Evaluation of in-pavement Flashing Lights on a Six-lane Arterial Pedestrian Crossing

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ABSTRACT

Three fatal traffic incidents involving pedestrians and vehicles occurred during the 1990s in the vicinity of the subject intersection which has a painted crosswalk as well pedestrian crossing warning signs and adequate nighttime illumination. The incidents involved pedestrians of advanced age who constitute a large part of the population at this location. The evaluation consisted of analysis and before-after comparisons of traffic volumes, vehicle spot speeds, pedestrian crossing observations, and pedestrians' and motorists' perceptions of change in the situation. Key results include the following:

- The effect on speeds was dramatic. On the NB direction, maximum speed decreased by 16.2% and average speed decreased by 25.2% when the lights are activated. On the SB direction, maximum speed decreased by 17.8% and average speed decreased by 27.2%.
- The average wait time at the curb was reduced from 26.7 to 13.2 seconds. Also, the average curb-to-curb duration of crossing was reduced from 33.6 to 27.1 seconds because pedestrians can cross at once. Before, they had to wait in the median for a gap in the other direction of traffic.
- Before, 21.6% of the pedestrians were observed to run during some part of the crossing. This dropped to 12.1% after the lights were installed. The proportion of pedestrians who crossed entirely outside the marked crosswalk decreased from 15.9% to 8.3%.

The evaluation showed that this experimental application of in-pavement flashing lights produced positive results. HDOT's action to deploy this technology as a stop-gap measure was appropriate and successful.

INTRODUCTION

The focus of the overall research project described in this paper was the seven lane wide pedestrian crossing on Pali Highway at the intersection with Jack Lane and Akamu Place, roughly a mile north of the Honolulu central business district. The location is in an older residential area consisting of medium density single housing, and a handful of consulates and churches. Pali Highway is a Class I arterial with an ADT of roughly 30,000 vehicles per direction. It connects Honolulu with the windward community of Kailua and provides access to a part of the Nuuanu residential area.

Three fatal traffic incidents involving pedestrian victims and vehicles occurred during the 1990s in the vicinity of this intersection. The intersection has a painted crosswalk as well pedestrian crossing warning signs and adequate night time illumination. The incidents involved pedestrians of advanced age who constitute a large part of the population in this location.

On March 6, 2000, the Hawaii Department of Transportation (HDOT) activated in-pavement traffic lights system consisting of 24 lights evenly distributed along the edge of the cross walk. Additional elements of the installation included a solar array, batteries, three poles with light-activating push buttons (one at each curb and one on the median) and two custom pedestrian crossing signs containing blinking lights as shown at the right edge of Figure 1.

FIGURE 1. Cars stopping for pedestrian crossing while in-pavement lights are flashing.

The in-pavement flashing lights were deemed experimental because at the time of deployment they were not approved as a traffic control device, i.e., they were not listed in the MUTCD. Because of the experimental nature of this application, monitoring and before-after evaluation of traffic measures were needed.

Documentation of this type of pedestrian crossing treatment in scant in the literature. They include guidelines of the Florida Department of Transportation (Huang, et al., 1999), unpublished guidelines by the City of Saint Louis Obispo in California, unpublished results from the City of Kirkland in Washington and an informational report by ITE’s Traffic Engineering Council Technical Committee.

This paper is organized as follows. A description of the methodology of analysis along with a description of the data collected follows this introductory section. Then the five separate analyses conducted as part of this evaluation: volumes, speeds, pedestrian crossing characteristics, pedestrian surveys and motorists surveys are presented followed by the conclusions of the study.

An explanation of some terms used in this paper is essential. Before or pre-implementation describe the time period prior to the activation of the in-pavement flashing lights. After or post-implementation describe the time period after the activation of the in-pavement flashing lights until the end of May 2000 when the data collection phase of this study was concluded. North-bound (NB) or uphill describe the Kailua-bound direction of traffic on Pali Hwy. South-bound (SB) or downhill describe the Honolulu-bound direction of traffic on Pali Hwy.

METHODOLOGY AND DATA

The evaluation consisted of analysis and before-after comparisons of:

- traffic volumes (through movements on Pali Hwy.)
- vehicle spot speeds (through movements on Pali Hwy.)
- pedestrian crossing observations
- pedestrians' perception of change in the situation
- motorists' perception of change in the situation.

Data were collected both in the field and through observation of video tapes recorded by a surveillance camera of the City and County of Honolulu, Department of Transportation Services (HDTS) located approximately ¼mile north of the pedestrian crossing. All vehicle spot speeds were collected in the field using a K-band radar gun provided by HDOT. Detailed pedestrian crossing observations were also made in the field. Field observations lasted two weeks in the "before" period and three weeks in the "after" period. Both weekdays and weekend days were covered. The project team covered several days and time periods including the three specific times when the pedestrian fatalities occurred. Surveillance tapes were used to count through traffic by direction and time of day. They were also used to count pedestrian crossings by time of day and the duration of crossings. Due to the distance of the camera from the crosswalk, detailed pedestrian crossing measures were not taken from the surveillance tapes (e.g., gender and age could not be discerned reliably, the flashing lights were not visible and the exact path of the pedestrian could not be determined.) Details of the data gathered are given below.

