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Evaluation of the Effectiveness of a HAWK Signal on Compliance in Las Vegas Nevada

A. Paz, M. Khadka, N. Veeramisti, B. Morris

***Abstract*—**There is a continuous large number of crashes involving pedestrians in Nevada despite the numerous safety mechanisms currently used at roadway crossings. Hence, additional as well as more effective mechanisms are required to reduce crashes in Las Vegas, in particular, and Nevada in general. A potential mechanism to reduce conflicts between pedestrians and vehicles is a High-intensity Activated crossWalK (HAWK) signal. This study evaluates the effects of such signals at a particular site in Las Vegas. Video data were collected using two cameras, facing the eastbound and westbound traffic. One week of video data before and after the deployment of the signal were collected to capture the behavior of both pedestrians and drivers. T-test analyses of pedestrian waiting time at the curb, curb-to-curb crossing time, total crossing time, jaywalking events, and near-crash events show that the HAWK system provides significant benefits.

***Keywords*—**Pedestrian crashes, HAWK signal, traffic safety, pedestrian danger index.

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I. Introduction

OVER the last two decades, the Las Vegas metropolitan area consistently has been listed as one of the urban areas with the highest crash rate in the nation [1]-[4]. For example, in 2010, Nevada's crash rate per 100 million vehicle miles for fatal, injury, and total crashes was 1.06. In 2010, Nevada experienced 806 crashes involving pedestrians. As a result, 796 people were injured and 41 were killed [3]. The numbers have increased substantially since 2010. Last year, the total number of pedestrian fatalities in Nevada was 69 [3]. In 1990, a Pedestrian Danger Index (PDI) was developed to compare metropolitan areas based on the danger to pedestrians. The 2011 PDI value for Las Vegas – calculated using 10 years of pedestrian fatality data (2000-2009) and the 2010 Census data on walking – was 135.2; this value ranked Las Vegas as 6th among the largest metropolitan areas in U.S. [4]. The average annual pedestrian fatality rate per 100,000 was 2.5, with a total of 421 pedestrian deaths during last decade [4].

In October 2010, a pedestrian safety program based on Intelligent Transportation Systems was initiated to enhance pedestrian safety in the Las Vegas metropolitan area. The program included the evaluation and implementation of various engineering strategies as well as education about and enforce of those strategies [2]. In order to evaluate their effectiveness on influencing motorists' behaviors as well as improving pedestrians' crossing attitudes, 15 countermeasures were installed at 14 sites across the Las Vegas metropolitan area [5]. Although numerous treatments exist at road crossings, there is growing concern about their effectiveness [6]. Thus, it is important to identify and study selected treatments to determine their effectiveness.

The objective of this study was to evaluate the effectiveness of the first HAWK pedestrian safety device in Nevada. The signal was installed at a pedestrian crossing at the intersection of E. Sahara Avenue and S. 15th Street in Las Vegas. The goal was to reduce the distance between signalized pedestrian crossings, as part of the Regional Transportation Commission's (RTC) Sahara Express rapid transit project along this corridor [7].

II. Literature Review

Pedestrians are the most vulnerable traffic on the road. Research has shown that pedestrians have a tendency to select crossing locations and timing with the intention to keep moving while minimizing the walking distance and delay time. Such activities increase the risk as well as cause pedestrians disobey the signals [8], [9]. In the last decade, from 2000 to 2009, more than 47,700 pedestrians were killed and 688,000 pedestrians were injured in the United States [4]. Considering the large number of pedestrian fatalities and injuries, transportation professionals are seeking innovative devices to improve pedestrian safety in order to make roadway crossings safer, especially for senior citizens and children, who need more time to cross streets [10], [11]. Developments in geometric design features, traffic control devices, and technologies improve vehicle safety; however, specific problems associated with roadway crossings need to be addressed for pedestrian safety and access [10]. Crosswalk markings – including such various crossing treatments as adding signals with pedestrian signals, providing raised medians, speed-reducing measures, and warning and regulatory signs – have benefited both motorists and pedestrians [12].

