistically significant reduction in vehicle speeds due to installation of speed trailer. Also, driver yielding behavior improved due to installation of the above countermeasure. The findings from this study could be used to enhance pedestrian safety by influencing driver behavior on arterial roads in other cities with similar demographic characteristics and traffic conditions.

Keywords: Pedestrians, safety, behavior, drivers, ITS based countermeasures

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INTRODUCTION

According to Traffic Safety Facts released by National Highway Traffic Safety Administration (NHTSA), 4,654 pedestrians were killed and more than 70,000 were injured in the year 2007 with a majority of the crashes (73%) being reported in the urban areas (1). These numbers are consistent with the state of Nevada, where majority of the fatalities (90%) and injuries (80%) are in urban areas (2). Clark County, (comprising of Las Vegas metropolitan area) Nevada reports at least 40+ pedestrian fatalities and 500 pedestrian injuries per year in road crashes. The pedestrian fatality rate in the State of Nevada has been among the worst in the nation over the past decade. Based on pedestrian fatality rates, Nevada has been among the 10 worst states for pedestrian safety since the early 1990s (3). Pedestrian fatalities per 100,000 population in the State of Nevada and the U.S. from 1994 to 2003 are shown in Table 1. Nevada has been ranked first on two occasions during the last 10 years, in 1996 and 1999, as having the worst pedestrian safety in the United States. Thus, the pedestrian safety problem (as quantified by fatal and injury crashes) in Clark County warrants immediate attention. Strategies to enhance pedestrian mobility and safety range from traffic signs and signals to those that are intelligent transportation systems (ITS) and infrastructure based countermeasures (4, 5, 6, 7, 8, 9, 10, 11, 12). This paper concentrates on measuring the effectiveness of ITS based countermeasures

This paper is based on efforts from a Federal Highway Administration (FHWA) sponsored program to enhance pedestrian safety. Las Vegas, Nevada is one of the three pilot study test sites selected for the study, the other two being San Francisco, CA and Miami Dade County, FL. High pedestrian risk locations were selected based on geo-coded pedestrian crash data and crash rates, demographic characteristics, land use characteristics and traffic characteristics (13, 14, 15) and suitable countermeasures were suggested, installed and evaluated. The focus of this paper is on an evaluation and comparison of pedestrian and driver behaviors “after” installation of the following ITS based countermeasures to enhance pedestrian safety in Las Vegas, Nevada.

1. ITS No-Turn on Red Signs

2. Smart Lighting

3. Automatic Pedestrian Detection Device

4. Portable Speed Trailers

Two of the above mentioned countermeasures (Smart Lighting and Automatic Pedestrian Detection Devices) were manufactured in-house at City of Las Vegas workshop while the other two (ITS No Turn on Red Signs and Portable Speed Trailer) were purchased from vendors. The cost of manufacturing and installing these countermeasures varied from $5,000 to $15,000. While the first sign was typically used at intersections, the other signs were used at midblock locations. It is worth noting that these signs are typically installed to influence (improve) driver behavior thereby showing indirect affect on the pedestrian safety.

DESCRIPTION OF SELECTED TRAFFIC SIGNS

A brief description of ITS based countermeasures considered for evaluation to enhance pedestrian safety in this paper is presented next. Problems typically addressed using these ITS related countermeasures are listed below description of each sign.
“ITS No-Turn on Red” Sign
This countermeasure is a symbol sign to remind motorists that turning vehicles must come to a full stop and yield to cross-street traffic and pedestrians prior to turning right on red. Many motorists do not fully comply with the regulations, especially at intersections with wide turning radii. Motorists are so intent on looking for traffic approaching on their left that they may not be alert to pedestrians approaching on their right. In addition, motorists usually pull up into the crosswalk to wait for a gap in traffic, blocking pedestrian crossing movements.

This sign is typically placed next to the traffic signal on the mast arm. It remains completely blank when not energized. No phantom words were seen under any ambient light conditions. Electronic blank-out sign are integrated into existing traffic management system. ITS No RTOR sign is following the standard in MUTCD 2003, Section 2B.45 (R10-11) (16).

