AN EVALUATION OF EFFECTIVENESS OF TRAFFIC SIGNS TO ENHANCE PEDESTRIAN SAFETY

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An Evaluation of Effectiveness of Traffic Signs to Enhance Pedestrian Safety

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ABSTRACT
This paper summarizes an evaluation of the effectiveness of traffic signs to improve driver behavior and contribute to enhanced pedestrian safety. Traffic signs considered for evaluation include “turning traffic must yield to pedestrians” sign, advance yield markings with “yield here to pedestrian” sign, and in-roadway knockdown signs. The evaluations are based on field observations of pedestrian and driver behaviors “before” and “after” installation of countermeasures at select locations in Las Vegas, Nevada. The effectiveness of “turning traffic must yield to pedestrians” sign at intersections was evaluated using proportion of pedestrians who looked for turning vehicles, proportion of pedestrians who were struck in crosswalks during flashing “DON’T WALK” and “DON’T WALK” phases, drivers yielding to pedestrians when turning on red or green, pedestrian delay and vehicle delay as measures of effectiveness. On the other hand, the effectiveness of advance yield markings with “yield here to pedestrian” sign and in-roadway knockdown signs at midblock locations was evaluated using proportion of pedestrians who looked to their left and right before and while crossing, proportion of pedestrians who changed their course of action, proportion of drivers who yielded to pedestrians, the distance from the crosswalk at which drivers yielded to pedestrians, pedestrian delay and vehicle delay as measures of effectiveness. The results show statistically significant improvement in driver yielding behavior due to installation of the above countermeasures. 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, traffic signs

INTRODUCTION
Crash statistics published by National Highway Safety Administration’s (NHTSA) National Center for Statistics Analysis indicate 4,654 pedestrian fatalities and 70,000 pedestrian injuries in road crashes in the United States during 2007\textsuperscript{(1)}. An urban area like Las Vegas, Nevada reports at least 40 pedestrian fatalities and 500 pedestrian injuries per year in road crashes. Strategies to enhance pedestrian mobility and safety range from traffic signs and signals to those that are

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This paper is based on efforts from a Federal Highway Administration (FHWA) sponsored program to enhance pedestrian safety in Las Vegas, Nevada and identify suitable pedestrian safety countermeasures for large-scale deployment in Las Vegas, Nevada and other areas as well. As a part of this program, high pedestrian risk locations with suitable pedestrian safety countermeasures were selected based on geocoded pedestrian crash data and crash rates, demographic characteristics, land use characteristics and traffic characteristics (11, 12, 13).

This paper focuses on an evaluation and comparison of pedestrian and driver behaviors “after” installation of the following low cost traffic signs to enhance pedestrian safety in Las Vegas, Nevada.

1. “Turning traffic must yield to pedestrian” sign
2. Advance yield markings with “yield here to pedestrian” sign
3. In-roadway knockdown signs – “yield to pedestrian within crosswalk” and “watch for pedestrian”

The cost of manufacturing and installing these signs varied from $100 to $500. While the first sign is typically used at intersections, the other signs are used at midblock locations. Note that these signs are typically installed to influence (improve) driver behavior.

DESCRIPTION OF SELECTED TRAFFIC SIGNS
A brief description of the traffic signs considered for evaluation to enhance pedestrian safety in this paper is presented next. Problems typically addressed using these traffic signs are listed below description of each sign.

“Turning Traffic Must Yield to Pedestrian” Sign
This countermeasure is a symbol sign that reminds turning drivers that they must yield to pedestrians at traffic signals. The distance at which the sign is placed could vary (say, next to the traffic signal on the far side of the intersection, 50 feet ahead of intersection, etc.) and play a role in enhancing safety. Turning traffic must yield to pedestrian sign are typically provided as recommended in MUTCD 2003, Section 2B.45 (R10-15) (14).