Studies have indicated that red signals or red beacon devices have the highest compliance rates (>95%) on high-volume, high-speed streets compared to other crossing treatments [6], [13]. The HAWK system studied in City of Tucson showed that the driver compliance rate was 97% [6]. Another study conducted at the intersection of Georgia Avenue and Hemlock Street NW, Washington, D.C. in 2010, showed a similar result with an average of 97.1% for motorist compliance with the HAWK signal [13]. This study was conducted at both A.M. and P.M. periods, typically during weekdays, for 11 months at three sites after the HAWK signal

A. Paz, M. Khadka, N. Veeramisti, B. Morris are with the University of Nevada, Las Vegas, NV 89154 USA (phone: 702-895-0571; fax: 702-895-3936; e-mail: apaz@unlv.edu, khadkam@unlv.nevada.edu, veeramis@unlv.nevada.edu, brendan.morris@unlv.edu).

installation. Frequencies of motorists yielding or stopping for pedestrians were counted for at least 100 pedestrian crossing events or 4 hours of crossing events, whichever came first. However, a low pedestrian compliance with the HAWK signal (50-66%) was observed.

In 2008, it was reported that the City of Tucson had experienced approximately 1.8 crashes per year at all locations with HAWK Crossing Beacon Signals [14]. The safety performance of HAWK devices was evaluated by conducting a before-and-after study at 21 HAWK sites and 102 reference sites. This study showed that all crashes reduced by 13% to 29%, and approximately 50% reduction in pedestrian crashes [15], [16].

A study on the HAWK signal in Lawrence, Kansas showed that the signal significantly reduced unnecessary vehicle delays compared to traditional system ($p < 0.05$) [17]. This study compared the HAWK signal installed at 11th street with a traditionally signalized mid-block pedestrian crossing at Massachusetts Street. Videos captured images at both sites for 6 hours each day for 10 days. The study revealed that 42% of the total drivers understood the operation of the HAWK signal; for those drivers, the average delay time was one-tenth of the delay time for the signalized mid-block. Also, the unnecessary delay time due to pedestrian clearance was 4.3% and 50.9% for the HAWK signal and the signalized mid-block crossing, respectively.

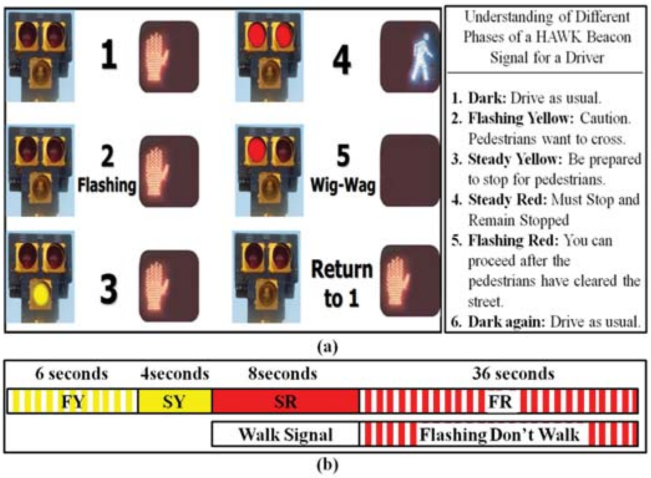
Another study examined the effectiveness of the HAWK signal activated on a mid-block crosswalk on Central Avenue near Cambridge. Observations were taken during the time periods (7:30 a.m. - 9:00 a.m. and 2:45 p.m. - 3:45 p.m.) when school children crossed the road the most. The evaluation of the signal was based on whether (i) the signal provided a safe crossing for school age children, (ii) if it minimized traffic flow interruptions, and (iii) if it prevented cut-through traffic on side residential streets. The results showed that the HAWK crosswalk was effective in achieving its goals [18].

The existing literature indicates that a HAWK signal could be a very effective to improve pedestrian safety in Las Vegas without increasing motorist delay. Before installing more HAWKs in Las Vegas, this study was required to evaluate its effectiveness under common conditions likely to be encountered in Las Vegas. In particular, it was of interest to observe both driver's and pedestrian's behavior and acceptance to this of technology new to the region.