Problems addressed
- Motorist failure to yield
- High pedestrian/ Right turning vehicle conflicts

“Smart Lighting”
The objective of the smart lighting strategy is to increase the intensity of illumination at the crosswalk when a pedestrian is detected in the crosswalk. The sudden increase in lighting intensity alerts motorists that pedestrians are in crosswalk more so than when continuous intensity light is used in the crosswalk. Note that high intensity lighting will remain only when pedestrians are present in the crosswalk.

Problems addressed
- High percent of elderly pedestrian involved in crashes
- Motorist failure to yield
- High percentage of night time crashes

Automatic Pedestrian Detection Devices
This countermeasure is a device that is installed with advance warning for motorists (roving eyes) or smart lighting. The detection devices use ultrasonic or microwave radar to detect pedestrians at crossing areas. This countermeasure is aimed at reducing overall pedestrian/vehicle conflicts and inappropriate crossings.

Problems addressed
- Pedestrians do NOT wait for signals/ acceptable gaps

Portable Speed Trailers
This mounted radar display trailer is accurate, at about five miles per hour, and easily read at a glance. Additionally, in addition to a traditional portable speed trailer which only provides feedback on vehicle speed, this speed trailer also informs the driver of the size of the fine associated with their speed (if they exceed the speed limit). These fine related information was collected from the local police departments.
Problems addressed

- Speeding
- Failure to yield to pedestrians

LITERATURE REVIEW

A review of literature on ITS related countermeasures selected for evaluation in this paper is presented next.

ITS-No Turn on Red Signs

Retting, Nitzburg, Farmer, and Knoblauch reported finding from field evaluation of two methods for restricting right turn on red (RTOR) to promote pedestrian safety. The implementation of signs prohibiting RTOR during specified hours yields better results than signs giving drivers discretion to determine whether pedestrians are present (17). Van Houten and Malenfant analyzed the effectiveness of an ITS LED at parking garage exit and mid-block locations (18). The main purpose of the study was to assess the effectiveness of an ITS signal that included animated eyes and pedestrian symbols at a garage exit with limited visibility. The result of the study showed that the introduction of ITS signs increased the percent of motorists yielding to pedestrians at the garage exit and mid-block crosswalk location. The ITS eyes sign produced a significantly larger increase in driver’s yielding behavior than a flashing beacon at the mid-block crossing.

Automated Pedestrian Detection Device and Smart Lighting

In the United Kingdom, Puffin (Pedestrian User-Friendly Intelligent) crossings respond to pedestrian demand and do not delay traffic unnecessarily when no pedestrians are present (19). Pedestrian presence is sensed either by use of a pressure-sensitive mat or by an infrared detector mounted above the crossing location. Pressure on the mat is used both for initial detection as well as to confirm that the pedestrian has not departed the crossing zone before the “WALK” signal appears. If the pedestrian departs the crossing zone prior to the appearance of the “WALK” signal, the call will be canceled.

Puffin crossings may also utilize an additional sensor to detect the continued presence of pedestrians in the crosswalk, thereby allowing the signal phase to be extended for those requiring additional time to cross. The conversion of a standard signal to a Puffin crossing in Victoria, Australia reduced the number of pedestrians who started to cross before the pedestrian “WALK” signal by 10 percent (20). The Dutch PUSSYCATS (Pedestrian Urban Safety System and Comfort At Traffic Signals) system consists of a pressure-sensitive mat to detect pedestrians waiting to cross, infrared sensors to detect pedestrians within the crossing, and a near-side pedestrian display (21). Although pedestrians perceived PUSSYCATS to be at least as safe as the old system, many pedestrians reported that they did not understand the function of the mat. As many as half of all pedestrians refuse to use the system. Similar applications are being used in the United Kingdom and France (21).