Problems addressed
• Pedestrian do NOT wait for signals/ acceptable gaps
• High pedestrian/ right turning vehicle conflicts

Advance Yield Markings with “Yield Here to Pedestrian” Sign
Installation of yield markings 30 to 50 feet in advance of crosswalks at uncontrolled locations produces a clear zone for pedestrians to reduce conflicts and crashes caused by the screening effect of vehicles on multilane streets. Advance yield markings are typically provided as recommended in MUTCD 2003, Section 3B.16 (14). Additionally, a sign displaying yield to pedestrians is provided as recommend in MUTCD 2003, Section 2B.11 (R1-5a) (14).
Problems addressed

- Driver failure to yield
- Pedestrian failure to yield
- High speed / high traffic volume

In-roadway Knockdown Signs

Pedestrian in-roadway knockdown sign or the in-street pedestrian crossing sign are used to remind drivers for pedestrians’ right of way at a crossing or to warn drivers about pedestrian traffic at a midblock. At midblock with a crosswalk, the legend “STATE LAW” is shown at the top of the sign if applicable. The legends “YIELD TO” may be used in conjunction with the appropriate symbol as recommended in MUTCD 2003, Section 2B.12 (R1-6) (14). At midblock without a crosswalk, the legend “WATCH FOR” with pedestrian pictogram is proposed for this study. Both these signs are expected to be effective in increasing the number of drivers stopping for pedestrians and reducing the number of pedestrians, who had to run, hesitate, or abort their crossing.

Problems addressed

- Pedestrian do NOT use the crosswalks
- Pedestrian trapped in the middle of street
- Driver failure to yield
- Pedestrian failure to yield
- High speed / high traffic volume

LITERATURE REVIEW

A review of literature on traffic signs selected for evaluation in this paper is presented next.

“Turning Traffic Must Yield to Pedestrian” Sign

Abdulsattar et al. (15) evaluated the effectiveness of the “turning traffic must yield to pedestrians” sign at 12 marked crosswalks. The authors state that the sign was effective in reducing left-turn conflicts by 20 to 65 percent, and right-turn conflicts by 15 to 30 percent. Both reductions are statistically significant at 95 percent confidence level.

Abdulsattar and McCoy (16) conducted drivers’ comprehension of a “turning traffic must yield to pedestrians” sign among different age groups during turning maneuvers. For the left-turn situation, drivers under 56 years paid more attention to the sign than older drivers. During right-turn movements, drivers and pedestrians always are in interaction, unless exclusive right-turn phase is provided. However, this research lacks information on other measures of effectiveness such as drivers’ yielding behaviors, pedestrian and vehicular delay, and vehicle speed.

Retting et al. (17) discussed an experiment in which special signs and pavement markings were used to prompt pedestrians to look for turning vehicles. Three signalized intersections were chosen, two in Nova Scotia, Canada, and one in Clearwater, Florida for the study. All sites are studied before, immediately after, and approximately one year after prompts are introduced. Results showed improvements in pedestrian looking for vehicles before crossing.
Advance Yield Markings with “Yield Here to Pedestrian” Signs

Van Houten and Malenfant (18) evaluated the effectiveness of signs reading “STOP HERE FOR PEDESTRIANS” alone 50 feet upstream of crosswalk and in conjunction with advance stop lines at multilane crosswalks with pedestrian activated amber flashing lights. Results indicated that signs alone increased the distance that drivers stopped upstream of the crosswalk when yielding to pedestrians and also decreased the percent of motor vehicle-pedestrian conflicts. The addition of advance stop lines produced a further increase in the distance that drivers stopped upstream of the crosswalk and further reductions in the percent of motor-vehicle conflicts. These results are observed under conditions when pedestrians activated and did not activate the amber flashing crosswalk light. It is also observed that the percent of pedestrians activating the light seemed to be a function of the amount of traffic on the street.