III. Operation of a Hawk Beacon Signal

The HAWK system is a pedestrian-activated signal used to stop vehicles and allow pedestrians to cross while also allowing vehicles to proceed as soon as the pedestrians have passed [15]. The 2009 edition of the Manual on Uniform Traffic Control Devices (MUTCD) provides guidance for the application, design, and operation of pedestrian hybrid signals similar to the HAWK [19]. Fig. 1 presents the phases of the HAWK signal for motorists and pedestrians as well as signal timing.

HAWK consists of a light system for drivers and a walk-stop signal for pedestrians; it is activated only when a pedestrian activates the pushbutton. For non-active conditions, the HAWK remains dark for vehicular traffic and displays the stop signal to pedestrians. Once a pedestrian activates the system, the overhead signal begins flashing yellow (FY) for six seconds, followed by solid yellow (SY), indicating that a red signal is forthcoming. After four seconds, the HAWK signal displays a solid red (SR) to the driver, and the pedestrian gets the WALK indication. After eight seconds into the pedestrian walk interval, the red light starts flashing (FR); during the pedestrian clearance interval, a driver may proceed through the intersection if the crosswalk is clear.



(a)

(b)

Fig. 1 (a) HAWK signal lens assembly with pedestrian phasing sequence and its meaning to motorist and (b) the timing of HAWK signal lighting

IV. Site Description

The signal was installed at a pedestrian crossing at the intersection of E. Sahara Avenue and S. 15th Street in Las Vegas, Nevada to replace the existing painted crosswalk. Sahara Avenue is an eight-lane divided roadway oriented in the east-west direction; 15th Street, the stem of the T-intersection, is a two-lane undivided roadway with an orientation north of Sahara Avenue, as shown in Fig. 2 (a). This intersection was selected because Sahara Avenue is one of the busiest arterial roads in the city, and also serves as a rapid transit corridor for buses. In 2011, the average annual daily traffic (AADT) for Sahara Avenue was 40,000 [20]. Bus stops on either side of the pedestrian crossing at Sahara (whose offset induces jaywalking) are major generators of pedestrian traffic; it has nearby apartment buildings, food and drug centers, and other institutional service centers. Figs. 2 (b), (c) show the bus stops as well as the signals for motorists and the pedestrian push button at the intersection.

The location of the HAWK signal installation is depicted in Fig. 2. The newly installed HAWK signal for motorists is suspended above the roadway, facing east-west on Sahara Ave. and 15th St., and pedestrian signals reside at either end of the crosswalk. The curb-to-curb length of the crosswalk at Sahara Avenue is 118 ft., and the posted speed limit is 45 mph. In addition to the HAWK signals, other signs indicating

‘Crosswalk, STOP ON RED’, and pedestrian crossing signs mounted on the HAWK signal posts are located at the corners of the intersection.