Portable Speed Trailers

Studies have shown that most drivers do not slow down in response to the standard regulatory or advisory speed signs that are customarily used to regulate speeds at temporary traffic control zones (work zones) (22). A study in Netherlands showed that local automatic speed warning at
an urban intersection reduced the mean speed by 5 km/hr (22). Also, on a two-lane rural road, the percent of speeders decreased from 40 to 10 percent. The total number of crashes is reduced by 35 percent. This effect is almost the same three years after concluding the experiment (23). A study conducted by Brown (24) on concentrated police enforcement had shown to positively influence driver behavior, but is difficult to apply to rural contexts. Signs of police enforcement in high crash-risk areas are placed in two rural locations in South Australia. The effects of these signs on vehicle speed are evaluated by conducting radar surveys of mean speeds on the approaches to, and exits from, the sign locations before and after their erection. A minor speed reduction on the exit from one of the signs is observed, but this is not observed in the speeds of the fastest 15 percent of vehicles. This suggested that the highest risk group of speeders is not affected by the signs. The signs did not affect heavy vehicle speeds. It is not considered likely that the signs had a substantial effect on road safety in rural areas.

DATA COLLECTION

Data were collected for five hours during morning and evening peak periods (7:00 to 9:00 a.m. and 4:00 to 7:00 p.m.) on each data collection day. The data collection days were primarily weekdays and data collection over the weekends was minimal. Weekend data collection was mainly intended for locations where pedestrian activities proximate to recreational and shopping areas are expected to be more during the weekends. At other locations, such as the residential and small commercial locations, more pedestrian activities are expected during weekdays. Depending on the pedestrian count and pedestrian activities at the data collection site, data collection was done maximum up to eight hours.

The pedestrians’ crossing behaviors were observed at a crosswalk and approximately within 200 feet from a crosswalk at all approaches of an intersection. At midblock locations, all pedestrians in the data collectors’ view were observed, where distance from a crosswalk was not a deciding factor.

FIELD OBSERVATIONS AND MEASURES OF EFFECTIVENESS

Field observations were conducted “before” and 3 weeks “after” installation of selected traffic signs (to eliminate any novelty effects) to obtain required data to derive the measures of effectiveness (MOEs). Observations include data pertaining to pedestrians and drivers.

ITS-No Turn on Red Signs

The following MOEs were used to evaluate the effectiveness of “ITS No Turn on Red” sign.

1. Percent of signal cycles in which call button has been pushed
2. Percent of drivers making RTOR that come to a complete stop
3. Percent of drivers violating the no RTOR (when pedestrians present)
4. Percent of drivers violating the no RTOR (when pedestrians NOT present)

MOEs 1 was used to determine if the selected countermeasures showed improvement in pedestrian action (i.e., pushing the button to activate the system). MOEs 2, 3 and 4 were used to study the motorist behavior / violation of the signal. MOEs 5 and 6 are related to pedestrian and vehicle delay – operational characteristics. MOE 7 denotes another operational characteristic of the location. These MOEs are explained next.
Percent of signal cycles in which call button has been 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. Signal cycles are scored if a pedestrian pushes the call button and the recorded data are converted to the percent of the total signal cycles at a signalized intersection. Also, the percent of pedestrians pushing the call button is considered.

Percent of drivers making RTOR that come to a 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.

Percent of drivers violating the No Turn on Red (when pedestrians present): Drivers are scored for not stopping while making the turn on red when the “NoTurn on Red signal” is activated i.e., pedestrians are in the crosswalk. This MOE is reported in terms of the percent of total observed vehicles during the study period.

Percent of drivers violating the No Turn on Red (when pedestrians NOT present): Drivers are scored for not stopping while making the turn on red when the “NoTurn on Red” signal is activated and no pedestrians are in the crosswalk. This MOE is reported in terms of the percent of total observed vehicles during the study period.

Smart Lighting and Automatic Pedestrian Detection Devices
The following MOEs were used to evaluate the effectiveness of smart lighting and automatic pedestrian detection devices.