Van Houten, et al. (19) studied two problems; the difference between the ‘yield’ and ‘stop’ situation while using the advance stop lines, and the use of text rather than symbol sign to support the markings. The advance yield markings and signs are placed at different distances in advance of the crosswalks to determine their effectiveness. Driver and pedestrian behaviors measured included the occurrence of motor vehicle/pedestrian conflicts such as evasive action, the distance drivers stopped before the crosswalk when yielding to pedestrians, and the percent of drivers yielding to pedestrians. It was found that placing advance yield markings and signs as close as 10 m upstream of the crosswalk and as far back as 15 m or even 25 m in advance of the crosswalk is effective. Although not all vehicles stopped at or near the yield lines, many drivers stopped 9 m or more upstream the crosswalk. It was noted that drivers tended to stop closer to the crosswalk during the treatment condition when traffic was heavy and vehicles are traveling slowly. Much of the improved yielding was likely the result of improved visibility of pedestrians crossing in front of vehicles stopped in advance of the crosswalk.

Huybers et al. (20) studied the effects of a symbolic “yield here to pedestrians” sign and advance yield pavement markings on pedestrian/motor vehicle conflicts, drivers’ yielding behavior, and the distance drivers’ yield in advance of crosswalks at multilane crosswalks at uncontrolled T intersections. When the sign symbolic was used alone, there was a reduction in pedestrian/motor vehicle conflicts and increased driver yielding distance. Further, decrease in pedestrian/motor vehicle conflicts and increase in yielding distance was observed with the addition of advance yield pavement markings.

In-roadway Knockdown Signs

Ellis Jr. et al. (21) studied the effect of placing in-roadway knockdown sings at the crosswalk, 20 ft in advance of the crosswalk and 40 ft in advance of the crosswalk. Data collected showed that the sign produced a marked increase in yielding behavior at all 3 crosswalks on Collins Avenue in Miami Beach, Florida. It was found to be effective or more effective when placed at the crosswalk.

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.
The pedestrians’ crossing behaviors were observed at a crosswalk and approximately within 200 feet from a crosswalk at all approaches of an intersection. All pedestrians were observed at midblock locations, 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.

“Turning Traffic Must Yield to Pedestrian” Sign
The following MOEs were used to evaluate the effectiveness of “turning traffic must yield to pedestrian” sign.

1. Pedestrians who looked for turning vehicles at the start of “WALK” phase
2. Pedestrians who were in the crosswalk during flashing “DON’T WALK” phase
3. Pedestrians who were in the crosswalk at the end of flashing “DON’T WALK” phase
4. Drivers yielding at right turn on red (in presence of pedestrian at turn or approach)
5. Drivers yielding at right turn on green (in the presence of pedestrian at turn or approach)
6. Vehicles blocking the crosswalk
7. Pedestrian delay
8. Vehicle delay

MOEs 1 was 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 during different signal phases. MOEs 2 and 2 are used to indicate if pedestrians were trapped in the crosswalk in addition to their crossing behavior. MOE 4 and 5 are used to analyze motorist compliance rate. MOE 6 was used to study vehicles blocking the crosswalk. MOEs 7 and 8 are related to pedestrian and vehicle delay – operational characteristics. These MOEs are explained next.

Pedestrians Who Looked for Turning Vehicles during the “WALK” phase: This MOE represents the proportion of total pedestrians who steps from the curb into the crosswalk and looked for turning vehicles during the “WALK” phase.

Pedestrians Who Were in the Crosswalk during Flashing “DON’T WALK” Phase: This MOE represents the proportion of pedestrians who initiated their crossing either during “WALK” or flashing “DON’T WALK” phase and are in the crosswalk during flashing “DON’T WALK” phase.

Pedestrians Who Were in the Crosswalk at the End of flashing “DON’T WALK” Phase: This MOE represents the proportion of total pedestrians who stepped from the curb into the crosswalk either during “WALK” or flashing “DON’T WALK” phase and are still in the crosswalk at the end of flashing “DON’T WALK” phase.
**Driver Yielding at Right-turn on Red:** A driver is scored as coming to a complete stop on red if the wheels stopped turning before they enter the crosswalk. A driver is scored as coming to rolling stop on red if the vehicle slows considerably, but the wheels do not stop turning before entering the crosswalk. If the driver turns without appreciably slowing on red, they are scored as without slowing. This MOE is reported in terms of the proportion of total observed vehicles during the study period when only in the presence of pedestrian at turn or approach.