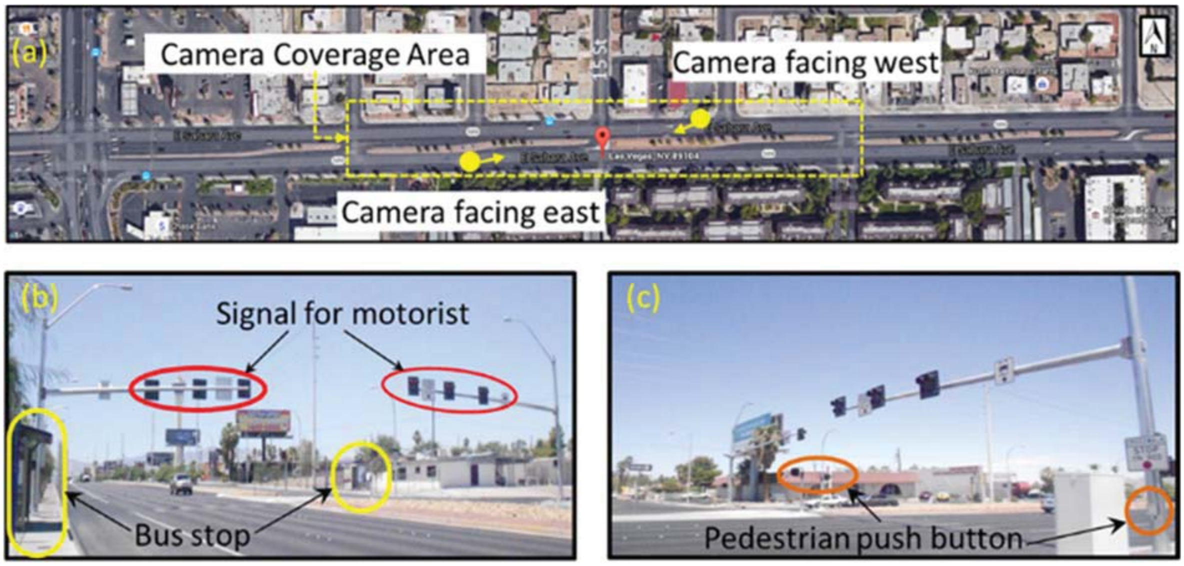


Fig. 2 (a) Site for HAWK system at Sahara Ave, and 15th St. and (b), (c) The HAWK light system and pushbutton are indicated by the circles in the images of the intersection

V. Data Collection and Analysis Methodology

The intersection data was collected using two cameras installed on the street light poles near the HAWK signal site facing towards the eastbound and westbound sections of Sahara Avenue. The locations and coverage of the cameras are shown in Fig. 2. The camera covered the road segment of approximately 100 meters in each direction. The cameras were able to capture the signal heads in both directions so that the signal operation can be seen while observing the vehicle and pedestrian movements during data extraction process. These cameras were installed on Tuesday, March 6, 2012 at 11 a.m. a week before the HAWK signal was officially activated on Tuesday, March 13, 2012 at 10 a.m. The cameras operated continuously to observe pedestrian and motorist movements until 9:30 a.m. on March 20, 2012, with the exception of a few periods when memory cards were replaced. This enabled a full one week of before-and-after analysis of the HAWK system. The video data was annotated to extract key pedestrian safety measures, which included:

- Pedestrian arrival time,
- Crossing start time,
- Trap duration in the median
- Crossing end time,
- The number of jaywalking events for both directions (northbound and southbound),
- The number of pedestrians for each crossing events,
- The number of vehicles that did not yield for pedestrians,
- The number of vehicles not stopped behind the stop-bar, and
- Near misses and crashes.

The following definitions were made before extracting the data from the video:

- A ‘non-yielding motorist’ is defined as a vehicle that passes through the crosswalk in front of a pedestrian, but would have been able to safely stop at the crosswalk when the pedestrian arrived at the crosswalk curb. Though Nevada law requires motorist to yield the pedestrian standing at the crosswalk curb with an intention to cross the road, the study counted only vehicle which is travelling to the adjacent bound and is not stopped to allow the pedestrian to cross the road is considered as a ‘non-yielding vehicle’. The safe stopping time for motorist was calculated as 5 seconds, based on the definitions of safe stopping time, stopping sight distance, and the posted speed limit.
- A ‘near miss’ is defined as an incident when a vehicle was close to hitting a pedestrian walking in the cross-walk, but did not result in injury or damage to the pedestrian.
- A ‘jaywalking’ event is defined as a pedestrian crossing event when a pedestrian(s) crosses the road without using the crosswalk. If a pedestrian(s) walks along the crosswalk partly and leaves the crosswalk to cross the road or vice versa, such event is also considered as ‘jaywalking’ event in this study.

The before-and-after analysis calculated a number of measures of effectiveness (MOEs) of the HAWK signal. The MOE analysis included:

- Comparison of the total crossing time,
- Motorists’ behaviors regarding yielding,
- Near misses and crashes,
- Behavior of pedestrians crossing.

A t-test analysis was conducted to determine if the waiting time at the curb, curb-to-curb crossing time, total crossing time, or percentage of jaywalking event per day significantly improved after HAWK installation.