1. Pedestrians who looked for vehicles before beginning to cross
2. Pedestrians who looked for vehicles before crossing 2nd half of the street
3. Drivers yielding to pedestrians
4. Distance driver stops/yields before the crosswalk
5. Pedestrian delay
6. Vehicle speed

MOEs 1 and 2 are used to determine if the selected countermeasures created a false sense of security to crossing pedestrians and if they have any negative implications such as not look for approaching vehicles. MOE 3 was selected to analyze motorist compliance rate, and MOE 4 was selected to study and identify the yielding distance preferred by motorists yielding to pedestrians. MOE 5 is related to pedestrian and MOE 6 is related to vehicle speed. These MOEs are explained next.

Pedestrians Who looked for Vehicles before Beginning to Cross: This MOE is scored if the pedestrians look in the direction of a potential threat before stepping off the curb onto the street. The data are reported as a percent of the total pedestrians observed during the study period.
**Pedestrians Who Looked for Vehicles before Crossing 2nd Half of the Street:** This MOE is evaluated for the pedestrians who are at the centerline/center of street and visibly scan for vehicles before continuing to cross the second half of the street. The observed data are reported as a percent of the total pedestrians observed during the study period.

**Drivers Yielding to Pedestrians:** The measure indicates the proportion of through vehicles that yielded to pedestrians.

**Distance Vehicle Yields before the Crosswalk:** The distance a driver yields at a midblock crosswalk was the distance between the vehicle and the crosswalk when the driver first begins to brake in advance of the midblock crossing. To score the distance the driver yield to a pedestrian, both a vehicle and a crossing pedestrian need to be present at the same time. The yielding distance of the vehicles was recorded in three categories, less than 10 ft, between 10 to 20 ft, and greater than 20 ft. To help with field observations, reference marks are identified on the curb at these intervals in advance of the crosswalk.

**Pedestrian Delay:** Pedestrian delay at a midblock location begins only when the pedestrian turns to initiate the crossing maneuver and stops walking to wait for a gap in traffic. If a pedestrian becomes delayed or trapped in the street after starting the crossing maneuver, this additional in-street delay is added to the delay the pedestrian experience before crossing to get the pedestrian’s total delay.

**Vehicle Speed:** Average vehicle speeds are measured using the space mean speed technique. A length of segment on the upstream of an intersection is measured and a corresponding time taken by a vehicle to travel this segment is recorded. The same strategy is used at midblock locations. The mean and 85th percentile speed and standard deviation of speed are reported.

**Portable Speed Trailer**

The following MOEs were used to evaluate the effectiveness of portable speed trailers.

1. Drivers yielding to pedestrians
2. Pedestrian delay
3. Vehicle speed

These MOEs are measured as explained in case of smart lighting and automatic pedestrian detection device.

**ANALYTICAL METHODS**

A Z-test was used to evaluate the effectiveness of the installed ITS based countermeasures in enhancing pedestrian safety using safety MOEs. A T-test was used to evaluate mobility MOEs. A description on Z-test and T-test is presented next.

**Z-test**

The Z-test for two proportions, a statistical tool, was used to determine if the proportions obtained during the two study periods are significantly different. Let \( P_B \) = proportion of MOE during the “before” period and \( P_A \) = proportion of MOE during the “after” period. The null hypothesis (\( H_0 \)) is that the proportion of MOE during “before” period (\( P_B \)) and “after” period (\( P_A \))
(P_\alpha) is the same. The alternative hypothesis (H_a) is the proportion of MOE during “after” (P_\alpha) period is greater than the proportion of MOE during “before” period (P_\beta). They are expressed as follows:

\begin{align*}
H_0: P_\beta &= P_\alpha \\
H_a: P_\beta &< P_\alpha
\end{align*}

The one-tail test for proportions is used to test these hypotheses at a 95 percent confidence level. Let X_B = number of observations related to the MOE in the “before” period, out of a total of n_B observations and X_A = number of observations related to the MOE in the “after” period, out of a total of n_A observations. The population proportions \( \hat{P}_A \) and \( \hat{P}_B \) are estimated by the sample proportions:

\begin{align*}
\hat{P}_A &= X_A / n_A \\
\hat{P}_B &= X_B / n_B
\end{align*}

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 significant probability or P-value for equality of proportions vs. the 1-sided alternative is calculated by P-value = P(Z < Z_0). The null hypothesis is rejected if the P-value < 0.05 (for 95 percent confidence level).