**Driver Yielding at Right-turn on Green:** A driver is scored as coming to a complete stop on green if the wheels stopped turning before they enter the crosswalk. A driver is scored as coming to rolling stop on green if the vehicle slows considerably, but the wheels do not stop turning before entering the crosswalk. If driver turns without appreciably slowing on green, they are scored as without slowing. This MOE is reported in terms of the proportion of total observed vehicles during the study period when only in the presence of pedestrian at turn or approach.

**Vehicles Blocking the Crosswalk:** A vehicle is scored as "blocking the crosswalk” if it encroaches the crosswalk. These data on the vehicles that block the crosswalk are converted into the proportion of total observed vehicles during the study period.

**Pedestrian Delay:** Pedestrian delay is the time a pedestrian has to wait before crossing the street at a marked or unmarked crosswalk. The duration starts when a pedestrian first orients to make the crossing and ends when they begin to cross. Pedestrian delays are measured using a stopwatch. At a signalized intersection, the stopwatch is started at the beginning of the flashing “DON’T WALK” phase. Each time a pedestrian arrives at a crossing area and prepares to cross the street, the time on the stopwatch is recorded for that pedestrian. When the “WALK” signal is displayed, the time appear on the stopwatch is recorded. The difference in time between the “WALK” signal display and the time each pedestrian spent waiting to cross the street is the individual pedestrian delay. The delay is averaged and reported based on the total observations. Pedestrian signal violators are not scored (i.e., pedestrians crossing during the flashing “DON’T WALK” or during the solid “DON’T WALK” phase).

**Vehicle Delay:** This MOE represents an average amount of time a vehicle has stopped waiting at a traffic signal and/or yielding to a crossing pedestrian. The average vehicle stopped delay was measured using standard methodologies for conducting stopped delay studies at intersections.

**Advance Yield Markings with “Yield Here to Pedestrian” and In-Roadway Knockdown Signs**

The following MOEs were used to evaluate the effectiveness of advance yield markings with “yield here to pedestrian” and in-roadway knockdown signs.

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

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 4 is to study if the countermeasures attract more pedestrians (who were previously crossing all along the corridor) to cross at the designated crosswalk and thus contribute to improved pedestrian safety at the test location. MOE 5 was selected to analyze motorist compliance rate, and MOE 6 was selected to study and identify the yielding distance preferred by motorists yielding to pedestrians. MOEs 7 and 8 are related to pedestrian and vehicle delay. 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 proportion 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 proportion of the total pedestrians observed during the study period.

Captured Pedestrians: This MOE indicates the proportion of pedestrians who modified their paths to use a safety countermeasure, but who do not go out of their way to do so.

Diverted Pedestrians: This MOE represents the proportion of pedestrians who modified their paths to use a safety countermeasure, and who went out of their way to do so. In this case, unlike “captured” pedestrians, these pedestrians would have to divert from their shortest path and walk some additional distance to use the safety countermeasure. This was determined based on observations of “back-tracking” movements by pedestrians.

Drivers Yielding to Pedestrians: At signalized intersections, the proportion of drivers who stop or slow to allow pedestrians to cross in front of them before proceeding was observed. Drivers’ yielding behavior was only scored when pedestrians have the right of way (i.e., during the “WALK” phase or during the flashing “DON’T WALK” phase if pedestrians started crossing when the “WALK” signal was displayed). At midblock locations, 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 Delay:** This MOE represents an average amount of time a vehicle has stopped yielding  
to a crossing pedestrian. The average vehicle stopped delay was measured using standard  
methodologies for conducting stopped delay studies at midblock locations.