VI. DATA ANALYSIS AND DISCUSSION

During the entire two-week study period, 3,848 pedestrians (2,034 before and 1,814 after the HAWK deployment) crossed the Sahara Avenue in 3,089 (1,646 before and 1,443 after the HAWK deployment) unique crossing events. A total of 825 (666 before and 159 after HAWK deployment) pedestrians were 'jaywalking' across Sahara in 679 (538 before and 141 after the HAWK deployment) unique events, which accounted for about 22% of the total crossing events. Fig. 3 shows the total crossing and jaywalking events per day.

A. HAWK System Usage

After implementation of the HAWK signal, the cameras were in operation for a week. However, the actual total time recorded was only 144 hours (6 days) due to space limitations on the hard drive. During the study period, on average, 62.2% of the pedestrians used the signal for crossing the road. Fig. 4 shows the percentage of HAWK signal usage during four-hour time segments.

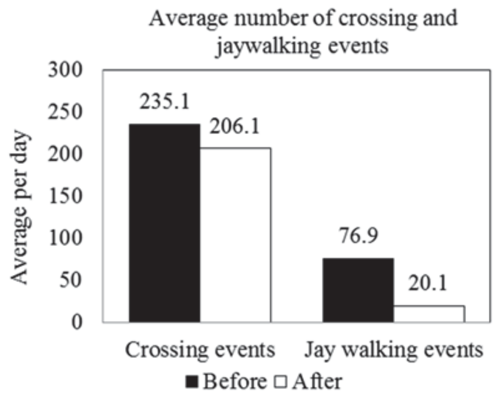


Fig. 3 Average number of crossing and jaywalking events per day before and after the installation of the HAWK signal

Notice that the HAWK usage decreases during the evening hours. Assuming that 7 a.m. to 7 p.m. is defined as 'day' and the rest of the time as 'night', the data indicates that the percentage of HAWK signal usage was significantly higher during the day than at night ($p < 0.005$). This likely can be attributed to the decreased motor traffic, because pedestrians tended to use signal when the traffic volume was greater, during the day, than when the traffic volume was less at night.

TABLE I
T-TEST RESULTS

Description	Mean Before	Mean After	Std. Dev. Before	Std. Dev. After	t-value	p-value (one-tail)
Avg. waiting time at curb	8.1	9.6	14.42	8.57	-3.4	<0.005
Avg. curb-to-curb crossing time	32.9	26.2	16.81	9.93	13.3	<0.005
Avg. total crossing time	41.1	35.8	23.00	12.41	7.9	<0.005
Avg. % daily jaywalking events	32.6	8.2	3.44	5.80	9.6	<0.005

It also is interesting to note the upward trend in pedestrian usage toward the end of the study period. A longer study is needed to ascertain whether this training and familiarity trend is valid.

B. Waiting Time and Crossing Time

The waiting time for a pedestrian at curb is 10 seconds because the HAWK signal turns 'steady red' 10 seconds after the pedestrian activates the system. Thus, the mean waiting time at the curb for the pedestrian was increased by 1.5 seconds. However, due to the lighting system, the number of pedestrians trapped in the median decreased; this, in turn, decreased the mean curb-to-curb crossing time by 6.7 seconds. After installation of the system, the total crossing time – the sum of the waiting time and the crossing time – saw a significant reduction ($p < 0.005$) of 5.3 seconds from 41.1 seconds to 35.8 seconds. The before-and-after wait and crossing times are summarized in Table I.