**T-test**

A T-test is used to compare if delay are statistically different at the 95 percent confidence level. It is used to identify the difference between means of independent samples.

Let M_B = population mean during before evaluation period, n_B = number of observations during before evaluation period, \( \bar{X}_B \) = sample mean of n_B observations, and \( S_B^2 \) = sample variance of observations during before study. Similarly, M_A, n_A, \( \bar{X}_A \), and \( S_A^2 \) are the population mean, number of observations, sample mean, and sample variance of after evaluation period, respectively.

The null hypothesis of equal means for “before” and “after” periods vs. the 1-sided alternative is expressed as:

\[ H_0: M_B - M_A = 0 \]
$H_a: M_B - M_A > 0$

The test statistic computed from the sample is:

$$t_0 = \frac{\bar{x}_B - \bar{x}_A}{\sqrt{\left(\frac{S^2_B}{n_B} + \frac{S^2_A}{n_A}\right)}}$$

The distribution of the test statistic when $H_0$ is true is a $t$-distribution with approximate degree of freedom given by:

$$df = \frac{\left(\frac{S^2_B}{n_B} + \frac{S^2_A}{n_A}\right)^2}{\left(\frac{S^2_B}{n_B}\right)^2 + \left(\frac{S^2_A}{n_A}\right)^2} \left(\frac{1}{n_B - 1} + \frac{1}{n_A - 1}\right)$$

The significance probability or P-value for equality of means vs. the 1-sided alternative is calculated by $P\text{-value} = P(t_{df} > t_0)$

If obtained P-value is greater than the critical $\alpha$-value, i.e., 0.05 at 95 percent confidence level, then $H_0$ is accepted. Similarly, if the P-value is less than the $\alpha$-value, then $H_0$ is rejected at a 95 percent confidence level.

**ANALYSIS AND DISCUSSION**

Table 2 summarizes ITS based countermeasures installed for evaluation at selected locations in Las Vegas, Nevada. The characteristics of these locations are also shown in this table. Data was collected, stratified and analyzed for morning and evening peak hours based on total observations during the period. As stated earlier, “before” and “after” study strategy was conducted to evaluate the effectiveness of selected ITS based countermeasures in this paper.

Tables 3, 4, and 5 summarize results obtained for “ITS No Turn on Red” sign, Smart Lighting – Automatic Pedestrian Detection Devices and Potable Speed Trailer. A negative sign for difference in “before” and “after” value in tables indicates an increase whereas a positive indicates otherwise.

**“ITS No Turn on Red” Sign**

“ITS No Turn on Red” sign was installed at one location: Flamingo Road and Koval Lane. These signs were installed along with another countermeasure (high visibility crosswalk treatment). Hence its individual effectiveness cannot be evaluated. Figure 1 shows “ITS No Turn on Red” sign installed at Flamingo Road and Koval Lane in Las Vegas, Nevada.
Table 3 shows the actual number of records collected during the field data collection. Table 3 summarizes difference in MOE “before” and “after” installation along with results from statistical analysis. When compared to the before data, the data collected after installation do not show significant improvement in percent of drivers yielding to pedestrians, and in percent of drivers making RTOR who come to a complete stop. However, a significant increase in the percent of pedestrians who look for vehicles before beginning to cross is found in before after analysis of the data.

The increment in percent of pedestrians who pushed the call button, percent of pedestrians who look for vehicles before beginning to cross the roadway, percent of pedestrians beginning their crossing during the “WALK” phase “after” installation of the sign shows an indication of improving crossing behavior. The decrease in the percent of pedestrians in the crosswalk at the end of all-red is an indication of increased safety for pedestrians. The decrease in the percent of drivers blocking crosswalk indicates that motorists are stopping/yielding far away from the pedestrians, thus increasing safety for pedestrians. There is a significant increase in the percent of drivers coming to complete stop before making a RTOR after the installation of the ITS “No-Turn On Red” Sign.