Volume: These data were produced by a straight forward manual count in 15-minute intervals from CCTV camera video recordings.
Speed: Spot speeds were collected at three different states of the system:

(1) system absent (pre-implementation),
(2) system present and off (no pedestrian activation), and
(3) system present and on (activated flashing lights.)

Crossings: similar forms were utilized for recording before and after observations. The form used in the after period had an additional column for recording whether the pedestrian activated the flashing lights or not. Day and time of day were recorded along with stopwatch measured times of wait and duration of crossing. Age group and gender of pedestrians were recorded along with the exact path that they followed. Attributes that may affect walking such as carrying a load, limping, running, using a walking stick, bicycling were recorded. In addition, the motorists reaction to pedestrians was recorded.

Perceptions: Two separate surveys were conducted about a month after the installation of the in-pavement flashing lights. One survey was distributed to all mailboxes in the greater neighborhood surrounding the subject crossing. On a Sunday, the same survey was also left on cars parked at three churches/temples in the immediate neighborhood. This constituted the pedestrian-and-neighbor survey. A separate survey was distributed at a signalized intersection immediately to the north of the subject crossing. This constituted the motorist survey.

ANALYSIS AND RESULTS

This section presents the results of the evaluation study. It is presented in five sections covering data on volumes, speeds, pedestrian crossings, pedestrians' perceptions and motorists' perceptions. The key output is the amount of change, if any, between pre- and post-implementation of the LightGuard™ in-pavement flashing lights.

Volume of Vehicular Traffic

Volumes were counted manually from eighteen surveillance tapes. Separate counts were obtained for NB and SB through traffic on Pali Hwy. An imaginary cross-section about 500 ft. north of Jack Ln. was the screen line for volume counts.

Because of day-to-day variation, volume counts were not identical in the before and after periods. On the NB direction, the total weekday count is lower by 9.1%, but the weekend count is higher by 7.4%. On the SB direction, the total weekday count is lower by 11.3%, but the weekend count is higher by 3.5%. These differences do not present a threat to the validity of the analysis of the effectiveness of the in-pavement flashing lights.

The SB direction is heavily loaded during the morning peak period until about 9:00 A.M with peak volume of about 3,600 vehicle per hour, or 1,200 vehicles per hour per lane. Throughout midday and afternoon, the SB direction carries a fairly steady load of about 1,600 vehicles per hour, or 500 vehicles per hour per lane. The opposite is observed on the NB direction which peaks between 4:30 and 5:30 P.M.

The midday volume of 1,500 vph per direction can serve as a base to illustrate the reason why the pedestrian crossing at this location is not a easy task. On one hand, the average headway between vehicles is 7.2 seconds. The duration of crossing three lanes of highway is 9 seconds, assuming the typical walking speed of 4 feet per second. Thus, at any time during the middle of a weekday, a lesser than 50% probability that a sufficiently long gap in traffic will be found exists (e.g., greater than 9 seconds.) As mentioned in the next section, the average prevailing speed is 40.4 miles per hour. Thus, for a safe crossing, the spacing between vehicles must be greater than 534 feet to allow for crossings.

Speed of Vehicular Traffic
Speed was a primary measure for assessing the effectiveness of the in-pavement flashing lights. The expectation was that the lights will generate a higher degree of motorist compliance which would produce more stoppages or speed reduction in order to accommodate pedestrians in the crosswalk. For this reason, several thousand measurements were taken so that statistically significant results could be obtained.

It must be mentioned that the accuracy of the speed measurements taken is modest. This is because “perfect” measurements with a radar gun of this technology can be made only if the observer is directly in line with the vehicle (i.e., in the middle of the traffic lane). In practice, the observer was 5 to 25 feet away for the vehicle paths. This was necessary for the observer’s safety, observer inconspicuity, and need to have a parked car nearby to power the radar gun. It is important to stress that this study focused on the before/after difference. Since before and after measurement conditions were identical, the (small) measurement errors in essence canceled out when the percentile change is assessed.

Table 1 summarizes the results. (Note: the posted speed limit is 35 mph.) The table consists of two sub-tables, one for NB and another for SB direction. Each sub-table presents the following data (all speed measurements are in miles per hour, mph):

- The number of observations (individual vehicle spot speed recordings.)
- Minimum recorded speed.
- Maximum recorded speed.
- Average recorded speed.
- 85th percentile speed (this means that 85% of vehicles were moving at this or lower speed, whereas 15% were moving at a speed higher than the 85% percentile speed.)