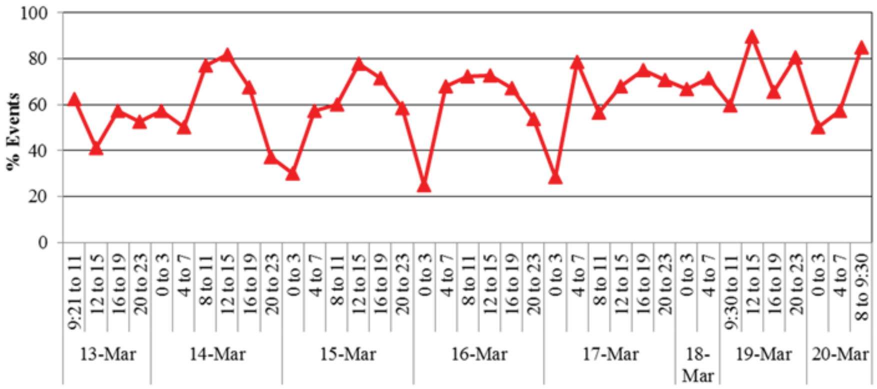


Fig. 4 HAWK signal usage by pedestrians before crossing

C. Jaywalking (Unauthorized Crossing)

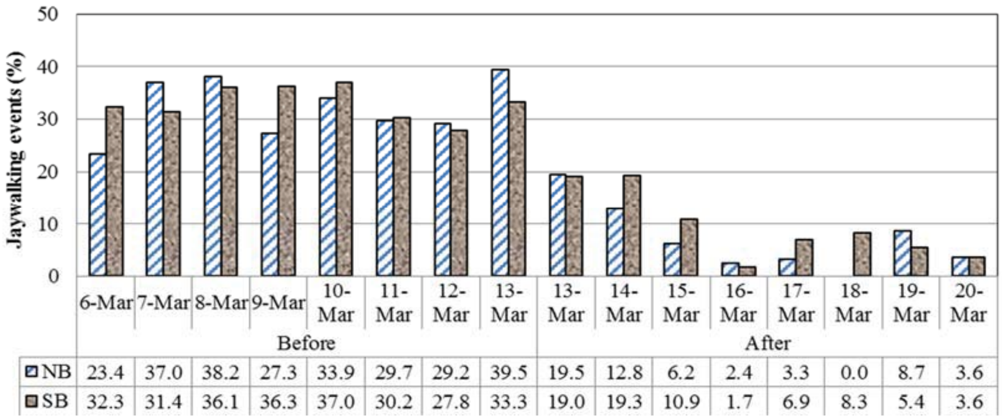
After the implementation of the HAWK signal, jaywalking events dropped significantly from 32.6% to 8.2% of total crossing events ($p < 0.005$) (see Table I). In terms of pedestrians crossing the road, 666 pedestrians were involved in jaywalking before installation; this is 32.7% of the total pedestrians crossing the road. After the signal was installed, the number of jaywalkers decreased to 159, which was 8.76% of the total pedestrians crossing the road.

Daily distribution of the percentage of jaywalking events during the study period is presented in the Fig. 5. The dotted vertical line demarcates before and after HAWK signal periods, and indicates a clear reduction in jaywalking rate.

D. Motorists not Yielding to Pedestrians

Three different scenarios were investigated: (i) motorists yielded to pedestrian but not stopped behind the designated stop-bar, (ii) motorists not yielded to pedestrian when pedestrian is standing at the curb and when pedestrian is walking at cross-walk, and (iii) pedestrian trapped in the median after crossing one direction of traffic.

The average number of motorists yielded to pedestrian but not stopped behind the stop-bar was reduced significantly from 1.75 to 1.24 ($p < 0.05$). In addition, the average number of non-yielding motorists during the study period before and after installation of the HAWK signal was 11.2 and 4.3 respectively. The data indicate that the HAWK signal has significantly reduced the total number of motorists not yielding to the pedestrians ($p < 0.05$). This means that motorist compliance on the signal was significantly increased. Table II presents data of vehicles not yielded to pedestrians.



	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	20-Mar
	Before								After							
▨NB	23.4	37.0	38.2	27.3	33.9	29.7	29.2	39.5	19.5	12.8	6.2	2.4	3.3	0.0	8.7	3.6
▨SB	32.3	31.4	36.1	36.3	37.0	30.2	27.8	33.3	19.0	19.3	10.9	1.7	6.9	8.3	5.4	3.6

Fig. 5 Distribution of jaywalking events; the vertical dotted line indicates the installation of the HAWK signal

Before the HAWK signal was installed, 463 events (28.2% of total crossing events) occurred during which motorists did not yield to pedestrians standing at the curb for crossing. On average, 9.82 motorists per crossing event did not yield to pedestrians waiting at the curb for crossing. The highest number of motorists not yielding to pedestrians at curb in a single crossing event was observed as 58. However, after the implementation of the HAWK signal, only 124 non-yielding events (8.6% of total crossing) were observed. On average, 4.35 motorists per crossing events did not yield to pedestrians waiting at the curb for crossing.