**ANALYTICAL METHODS**

A Z-test was used to evaluate the effectiveness of the installed traffic signs 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  
observed 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  
\((P_A)\) is the same. The alternative hypothesis \((H_a)\) is the proportion of MOE during “after” \((P_A)\)  
period is greater than the proportion of MOE during “before” period \((P_B)\). They are expressed as  
follows:

\[
H_0: P_B = P_A \\
H_a: P_B < P_A
\]

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:

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

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 \( \mathcal{N}(0, 1) \) when \( H_0 \) is true.
The significant probability or P-value for equality of proportions vs. the 1-sided alternative is calculated by $P(Z < Z_0)$. 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 $M_B = \text{population mean during before evaluation period}$, $n_B = \text{number of observations during before evaluation period}$, $\bar{x}_B = \text{sample mean of } n_B \text{ observations}$, and $s^2_B = \text{sample variance of observations during before study}$. Similarly, $M_A$, $n_A$, $\bar{x}_A$, and $s^2_B$ 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:

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

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

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 1 summarizes traffic signs 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 traffic signs in this paper.

Tables 2, 3, and 4 summarize results obtained for “turning traffic must yield to pedestrian”, advance yield markings with “yield here to pedestrian”, in-roadway knockdown – “yield to pedestrian within crosswalk”, and in-roadway knockdown – “watch for pedestrian” signs. A negative sign for difference in “before” and “after” value in tables indicates an increase whereas a positive indicates otherwise.

“Turning Traffic Must Yield to Pedestrian” Sign
“Turning traffic must yield to pedestrians” was installed at two intersections: Harmon Ave / Paradise Rd, and Lake Mead Blvd / Pecos Rd. It was installed without any other countermeasure to evaluate their effectiveness individually. Figure 1(a) shows “turning traffic must yield to pedestrian” sign installed at one of the intersections in Las Vegas, Nevada.

Table 2 summarizes difference in MOE “before” and “after” installation along with results from statistical analysis. An increase in proportion of pedestrians who looked for turning vehicles was only observed at Harmon Ave / Paradise Rd intersection. However, a decrease in pedestrians who were in the crosswalk during and at the end of flashing “DON’T WALK” phase was observed at both intersections.

An increase in the proportion of the drivers looking for pedestrians before turning on red was observed at both intersections. On the other hand, vehicles blocking crosswalk was only observed at Harmon Ave / Paradise Rd intersection.

Statistical analysis also shows an improvement in driver behavior at both intersections. As expected the sign have been effective in improving driver yielding behavior as more number of drivers yielded to pedestrians “after” the installation of the sign. Other safety MOEs do not show any specific statistical trends.

Analysis based on mobility MOEs indicates an increase in pedestrian delay and vehicle delay “after” the installation of the sign at both the intersections. However, the increase was not observed to be statistically significant (except in case of pedestrian delay at one intersection).

Advance Yield Markings with “Yield Here to Pedestrian” Sign
Advance yield markings with “yield here to pedestrian” sign were installed at two midblock locations: Harmon Ave: Paradise Rd to Tropicana Wash, and, Maryland Pkwy / Dumont St. Figure 1(b) shows advance yield marking with “yield here to pedestrian” sign at one of the midblock locations in Las Vegas, Nevada. While other countermeasures were deployed as a part of FHWA pedestrian safety program at these locations, the effectiveness of advance yield markings with “yield here to pedestrian” sign was evaluated individually by collecting data “before” and “after” its installation.

Table 3 summarizes difference in MOE “before” and “after” installation along with results from statistical analysis. Observations show an improvement in pedestrian crossing behavior “after” installation of advance yield markings with “yield here to pedestrian” sign (though the countermeasure does not interact directly with pedestrians). However, it was not statistically significant at a 95 percent confidence level.
Results indicate that there was a significant increase in proportion of drivers yielding to pedestrians. However, this was statistically significant at only one midblock location.