These statistics are presented for three conditions:

- Before with the in-pavement flashing lights absent.
- After with the in-pavement flashing lights inactive. These data include a few occasions with a pedestrian using the crosswalk without activating the lights.
- After with the in-pavement flashing lights active. Data were taken as long as the lights were active including the time after a pedestrian has finished crossing.

The following conclusions can be drawn from the analysis of spot speeds. Average spot speeds are practically identical for both the before and after conditions (with flashing lights off.) This is an important result because it shows that the data are not biased given that both mean and variance for the before and after periods are closely similar, although the data were collected more than a month apart. Data were not taken on weekdays during the 7:00 to 9:00 A.M. peak period when typically “bumper-to-bumper” conditions are observed in the town-bound direction.

Another important result is that the initial expectation that downhill (SB) speeding is worse is not supported by the data: uphill (NB) and downhill (SB) average spot speeds are not significantly different at this location. This can be explained by the fact that uphill traffic moves into lower density conditions which permit higher speeds. In contrast, although the downhill slope facilitates higher speeds, traffic on this direction moves into denser conditions which restrict speeds. An initial break-down into week and weekend days was abandoned because no significant differences were revealed.

The effect of the in-pavement flashing lights on speeds was dramatic. When the lights were absent or inactive, the minimum recorded speed was never lower than 12 mph; this includes times when pedestrians were in the crosswalk. In contrast, many observations of 0 mph speed were recorded with the lights active. Although the uphill and downhill directions of the Pali Hwy. flow independently, the results were nearly identical.

TABLE 1. SUMMARY OF SPEED MEASUREMENTS

UPHILL	BEFORE (no pavement lights) (1)		AFTER (pavement lights OFF) (2)		AFTER (pavement lights ON) (3)		**% change (3) - (1)**
No. obs.	5462		8201		3188		
min V	12.0		17.0		0.0		
max V	68.0		62.0		57.0		**-16.2%**
mean V	**40.4**	4.7	**39.7**	4.6	**30.2**	9.3	**-25.4%**
85th %	**45.7**	2.4	**44.7**	1.6	**39.3**	5.2	**-14.0%**
		std. dev.		std. dev.		std. dev.	

DOWNHILL	BEFORE (no pavement lights) (1)		AFTER (pavement lights OFF) (2)		AFTER (pavement lights ON) (3)		**% change (3) - (1)**
No. obs.	5340		8000		3109		
min V	15.0		20.0		0.0		
max V	73.0		69.0		60.0		**-17.8%**
mean V	**40.4**	5.4	**39.4**	4.4	**29.4**	9.2	**-27.3%**
85th %	**45.5**	2.0	**44.2**	1.9	**38.1**	3.9	**-16.2%**
		std. dev.		std. dev.		std. dev.	

For the uphill (NB) direction of travel, compared with before conditions, the maximum speed decreased by 16.2%, the average speed decreased by 25.4% and the 85th-percentile speed decreased by 14.0% when the in-pavement flashing lights were activated. For the downhill (SB) direction of travel, compared with before conditions, the maximum speed decreased by 17.8%, the average speed decreased by 27.3% and the 85th-percentile speed decreased by 16.2% when the in-pavement flashing lights were activated.

Pedestrian Crossings

Detailed before and after observations of individual pedestrians crossings were made in the field. Each pedestrian was monitored closely. Two stopwatches were used. One to measure the wait time at the curb and another to measure the duration of the crossing once the pedestrian stepped onto the pavement. Unambiguous characteristics of each pedestrian were recorded. In addition, the behavior of motorists also was recorded. During the pre-implementation period, there were few observations on motorist behavior since most pedestrians crossed during gaps in traffic.

TABLE 2. SUMMARY OF PEDESTRIAN CROSSING OBSERVATIONS

	BEFORE			AFTER			stat.
	mean	st.dev.	obs.	mean	st.dev.	obs.	signif.
Wait time prior to crossing	26.7	38.0		13.2	19.8		99.9%
Duration of crossing (curb-to-curb)	33.6	16.9		27.1	12.3		99.9%
% of vehicles that slowed or stopped	30%	46%	176	62%	49%	132	99.9%
distance at which vehicles stopped	20.0	8.9		16.9	6.4		NS
% of vehicles that disregarded peds in crossing	31%	46%		8%	27%		99.9%
Day and time of the week							
week day	72.2%			77.3%			
weekend day	27.8%			22.7%			100.0%
9 AM to 2 PM	38.0%			33.0%			
2 PM to 7 PM	57.0%			61.0%			
7 PM to 9 AM	5.0%			6.0%			100.0%
Crossed during a gap in traffic							
Uphill	50.3%			50.8%			
Downhill	56.6%			37.2%			

Table 2 summarizes the results of this analysis. The results revealed a significant improvement with the in-pavement flashing lights in place. Specifically:

- The wait time was reduced by 50.5% from 26.7 seconds to 13.2 seconds. This result is significant at the 99% confidence level.
- The curb-to-curb duration of crossing was reduced by 19.3% from 33.6 seconds to 27.1 seconds. This result is significant at the 99% confidence level. This reduction is due to the fact that with the lights activated, pedestrians can cross Pali Hwy. at once as opposed to the previous condition when frequently the pedestrian had to wait in the median for a gap in the other direction (2-stage

crossing.)