In the situation where a pedestrian was trapped in the median after crossing one direction of traffic, 739 events (44.9%) occurred before installation of the signal and 159 events (11.0%) occurred after. The average number of motorists that did not yield to pedestrians while at the cross-walk, before and after the HAWK signal installation, were 6.38 and 3.26, respectively. The maximum number of motorists that did not yield to pedestrians at the cross-walk in one event was 49 before and 39 after the installation of the HAWK system.

E. Near Misses and Crashes

During the study period, before HAWK signal implementation, 10 near misses were observed. Also, one rear-end collision occurred when a stopped vehicle was yielding for a pedestrian at the curb. After the implementation of HAWK signal, only one near-miss event was observed.

VII. CONCLUSION AND RECOMMENDATIONS

This study indicates that jaywalking events, near misses/crash events, total pedestrian crossing time, and average number of motorists not yielding to the pedestrians were significantly reduced after the installation of the HAWK signal on Sahara Avenue in Las Vegas, Nevada. On average, 62.2% of pedestrians used the HAWK signal to cross the roadway. Similarly, jaywalking occurrences dropped significantly from 32.6% to 8.2%. The total crossing time – the sum of the waiting time and the crossing time – decreased 5.3 seconds. In addition, motorist compliance – by yielding to pedestrians attempting to cross the street – improved to 6.9 fewer non-yielding vehicles.

The results indicate that the HAWK signal can be used effectively for safe and quick pedestrian crossings.

Considering that the HAWK signal would be new for pedestrians and motorists in Las Vegas, public awareness and education programs should be conducted to achieve near 100% usage.

TABLE II
NUMBERS OF VEHICLES NOT YIELDED TO PEDESTRIANS

Study Period	Items	Vehicles Yielded to Pedestrian but Not Behind Stop-Bar	Vehicles Not Yielded to Pedestrian Behind Stop-Bar When Pedestrian is at						
			Curb			Cross-walk			Total
			EB	WB	Sub-Total	EB	WB	Sub-Total	
Before	No. of vehicles	404	2267	2289	4556	1977	2960	4937	9493
	No. of crossing events	231	242	221	463	385	389	678	846
	Mean per event	1.75	9.33	10.4	9.84	5.14	7.61	7.28	11.2
	Std. Deviation	1.0	12.2	10.8	11.6	7.4	10.0	9.3	13.1
	Minimum	1	1	1	1	1	1	1	1
	Maximum	7	58	54	58	47	49	49	84
After	No. of vehicles	243	301	238	539	344	507	852	1390
	No. of crossing events	192	67	57	124	121	140	220	324
	Mean per event	1.24	4.49	4.18	4.35	2.84	3.62	3.87	4.3
	Std. Deviation	0.6	7.9	7.3	7.6	3.2	4.9	4.8	6.5
	Minimum	1	1	1	1	1	1	1	1
	Maximum	4	46	37	46	25	39	39	46

EB = East Bound, WB = West Bound

REFERENCES

[1] Cui, Z., and S. S. Nambisan, “Methodology for Evaluating the Safety of Mid-Block Pedestrian Crossings”, *In Transportation Research Record: Journal of the Transportation Research Board, No. 1828, Transportation Research Board of the National Academies*, Washington, D.C., 2003, pp. 75-82.

[2] Pulugurtha, S. S., and S.S. Nambisan, “A methodology to identify high pedestrian crash locations: an illustration using the Las Vegas metro area”, *In 82nd Annual Transportation Research Board Meeting, CD-ROM, Transportation Research Board of the National Academies*, Washington, D. C., 2003.

[3] Zero Fatalities: Drive Safe Nevada. Nevada Department of Public Safety, Office of Traffic Safety. Carson City, NV, 2010.

[4] Ernst, M., M. Lang, and S. Davis, “Dangerous by Design 2011”. Transportation for America, 2011. http://www.aarp.org/content/dam/aarp/livable-communities/learn/transportation/dangerous-by-design-2011-aarp.pdf. Accessed on July 10, 2012.