Analysis considering distance driver stops/yield before the crosswalk show a shift in yielding distance from <10 ft and >20 ft to 10-20 ft range. An increase in proportion of drivers yielding at 10-20 ft was observed at both midblock locations. This was observed to be statistically significant at a 95 percent confidence level. Overall, consistent favorable results across both the locations indicate that advance yield markings with “yield here to pedestrian” sign do play a vital role in enhancing safety at midblock locations.

Analysis based on mobility MOEs indicates a decrease in pedestrian delay at both midblock locations and vehicle delay at one midblock location “after” the installation of advanced yield marking with “yield here to pedestrian” sign. However, the decrease was only statistically significant in case of pedestrian delay at one midblock location.

**In-roadway knockdown signs**

In-roadway knockdown signs were installed at 3 midblock locations. The sign with “yield to pedestrian within crosswalk” was installed at two midblock locations - Harmon Ave: Paradise Rd to Tropicana Wash, and, Bonanza Rd: D St to F St. The sign with “watch for pedestrian” was installed along Twain Ave: Swenson St and Palos Verde St midblock location. Figure 1(c) shows in-roadway knockdown signs used for analysis in this paper. While other countermeasures were installed as a part of FHWA pedestrian safety program at these locations, data collected “before” and “after” installing in-roadway knockdown signs individually were used for evaluation.

Table 4 summarizes difference in MOE “before” and “after” installation along with results from statistical analysis for sign with “yield to pedestrian within crosswalk”. Results showed that there was a significant increase in captured pedestrians (possible due to shift in crossing patterns for diverted pedestrians in the “before” condition) at both midblock locations. This was statistically significant at a 95 percent confidence level.

Observations indicate a decrease in drive yielding behavior after installation of “yield to pedestrian within crosswalk” in-roadway knockdown sign. While most drivers tend to prefer <10 feet as yielding distance along Harmon Ave: Paradise Rd to Tropicana Wash midblock location, the preferred yielding distance seems to be greater than 10 ft along Bonanza Rd: D St to F St midblock location.

Analysis based on mobility MOEs indicates a general decrease in pedestrian delay and vehicle delay “after” the installation of “yield to pedestrian within crosswalk” sign. However, the decrease was only statistically significant in case of vehicle delay at one midblock location.

Table 4 also summarizes difference in MOE “before” and “after” installation along with results from statistical analysis for sign with “watch for pedestrian”. Observations indicate an increase in pedestrians looking for vehicles before beginning to cross or before crossing 2nd half of street. The results are statistically significant at a 95 percent confidence level. In addition, an improvement in driver yielding behavior was observed. This was also statistically significant at a 95 percent confidence level.

Analysis based on mobility MOEs indicates a decrease in pedestrian delay and vehicle delay along midblock location “after” the installation of “watch for pedestrian” sign. However, the decrease was not statistically significant.

Overall, observations show that “watch for pedestrian” in-roadway knockdown sign is very effective in improving pedestrian and driver yielding behavior than when compared to “yield to pedestrians in crosswalk” in-roadway knockdown sign.
CONCLUSIONS
This paper presents an evaluation of “turning traffic must yield to pedestrian”, advance yield marking with “yield here to pedestrian”, and in-roadway knockdown signs to enhance pedestrian safety by comparing data collected “before” and “after” installation of these signs. Change in proportion of measures of effectiveness along with Z-test and T-test was used to draw meaningful conclusions.

Observations show an improvement in driver yielding behavior at locations with installation of “turning traffic must yield to pedestrian” sign. Installation of advance yielding markings with “yield here to pedestrian” sign results in improved driving behavior. More drivers tend to stop/yield at 10-20 ft from crosswalk. However, improvement in pedestrian behavior was not observed to be statistically significant.