**Smart Lighting and Automatic Pedestrian Detection Devices**

Smart lighting and automatic pedestrian detection devices are installed at one location in the Las Vegas area: Charleston Boulevard: Spencer Street and 17th street. As smart lighting is linked with the automatic detection of pedestrian, both the countermeasures are installed at the same time.

Table 4 summarizes the data collected “before” and “after” the installation of the countermeasure. It also shows the statistical analysis of the same. During both the “before” and “after” data collection periods, all the observed pedestrians look for vehicles before beginning to cross and before crossing second half of the roadway. Data show that the countermeasures installed results in increase in the number of diverted pedestrians. In addition, the proportion of pedestrians trapped in the roadway reduced “after” installation of the countermeasures. An increase in the proportion of drivers who stop/yield to pedestrians at a distance greater than 20 feet is observed in the after data collection. However, a notable proportion of drivers blocked the crosswalk during after data collection. The increase in the proportion of drivers yielding at 10 feet to 20 feet are statistically significant (P<0.001). There is no significant increase in the proportion of drivers blocking the crosswalk from stage 1 to stage 2 at this location as shown in Table 3 (P>0.05).

It is clear that implementation of ITS pedestrian detection device and smart lighting has a significant effect in increasing the proportion of diverted pedestrians and decreasing the proportion of pedestrians trapped in the roadway, thereby increasing the pedestrian safety.

**Portable Speed Trailer**

Portable speed trailer with the customized messages were installed at two locations. These locations are (1) Twain Avenue: Swenson Street to Palos Verdes Street and (2) Fremont Street: Between 6th and 8th streets. At location 1: the average pedestrian delay “before” the installation of the countermeasure is 9.8 sec/ped. There is a reduction in average pedestrian delay “after” the installation of the countermeasure compared to baseline data. It is clear from Table 5 that there is no significant increase in the proportion of drivers yielding to pedestrians in stage 1 compared to baseline (P>0.05). Similar is the case at location 2, where in the after data, the proportion of
drivers yielding to pedestrians slightly decreased to 0.29. Since the location is a midblock, the distance of drivers stopping/yielding before crosswalk and the percent of drivers blocking the crosswalk are not applicable.

Statistical tests revealed no significant difference in results obtained for average pedestrian delay and average vehicle delay. The decrease in eastbound mean speed is found to be significant for all three cases as seen in Tables 5. The decrease in the westbound mean speed, when baseline data is compared with “before” and “after” is found to be significantly different. However, difference obtained in westbound mean speed between “before” and “after” deployment of portable speed trailer is not statistically significant as seen in Table 5.

Overall at both the locations, the speed trailer decreased the vehicle speeds and increased the yielding behavior of the drivers thereby increasing the pedestrian safety at the installed locations. However, the effects of the speed trailer are not permanent and the benefits vanish once the speed trailer was removed from the locations.

CONCLUSIONS

This paper presents an evaluation of “ITS No Turn on Red”, “smart lighting and automatic pedestrian detection devices”, and “portable speed trailer” to enhance pedestrian safety by comparing data collected “before” and “after” installation of these ITS based countermeasures. Change in proportion of measures of effectiveness along with Z-test and T-test was used to draw meaningful conclusions.

Motorists are more cautious before they make a right turn and thereby increasing the pedestrian safety at the intersection with “ITS No Turn on Red” sign. More drivers tend to stop/yield at 10-20 ft from crosswalk. Also improvement in pedestrian behavior was also observed at this location. More pedestrians pushed the call button for the “ITS No Turn on Red” sign to be activated.

A decrease in number of pedestrians trapped in the roadway and increase in percent of drivers yielding to pedestrians was observed after installation “smart lighting and automatic pedestrian detection device”. Drivers tend to stop/yield at >20 ft from crosswalk at midblock with this countermeasure.