[5] Nambisan, S. S., M. R. Dangeti, and V. Vasudevan, “*Pedestrian Safety Engineering and Intelligent Transportation System-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injuries, Conflicts, and Other Surrogate Measures (Phase 2 Final Technical Report)*”, FHWA, U.S. Department of Transportation, 2008.

[6] Fitzpatrick, K., S. Turner, M. Brewer, P. Carlson, B. Ullman, N. Trout, E.S. Park, J. Whitacre, N. Lalani, and D. Lord, “*Improving Pedestrian Safety at Unsignalized Crossings*”, TCRP/NCHRP Report 112/562, Transportation Research Board, Washington, D. C., 2006.

[7] City of Las Vegas, Nevada. Media Release. http://lasvegasnevada.gov/Publications/26223.htm. Accessed on July 10, 2012.

[8] Martin, A, “*Factors Influencing Pedestrian Safety: A Literature Review*”, Project report UPR SE/199/05, TRL Limited, 2006 (unpublished)

[9] Sisiopiku, V. P., and D. Akin, “Pedestrian behaviors at and perceptions towards various pedestrian facilities: an examination based on observation and survey data”, *Transportation Research Part F: Traffic Psychology and Behavior*, vol. 6, No.4, 2003, pp. 249-274.

[10] Lu, G., and D. A. Noyce, “Noyce. Pedestrian Crossings at Mid-Block Locations: A Fuzzy Logic Solution for Existing Signal Operations”, *In 88th Annual Transportation Research Board Meeting, Transportation Research Board of the National Academies*, Washington, D.C., 2009.

[11] Copeland, L., “*Cities try to improve crosswalk safety*”, USA Today. http://www.usatoday.com/news/nation/2008-02-24-crosswalk_N.htm. Accessed on July 12, 2012.

[12] Zegeer, C. V., J. R. Stewart, H.H. Huang, P. A. Lagerwey, J. Feaganes, and B. J. Campbell, “*Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines*”, Publication FHWA-HRT-04-100, FHWA, U.S. Department of Transportation, 2005.

[13] Arhin, S., and E. C., Noel, “*Evaluation of Hawk Signal at Georgia Avenue and Hemlock Street, NW in the District of Columbia*”, Publication DDOT-PPSA-HAWK-001. District Department of Transportation Planning, Policy and Sustainability Administration, 2010.

[14] Nassi, R. B., and M. J. Barton, “*New Traffic Control for an Old Pedestrian Crossing Safety Problem*”, APWA Reporter, June 2008, pp. 44–49. http://www.apwa.net/Resources/Reporter/Articles/2008/6/New-traffic-control-for-an-old-pedestrian-crossing-safety-problem. Accessed on July 9, 2012.

[15] Fitzpatrick, K., and E. S. Park, “Safety Effectiveness of HAWK Pedestrian Treatment”, *In Transportation Research Record: Journal of the Transportation Research Board, No. 2140, Transportation Research Board of the National Academies*, Washington, D.C., 2009, pp. 214–223.

[16] Fitzpatrick, K., and E. S. Park, “*Safety Effectiveness of the HAWK Pedestrian Crossing Treatment*”, Publication FHWA-HRT-10-042. FHWA, U.S. Department of Transportation, 2010.

[17] Godavarthy, R. P., and E. R. Russell, “Effectiveness of a HAWK Beacon Signal at Mid-Block Pedestrian Crossings in Decreasing Unnecessary Delay to the Drivers”, *In 89th Transportation Research Board Annual Meeting, CD-ROM, Transportation Research Board of the National Academies*, Washington, D.C., 2010.

[18] “*Effectiveness of the HAWK pedestrian activated mid-block crosswalk located in central avenue nearest to Cambridge*”, Westfield Police Department, 2011.

[19] “*Manual on Uniform Traffic Control Devices (2009 Edition)*”. FHWA, U.S. Department of Transportation. 2009.

[20] “*TRINA- Traffic Records Information Access*”, Nevada Department of Transportation, Carson City, NV. http://apps.nevadadot.com/Trina/. Accessed on July 8, 2012.