- The distance at which vehicles stopped changed from 20 feet to 17 feet, but this difference is not statistically significant.
- The percentage of vehicles that disregarded a pedestrian in the crossing (as manifested by no stopping or slowing) decreased from 31% to 8%. This result is significant at the 99% confidence level.
- In the uphill direction where the arrival of vehicles is practically random, about 50% of crossings occur during gaps in traffic. There was no change between before and after conditions. In the downhill direction, during the pre-implementation period, about 57% of the crossings occurred when the signal at Laimi St. (approximately ¼mile upstream) stopped the flow on this direction of traffic. After the flashing lights were installed, pedestrians did not wait for these gaps and the proportion of crossings during gaps dropped to 37%.
- During the pre-implementation period, 21.6% of the pedestrians were observed to run during some part of the crossing in order to avoid approaching traffic. This dropped to 12.1% after the implementation of the in-pavement flashing lights.
- During the pre-implementation period, 72.1% of the pedestrians were observed to cross entirely inside the marked crosswalk. This pedestrian compliance figure increased to 82.6% after the implementation of the in-pavement flashing lights.
- The proportion of pedestrians who crossed entirely outside the marked cross walk decreased from 15.9% to 8.3%.

Various characteristics of pedestrians were as follows. The majority of pedestrians in the before period were female (63.1%) whereas the majority in the after period were male (55%). Given that our observations occurred at identical days and times, this difference indicates that a large number of pedestrians who cross Pali Hwy. in this area are visitors (to churches, consulates, etc.) rather than residents. The pedestrians' age distribution is closely similar for the before and after periods. The majority of pedestrians can be characterized as adults (about 52%), but a large number of the pedestrians can be characterized as senior people (about 36%). Although there are several small schools in the area, less than 2% of the pedestrians were pre-teen children. Several of the pedestrians (15% to 18%) were walking slowly and/or were carrying grocery bags and the like.

Figure 2 presents the pattern of pedestrian crossings and delays in a typical day during the pre-implementation period. Note that the time of day on the horizontal axis is in decimal form, e.g., 11.5 is 11:30 A.M. Figure 2 reveals that wait times at the curb become very long (e.g., about 3 minutes) during the afternoon peak period. This is largely attributed to the heavy and randomly arriving traffic in the NB direction. Figure 3 depicts similar data from the post-implementation period. A large difference in delay (wait time at the curb) is observed by comparing the two graphs. Note that both graphs are on the same scale. The days for which the graphs were derived were chosen so that an approximately equal number of pedestrians are depicted.