Observations show an improvement in driver yielding behavior at locations with installation of “portable speed trailer”. However, speed trailer effects are limited only to the installation time. Once the speed trailer is removed from the locations, the vehicle speeds are back to the prior conditions.

Evaluation of crash data was not included in the current scope of the paper due to lack data “after” installation of the countermeasures. Evaluating the effectiveness of these countermeasures using crash data warrants investigation.

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**DISCLAIMER**

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<td>2.40</td>
<td>6</td>
</tr>
<tr>
<td>2003</td>
<td>1.63</td>
<td>2.90</td>
<td>3</td>
</tr>
</tbody>
</table>

## TABLE 2 Study Locations and Characteristics

<table>
<thead>
<tr>
<th>Study Location</th>
<th>Location Type</th>
<th>Countermeasure(s)</th>
<th># Lanes</th>
<th>ADT*</th>
<th>Speedlimit (mph)</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flamingo Rd / Koval Ln</td>
<td>Intersection</td>
<td>1</td>
<td>8</td>
<td>63,000</td>
<td>45</td>
<td>Commercial</td>
</tr>
<tr>
<td>Charleston Blvd: 17th - Spensor St</td>
<td>Mid-block</td>
<td>2, 3</td>
<td>7</td>
<td>39,000</td>
<td>45</td>
<td>Residential / Commercial</td>
</tr>
<tr>
<td>Fremont St: 6th - 8th</td>
<td>Mid-block</td>
<td>4</td>
<td>5</td>
<td>13,000</td>
<td>25</td>
<td>Commercial</td>
</tr>
<tr>
<td>Twain Ave: Palos Verdes - Swenson</td>
<td>Mid-block</td>
<td>4</td>
<td>5</td>
<td>18,000</td>
<td>35</td>
<td>Residential</td>
</tr>
</tbody>
</table>

* For year 2007

Countermeasure
1. ITS No Turn on Red Sign
2. Smart Lighting
3. Automatic Pedestrian Detection Devices
4. Portable Speed Trailer
# TABLE 3 Summary of Results – “ITS No Turn on Red” Sign

<table>
<thead>
<tr>
<th>Measures of Effectiveness (Safety)</th>
<th>Total Sample</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent signal cycles in which call button has been pushed</td>
<td>202</td>
<td>172</td>
<td>85</td>
</tr>
<tr>
<td>Percent pedestrians who look for vehicles before beginning to cross</td>
<td>202</td>
<td>194</td>
<td>96</td>
</tr>
<tr>
<td>Frequency of pedestrian signal violation</td>
<td>202</td>
<td>22</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures of Effectiveness (Safety)</th>
<th>Total Sample</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of drivers making RTOR who come to a complete stop</td>
<td>276</td>
<td>132</td>
<td>48</td>
</tr>
<tr>
<td>Percent of drivers violating the no RTOR (when pedestrian present)</td>
<td>276</td>
<td>88</td>
<td>32</td>
</tr>
<tr>
<td>Percent of drivers violating the no RTOR (when pedestrian not present)</td>
<td>276</td>
<td>188</td>
<td>68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures of Effectiveness (Safety)</th>
<th>Before vs. After</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOEs below are tested for H₀: ( P_{\text{before}} = P_{\text{after}} ) vs. ( H₀: P_{\text{after}} &gt; P_{\text{before}} )</td>
<td></td>
</tr>
<tr>
<td>Percent signal cycles in which call button has been pushed</td>
<td>( -0.05 ) &gt; 0.05 \uat \text{Reject}</td>
</tr>
<tr>
<td>Percent pedestrians who look for vehicles before beginning to cross</td>
<td>( -0.09 ) &lt; 0.001 \text{Reject}</td>
</tr>
<tr>
<td>Percent of pedestrians beginning their crossings during the WALK phase</td>
<td>(</td>
</tr>
</tbody>
</table>

Frequency of pedestrian signal violation | \( -0.06 \) \> 0.05 \text{Do not reflect} |

Percent of pedestrians in crosswalk at the end of flashing DON'T WALK | \(| \text{DONT WALK} |