In-roadway knockdown sign with “yield to pedestrian within crosswalk” at crosswalks along midblock location was effective in capturing pedestrians’. However, results do not show statistically significant improvement in driver yielding behavior due to this countermeasure. On the other hand, in-roadway knockdown sign with “watch for pedestrians” along midblock locations with no crosswalk was very effective in improving pedestrian crossing and driver yielding behavior.

While pedestrian and vehicle delay was observed to generally decrease (except in case of advance yield markings with “yield here to pedestrian” sign), it was not observed to statistically significant. Thus, it can be concluded that traffic signs in general do not change operational performance.

The evaluation of traffic signs using crash data merits further study.

REFERENCES


**ACKNOWLEDGMENTS**

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**DISCLAIMER**

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**TABLE 1 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>Speed Limit (mph)</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmon Ave / Paradise Rd</td>
<td>Intersection</td>
<td>2</td>
<td>5</td>
<td>17,100</td>
<td>35</td>
<td>Residential, commercial,</td>
</tr>
<tr>
<td>Lake Mead Blvd / Pecos Rd</td>
<td>Intersection</td>
<td>2</td>
<td>7</td>
<td>44,000</td>
<td>45</td>
<td>Residential</td>
</tr>
<tr>
<td>Harmon Ave: Paradise Rd to Tropicana Wash</td>
<td>Midblock</td>
<td>1, 3</td>
<td>5</td>
<td>17,100</td>
<td>35</td>
<td>Residential, commercial, recreational</td>
</tr>
<tr>
<td>Maryland Pkwy / Dumont St</td>
<td>Midblock</td>
<td>1</td>
<td>7</td>
<td>43,000</td>
<td>30 / 25</td>
<td>Commercial, residential</td>
</tr>
<tr>
<td>Bonanza Rd: D St to F St</td>
<td>Midblock</td>
<td>4</td>
<td>7</td>
<td>20,100</td>
<td>35</td>
<td>Commercial</td>
</tr>
<tr>
<td>Twain Ave: Cambridge St to Swenson St</td>
<td>Midblock</td>
<td>4</td>
<td>5</td>
<td>21,400</td>
<td>35</td>
<td>Residential, commercial</td>
</tr>
</tbody>
</table>

* ADT is for year 2006

**Countermeasure:**

1. Advance yield markings with "yield here to pedestrian" sign
2. "Turning vehicles yield to pedestrian" sign
3. In-roadway (yield) knockdown sign
4. In-roadway (watch) knockdown sign
TABLE 2 Summary of Results – “Turning traffic must yield to pedestrians” Sign

<table>
<thead>
<tr>
<th>Measures of Effectiveness</th>
<th>Harmon Av / Paradise Rd</th>
<th>Lake Mead Blvd / Pecos Rd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrians who looked for turning vehicles during the &quot;WALK&quot; phase</td>
<td>-0.396</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pedestrians who were in the crosswalk during flashing &quot;DON'T WALK&quot; phase</td>
<td>0.017</td>
<td>&gt;0.005</td>
</tr>
<tr>
<td>Pedestrians who were in the crosswalk at the end of flashing &quot;DON'T WALK&quot; phase</td>
<td>0.006</td>
<td>&gt;0.005</td>
</tr>
<tr>
<td>Driver yielding at right turn on red (in the presence of pedestrian at turn or approach)</td>
<td>-0.120</td>
<td>&gt;0.005</td>
</tr>
<tr>
<td>Driver yielding at right turn on green (in the presence of pedestrian at turn or approach)</td>
<td>-0.031</td>
<td>&gt;0.005</td>
</tr>
<tr>
<td>Vehicles blocking crosswalk</td>
<td>0.109</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pedestrians trapped in the roadway</td>
<td>0.018</td>
<td>&gt;0.005</td>
</tr>
<tr>
<td><strong>Mobility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian delay</td>
<td>-0.167</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vehicle delay</td>
<td>-0.088</td>
<td>&gt;0.005</td>
</tr>
</tbody>
</table>
### TABLE 3 Summary of Results - Advance Yield Markings with “Yield Here to Pedestrian” Sign