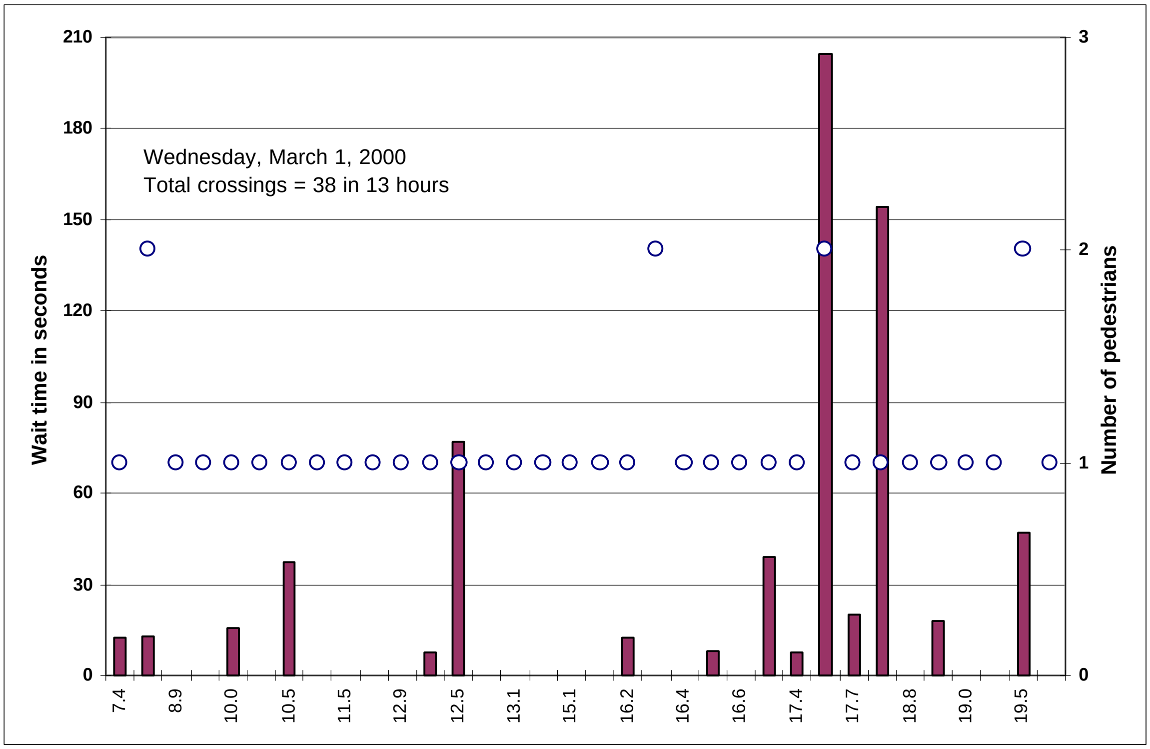

FIGURE 2. Pedestrian crossings and delays without in-pavement lights.

The wait time was measured from the moment that the pedestrian was practically still until the time when he or she stepped onto the travel lane. When two or more pedestrians arrived at the curb, the wait time of the first arrival (which was the longest) was measured. Crossing time was measured with a second stop-watch which was started at the same time when the first stop-watch was stopped. When two or more pedestrians crossed, the crossing time covered the duration from the first pedestrian starting to cross to the last pedestrian completing the crossing.

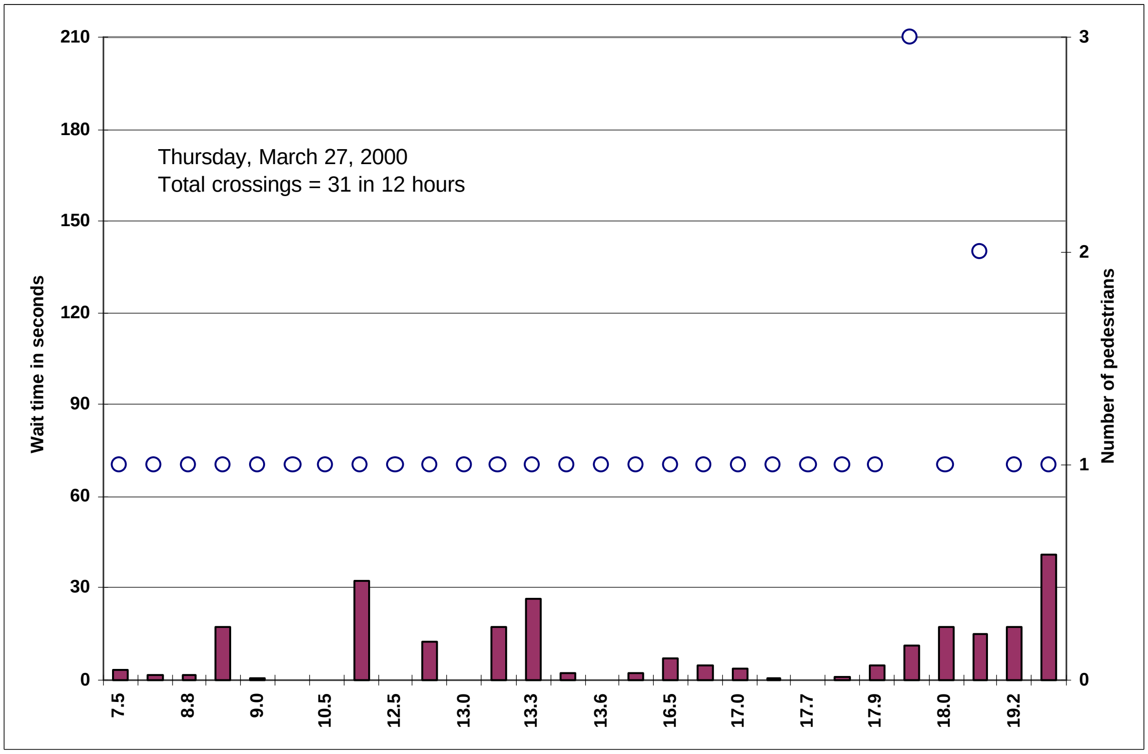

FIGURE 3. Pedestrian crossings and delays with flashing in-pavement lights.

Pedestrian Survey

A two-page survey was developed to request the input of pedestrians and neighbors in the vicinity of the subject crossing. Each survey was placed in a large envelope and was accompanied by a standard size business reply return envelope. The instruments were distributed to approximately 200 mailboxes in the neighborhood of the crossing. Another 75 surveys were placed on parked cars at three nearby churches or temples.