Percent of pedestrians in crosswalk at the end of All-Red | \(| \text{DONT WALK} |
TABLE 4 Summary of Results – Smart Lighting and Automatic Pedestrian Detection Devices

<table>
<thead>
<tr>
<th>Pedestrians</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
<th>P-Value</th>
<th>H0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent pedestrians who look for vehicles before beginning to cross</td>
<td>No Change</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Percent of captured pedestrians</td>
<td>0.167</td>
<td>&gt;0.05</td>
<td>Do not Reject</td>
</tr>
<tr>
<td></td>
<td>Percent of diverted pedestrians</td>
<td>-0.167</td>
<td>&lt;0.001</td>
<td>Reject</td>
</tr>
<tr>
<td></td>
<td>Percent of pedestrians trapped in the roadway</td>
<td>0.152</td>
<td>&lt;0.05</td>
<td>Reject</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motorists</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
<th>P-Value</th>
<th>H0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percent of drivers yielding to pedestrians</td>
<td>-0.78</td>
<td>&lt;0.001</td>
<td>Reject</td>
</tr>
<tr>
<td></td>
<td>Distance driver stops/yields before crosswalk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 10 feet</td>
<td>0.058</td>
<td>&gt;0.05</td>
<td>Do not Reject</td>
</tr>
<tr>
<td></td>
<td>10-20 feet</td>
<td>0.28</td>
<td>&gt;0.05</td>
<td>Do not Reject</td>
</tr>
<tr>
<td></td>
<td>&gt;20 feet</td>
<td>-0.121</td>
<td>&lt;0.05</td>
<td>Reject</td>
</tr>
<tr>
<td></td>
<td>Percent of drivers blocking crosswalk</td>
<td>-0.121</td>
<td>&gt;0.05</td>
<td>Do not Reject</td>
</tr>
</tbody>
</table>
TABLE 5 Summary of Results – Portable Speed Trailer

Location: Fremont Street: 6th to 8th street

<table>
<thead>
<tr>
<th>Pedestrians</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PBefore – PAfter</td>
<td>P-value</td>
</tr>
<tr>
<td>Percent of pedestrians trapped in the roadway</td>
<td>-0.009</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Percent of pedestrians who look for vehicles before beginning to cross</td>
<td>No Change</td>
<td></td>
</tr>
<tr>
<td>Frequency of pedestrian signal violation</td>
<td>0.023</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Percent of pedestrians who begin their crossing during WALK phase</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motorists</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PBefore – PAfter</td>
<td>P-value</td>
</tr>
<tr>
<td>Percent of drivers yielding to pedestrians at crosswalk</td>
<td>0.238</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>Distance driver stop between crosswalk and stop bar</td>
<td>0.64</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Distance driver stop away from stop bar</td>
<td>-0.76</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Percent of drivers blocking crosswalk</td>
<td>0.119</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

Location: Twain Avenue: Palos Verdes Street to Swenson Street

<table>
<thead>
<tr>
<th>Pedestrian</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PBefore – PAfter</td>
<td>P-value</td>
</tr>
<tr>
<td>Percent pedestrians who look for vehicles</td>
<td>No Change</td>
<td></td>
</tr>
<tr>
<td>Percent of captured pedestrians</td>
<td>No Change</td>
<td></td>
</tr>
<tr>
<td>Percent of diverted pedestrians</td>
<td>No Change</td>
<td></td>
</tr>
<tr>
<td>Percent of pedestrians trapped in the roadway</td>
<td>-0.03</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motorists</th>
<th>Measures of Effectiveness (Safety)</th>
<th>Statistical Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PBefore – PAfter</td>
<td>P-value</td>
</tr>
<tr>
<td>Percent of drivers yielding to pedestrians</td>
<td>0.06</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>
(a) ITS No Turn on Red Signs

(b) Smart Lighting and Automatic Pedestrian Detection Devices

(c) Portable Speed Trailer

FIGURE 1 ITS Based Countermeasures installed in Las Vegas Metropolitan Area