<table>
<thead>
<tr>
<th>Measures of Effectiveness</th>
<th>Harmon Av: Paradise Rd to Tropicana Wash</th>
<th>Maryland Pkwy / Dumont St</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>P_B – P_A</td>
<td>P-value</td>
</tr>
<tr>
<td>Pedestrians who looked for vehicles before beginning to cross</td>
<td>No change</td>
<td>0.020</td>
</tr>
<tr>
<td>Pedestrians who looked for vehicles before crossing 2nd half of street</td>
<td>No change</td>
<td>0.030</td>
</tr>
<tr>
<td>Captured pedestrians</td>
<td>-0.040</td>
<td>0.056</td>
</tr>
<tr>
<td>Diverted pedestrians</td>
<td>0.040</td>
<td>&gt;0.050</td>
</tr>
<tr>
<td>Drivers yielding to pedestrians</td>
<td>-0.060</td>
<td>&gt;0.050</td>
</tr>
<tr>
<td>Distance driver stops/yields before the crosswalk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 ft</td>
<td>0.270</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>10-20 ft</td>
<td>-0.260</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&gt;20 ft</td>
<td>-0.006</td>
<td>&gt;0.051</td>
</tr>
<tr>
<td><strong>Mobility</strong></td>
<td>M_B – M_A</td>
<td>P-value</td>
</tr>
<tr>
<td>Pedestrian delay</td>
<td>0.900</td>
<td>&gt;0.050</td>
</tr>
<tr>
<td>Vehicle delay</td>
<td>-0.030</td>
<td>&gt;0.050</td>
</tr>
</tbody>
</table>
### TABLE 4 Summary of Results – In-roadway Knockdown Signs

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>&quot;Yield to Pedestrian Within Crosswalk&quot;</th>
<th>&quot;Watch for Pedestrian&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measures of Effectiveness</strong></td>
<td>Harmon Av: Paradise Rd to Tropicana Wash</td>
<td>Bonanza Rd: D St to F St</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrians who looked for vehicles before beginning to cross</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Pedestrians who looked for vehicles before crossing 2nd half of street</td>
<td>No change</td>
<td>No change</td>
</tr>
<tr>
<td>Captured pedestrians</td>
<td>-0.050 &lt;0.050 Reject</td>
<td>-0.120 &lt;0.001 Reject</td>
</tr>
<tr>
<td>Diverted pedestrians</td>
<td>0.050 &gt;0.050 Accept</td>
<td>0.260 &gt;0.050 Accept</td>
</tr>
<tr>
<td>Drivers yielding to pedestrians</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance driver stops/yields before the crosswalk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 ft</td>
<td>-0.050 &gt;0.050 Accept</td>
<td>0.290 &gt;0.050 Accept</td>
</tr>
<tr>
<td>10-20 ft</td>
<td>0.020 &gt;0.050 Accept</td>
<td>-0.260 &lt;0.005 Reject</td>
</tr>
<tr>
<td>&gt;20 ft</td>
<td>0.020 &gt;0.050 Accept</td>
<td>-0.006 &lt;0.050 Reject</td>
</tr>
<tr>
<td>Vehicles blocking the crosswalk</td>
<td>0.004 &gt;0.050 Accept</td>
<td>0.010 &gt;0.050 Accept</td>
</tr>
<tr>
<td>Pedestrians trapped in the roadway</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian delay</td>
<td>-2.660 &gt;0.050 Accept</td>
<td>-4.500 &gt;0.05 Accept</td>
</tr>
<tr>
<td>Vehicle delay</td>
<td>1.180 &lt;0.001 Reject</td>
<td>Not available</td>
</tr>
</tbody>
</table>
(a) “Turning Traffic Must Yield to Pedestrian” Sign.

(b) Advance Yield Markings with “Yield Here to Pedestrians” Sign.

(c) In-roadway Knockdown Signs.

FIGURE 1 Traffic Signs for Evaluation.