The overall response rate was 37% which is high compared with most mail-back surveys which typically deliver in the 15% to 25% range. The high response rate reflects in part the interest of people in this issue. More females (57.4%) than males responded to the survey. The majority of them (57%) can be characterized as adults and the remainder (43%) can be characterized as seniors. Thus, the survey reflects the fact that this is an old neighborhood with many senior residents.

On the average, the 101 respondents from the neighborhood used this crosswalk about 0.5 times per day or 2.7 times per week. This amount of use is quite low. They revealed that their weekly average is likely to increase to 3.9 crossings per week (a 44% increase) if the crossing is made very safe. The majority of the crossings (51.5%) was to or from a city bus stop.

The number of crossings was spread fairly evenly throughout daylight hours, with a slightly higher concentration of crossings in the afternoon period. The level of service (LOS) ranges of wait time (or pedestrian delay) in the Highway Capacity Manual was given and respondents were asked which bracket they would choose. The results show that 64% are willing to wait up to one minute or less which is the maximum acceptable (e.g., LOS D in HCM2000). Interestingly, the weighted average of the responses also is 59.8 seconds.

A large proportion of the respondents, 31%, believe that traffic moves at speeds in excess of 50 mph at this location. Three brackets were used for assessing the residents' perceptions: less than 40 mph, 40 to 50 mph and more than 50 mph. If 30, 45 and 55 mph are used as the mid-points for these three brackets, then the average speed perceived by the respondents is 46.2 mph, which is about 14% higher than the actual observation of 40.4 mph.

The respondents' opinions with regard to the in-pavement flashing lights and their preference for a traffic solution at this location may be summarized as follows (the *percent positive* column presents the added percentages of those who "strongly agree" or "agree"):

Statement	Average Response	Percent Positive
Less wait time at the curb	positive	42.2%
Do not need to walk fast or run	neutral	29.7%
Do not need to wait at the median	neutral	31.7%
Less jay-walking	positive	46.0%
Motorists are more attentive	positive	46.8%
Not as safe as they would like it to be	strongly positive	**74.2**%
Crossing safety has improved	positive	42.2%
Reduced wait time at the curb	positive	**59.2**%
Bring back the plain crosswalk	strongly negative	9.9%
Prefer the in-pavement lights	positive	**57.5**%
Prefer a traffic signal	strongly positive	**82.9**%
Prefer a pedestrian overpass	positive	49.4%
Prefer a pedestrian underpass	negative	20.0%

Thus, the overall perception of respondents is that of an improvement. It also is clear that respondents prefer the installation of a traffic signal (only 15% of the respondents were neutral or negative to the installation of a traffic signal.) The percentages in boldface highlight the main sentiments of the respondents: The in-pavement flashing lights were a welcome improvement to pedestrian crossing safety at the subject location and they were responsible for reducing the wait time at the curbside. However, these lights do not make the crossing as safe it can be and about 83% of the respondents would prefer a traffic light at this location.

In response to the desires of the neighborhood as well as considerable political pressure, the channelization of the subject intersection was modified and a fully actuated signal was installed and activated in October, 2000.

Motorist Survey

A two-page survey was developed to request the input of motorists driving on Pali Hwy. and intersecting the subject crossing. The instruments were distributed to 700 drivers stopped on Pali Hwy. at the traffic signal at the intersection with Laimi St. This intersection is located about ¼mile to the north of the subject crossing. Questionnaires were distributed on both the NB and SB approaches of Pali Hwy. as well as on Laimi St. which (conveniently for our purpose) develops long queues in the morning peak period. The overall response rate was 33%.

The questionnaire survey produced a large number of useful results. Opposite to the use of the crosswalk by the respondents to our pedestrian and neighbor survey, the surveyed motorists cross this location frequently; the average response was about 13 one-way trips per week. As expected, about 5.5 of these weekly trips occur in the 6:00 to 9:00 A.M. period and 4.5 trips occur in the 2:00 to 7:00 P.M. period.

Motorists were asked about their preferred speed limit on this specific stretch of the Pali Hwy. The majority of the respondents prefer a 40 mph or a 45 mph posted speed limit, whereas 7% prefer a 30 mph or less posted speed limit. The weighted average of the responses is 40.1 mph.

The level of service (LOS) ranges of traffic signal delay and wait time at the curb in the Highway Capacity Manual were given and respondents were asked which bracket they would choose. The results showed that:

- 71% are willing to wait up to 55 seconds or less which is the maximum acceptable (e.g., LOS D in HCM2000). Interestingly, the weighted average of the responses also is 55.9 seconds.
- A minority of 41% find that delay up to 55 seconds (LOS D) is appropriate for pedestrians. The majority think that pedestrians should wait for more than one minute; the weighted average of the responses is 76.1 seconds which is considerably higher than the average given by the pedestrian and neighbor respondents (59.8 seconds.)

A modest proportion of the respondents, 18%, believed that traffic moves at speeds of more than 50 mph at this location on Pali Hwy. However, nearly 50% mentioned that speeds are in the 40 to 50 mph range, that is 5 to 15 mph over the posted speed limit. Three brackets were used for assessing the residents' perceptions: less than 40 mph, 40 to 50 mph and more than 50 mph. If 30, 45 and 55 mph are used as the mid-points for these three brackets, then the average speed perceived by the responding motorists is 41.9 mph (in contrast to the 46.2 mph perceived by pedestrians and neighbors), which is only 4% higher than the actual observation of 40.4 mph. It appears that responding motorists have an accurate perception of speeds at this location.

Selected positions and perceptions of motorists are summarized below (the *percent positive* column presents the added percentages of those who “strongly agree” or “agree” with each statement.)

Statement	Average Response	Percent Positive
More traffic signals are needed	negative	23.2%
A traffic signal at Jack Lane will increase delays significantly	positive	44.6%
Always stop for pedestrians	positive	**52.2**%
It is hard to stop for pedestrians	negative	32.3%
Fear of rear-end if stop for ped.	negative	33.6%
Pedestrian safety has improved	positive	48.3%
Flashing lights are useful to peds.	positive	**71.5**%
Fl. lights are useful to motorists	positive	**77.3**%
Fl. lights preferred to a signal	positive	**61.1**%
Solutions other than signals are needed	positive	**73.7**%
Traffic stops for pedestrians because of the flashing lights	positive	41.7%

The overall perception of respondents is that of an improvement. It also is clear that respondents prefer a solution other than a traffic signal (only 26.3% of the respondents were neutral or did not object to the installation of a traffic signal.) It is interesting to note that although 52% of the respondents always stop for pedestrians, about one third of the respondents finds stopping difficult and is afraid of being rear ended if he/she stops for a pedestrian. About three quarters of the respondents think that the flashing lights are useful to both pedestrians and motorists alike. Although more than 70% prefer a solution other than a traffic signal and more than 60% prefer the flashing lights, a much smaller proportion, 42%, find that traffic stops for pedestrians due to the flashing lights. Only 17.3% find that safety has not improved with the introduction of the in-pavement flashing lights.

The findings indicate that motorists will not be happy with the additional traffic light but delays because of it are not expected to cause major discomfort to the majority of the respondents who also stated that although the flashing lights are an effective warning, they do not guarantee a safe crossing for pedestrians. The motorists preferences for higher speed limits, preference for the flashing lights and aversion to the proposed traffic signal are consistent with the fact that most of them are not from the neighboring area. The goals of the motorists are different from those of the affected neighborhood.

CONCLUSIONS

In response to pedestrian fatalities in the 1990s in the vicinity of the intersection of Pali Hwy. with Jack Lane, the Hawaii Department of Transportation installed experimental in-pavement flashing lights in spring 2000. Because of the experimental nature of this application, close monitoring and before-after evaluation of traffic measures was needed. This was conducted by the University of Hawaii, Department of Civil Engineering. A large number of volume, speed and pedestrian crossing data were gathered along with perceptions of pedestrians and motorists with the use of mail-back questionnaire surveys in order to conduct this evaluation.

The application in Honolulu had several similarities and differences compared with those in California, Washington and Florida. A brief comparison is shown below:

	ADT	Speed	Lanes	Pedestrians
Honolulu application	~30,000	45 mph(^{1})	7	<100/day
California guidelines	>10,000	<35 mph(^{1})	≤4	>100/hour
Florida guidelines	5,000-30,000	<45 mph(^{2})	(^{3})	>100/day

Notes: (^{1}) = 85th percentile, (^{2}) = mean speed, (^{3}) not specified.

The evaluation showed that this experimental application of in-pavement flashing lights produced clearly positive results and the experiment can be characterized as a success (Figures 4 and 5). The processing of pedestrians in terns of efficiency (lower delays) and safety (many more vehicles stopped or slowed down) improved considerably and several of the tested differences were statistically significant. The results may be summarized as follows:

The effect of the in-pavement flashing lights on speeds was dramatic. On the north-bound direction of travel, maximum speed decreased by 16.2%, average speed decreased by 25.2% and the 85th-percentile speed decreased by 14.0% when the in-pavement flashing lights are activated. On the south-bound direction of travel, maximum speed decreased by 17.8%, average speed decreased by 27.2% and the 85th-percentile speed decreased by 16.3%.

The wait time for pedestrians at the curb was reduced by 50.5% from 26.7 seconds to 13.2 seconds.

The curb-to-curb duration of crossings was reduced by 19.3% from 33.6 seconds to 27.1 seconds because pedestrians can cross at once as opposed to the previous condition when frequently they had to wait in the median for a gap in the other direction of traffic.

The percentage of motorists that disregarded a pedestrian in the crossing decreased from 31% to 8%.

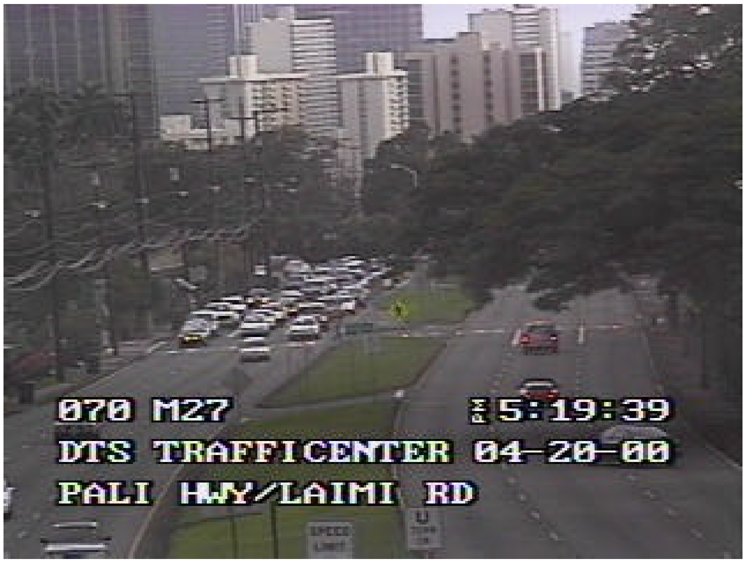

FIGURE 4. Although the in-pavement lights cannot be seen due to distance and CCTV camera location, it is obvious that they caused a large NB platoon to stop for a pedestrian. The pedestrian is about 3 ft. to the right of the stopped car in the fast lane. Also, the brake lights of SB vehicles are on.

FIGURE 5. An image capture about 6 minutes later shows a typical view of traffic flow by the subject pedestrian crossing.

Images courtesy of the website provided by the Traffic Center, Department of Transportation Services, City and County of Honolulu.

In the pre-implementation period, 21.6% of the pedestrians were observed to run during some part of the crossing in order to avoid approaching traffic. This dropped to 12.1% in the post-implementation period.

The proportion of pedestrians who crossed entirely outside the marked cross walk decreased from 15.9% to 8.3%.

On the average, respondents from the neighborhood use this crosswalk about 0.5 times per day or 2.7 times per week. Their perception of average speed on Pali Hwy. is 46.2 mph which is about 14% higher than the actual observation of 40.4 mph.
The neighbors survey revealed that the in-pavement flashing lights are a welcome improvement to pedestrian crossing safety and are responsible for reducing the wait time at the curbside. However, these lights do not make this crossing as safe it can be and about 83% of the respondents would prefer a traffic light at this location.

Surveyed motorists cross this location frequently; the average response was 13 one-way trips per week. Their perception of average speed on Pali Hwy. is 41.9 mph which is about 4% higher than the actual observation of 40.4 mph. Their preference for posted speed limit is 40 mph.

About three quarters of the motorists surveyed think that the flashing lights are useful to both pedestrians and motorists alike. Although more than 70% prefer a solution other than a traffic signal and more than 60% prefer the flashing lights, a much smaller proportion, 42%, think that traffic stops for pedestrians due to the flashing lights.

Disadvantages of the in-pavement flashing lights included visibility problems during some daylight hours (depending on the position of the sun vis-à-vis the face of the lights as well as the brightness of sunlight,) inability to generate very high or total compliance by motorists (i.e., this device provides a warning rather than a regulation with "yield" or "stop" properties,) and a potential that some pedestrians may perceive a false sense of security (a handful of respondents mentioned that they saw people putting themselves in harm's way by stepping onto the crosswalk after pressing the light-activating button without checking for traffic.)

A traffic signal replaced the in-pavement flashing lights in October of 2000. Although a signal may seem hard to justify based on the very low number of pedestrians, one should consider that:

- Many of the pedestrians are old and have attention, reaction time and walking impediments.
- Some residents avoid this crossing or do not allow their children to use it.
- Minor movements of vehicles (e.g., left turn movements from Jack Lane and Akamu Place) are risky at times (several near-misses were observed.)

In-pavement traffic lights are an effective warning to motorists and they improve both the efficiency and safety of pedestrian movements. They should be given serious consideration for implementation at other locations in the state where pedestrian safety risk is an issue and signalization is not warranted. These lights are expected to be even more effective at narrower crossings along streets which are not class I arterials.

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Disclaimer

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