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ALASKA DEPARTMENT OF TRANSPORTATION

Above-Ground Actuated Yellow Crosswalk Lights at Uncontrolled Pedestrian Crossings

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13. ABSTRACT (Maximum 200 words)

There has been a significant amount of studies that investigate a wide variety of measures, devices, and treatments that improve pedestrian safety at different locations (sidewalks, intersection crossing, and midblock crossing). These measures are can be classified into three main categories: Physical separation, time separation, Warning and Traffic Calming Measures.

The focus of this study is limited to investigating the effectiveness of flashing lights in increasing pedestrian safety and reducing traffic accidents at uncontrolled pedestrian crossing, as indicated in the blue shaded blocks of Figure 1. This study reviews the experimental research and test cases that investigate the effectiveness of the above-ground flashing beacons as a warning device at uncontrolled crosswalks. In particular, it investigate the usefulness of the above-ground flashing beacons in reducing traffic speeds at pedestrians crosswalks, increasing the percentage of motorists that are yielding to pedestrians, reducing conflicts between motorists and pedestrians, reducing accidents, and increasing pedestrians safety. This study also reviews the comparisons between the effectiveness of the above-ground flashing beacons and the in-pavement flashing lights as warning devices for motorists at uncontrolled crosswalks.

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APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
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ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
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yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
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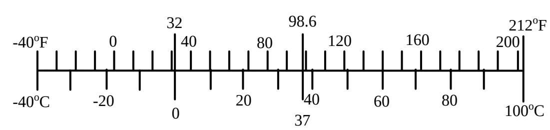
ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (°F-32)	Celsius temperature	°C	°C	Celsius temperature	9/5 °C+32	Fahrenheit temperature	°F
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2	cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

These factors conform to the requirement of FHWA Order 5190.1A *SI is the symbol for the International System of Measurements



Above-Ground Actuated Yellow Crosswalk Lights at Uncontrolled Pedestrian Crossings

Final Report for:

Alaska DOT & PF Research and Technology Transfer

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Table of Contents

List of Figures

List of Tables

Executive Summary

This study reviews the experimental research and test cases that investigate the effectiveness of the above-ground flashing beacons as a warning device at uncontrolled crosswalks. In particular, it investigates the usefulness of the above-ground flashing beacons in reducing traffic speeds at pedestrian crosswalks, increasing the percentage of motorists that are yielding to pedestrians, reducing conflicts between motorists and pedestrians, reducing accidents, and increasing pedestrians safety. This study also reviews the comparisons between the effectiveness of the above-ground flashing beacons and the in-pavement flashing lights as warning devices for motorists at uncontrolled crosswalks.

Findings:

Based on the review of the experiments related to crosswalk flashing lights, several findings regarding the impact of the flashing lights at midblock crosswalks can be summarized as follows:

1- Studies that considered studying the impact of crosswalk above-ground flashing lights in reducing traffic speeds at midblock crosswalks have found that flashing lights have no or slight (2-3 mph) impact on reducing traffic speed near the crosswalk.
2- Most of the studies have reported that considerable percentage of vehicles yield to crossing pedestrians at midblock crosswalks with flashing lights (ranging from 10% to 74%). However, the results were sometimes misleading since it did not consider the fact that vehicles are yielding anyway even when the flashing lights are not activated.
3- Several studies have reported results from before-and-after analysis that investigated the yielding behavior of traffic at crosswalks before and after installing flashing lights. Most of the studies have indicated that flashing lights increase the percentage of vehicles that yield to crossing pedestrians (average of about 100%). However, the range of this increase was significantly different from a study to another, raising questions regarding the possible existence of other factors that might impact the yielding behavior of vehicles. One of the results have indicated that the impact of the flashing lights at crosswalks tend to decline with time.
4- Two non-U.S. studies have indicated that above-ground flashing lights tend to reduce accidents during nighttime. About 30% and 62% reduction in accidents have been reported in the two studies.
5- Only one study considered studying the impact of the flashing lights at midblock crosswalk in reducing conflicts between vehicles and crossing pedestrians. In this study, it is reported that conflicts are reduced by about 66%, when flashing lights are implemented at the crosswalk.

6- As reported by one study, the existence of the above-ground flashing beacons encouraged more pedestrians to use the crosswalk. However, results indicated that there is slight increase of about 5% in pedestrians' activities after installation of the above-ground flashing lights at the crosswalk.
7- Most of the flashing light systems are adopted with non-passive activation system (push buttons), where pedestrians at the crosswalk might press a button to activate the flashing lights. Pedestrians might feel that it is unnecessary to push the button and they can cross, while the flashing lights are not active. The percentage of pedestrians who activate the flashing lights differed among the studies that reported this number, ranging from 33% of crossing pedestrians to 71.3%. Nonetheless, it was not possible to explain the reason behind this variation at the different locations.
8- It is indicated that flashing lights at pedestrians' crosswalk might not be effective in urbanized areas, where drivers might be distracted by many lighting sources including traffic signals. However, it can be more effective in dark places where the existence of the flashing lights can better get the attention of drivers for possible activities on crosswalks.
9- Embedded flashing lights are generally more effective than the above-ground flashing lights at midblock crosswalks. They also tend to remain effective for longer periods.
10- Studies have indicated that embedded flashing lights might require more consideration for its maintenance, raising questions about is reliability. However, it has been observed that over the last few years new systems have been developed which tend to be more reliable and requires less maintenance consideration.
11- No studies have indicated the impact of existence of snow on the top of the embedded flashing lights on its effectiveness or the impact of snowplowing on its durability.

Recommendations and guidelines:

The findings of this study have found that there is a wide range of possible impact of the above-ground flashing beacons at midblock crosswalks. This implies that the system can be effective only at some locations and not in others. It is highly recommended that traffic engineers are to study crosswalk locations at individual basis before deciding on implementing above-ground flashing beacons. Also, the study has found that the embedded flashing lights are generally more effective that the above-ground flashing beacons as a warning system at midblock crosswalk.

The main recommendation for using flashing beacons at midblock crosswalks can be summarized as follows:

- The above ground flashing beacons should only be implemented when it is warranted. The study provides a presentation of general guidelines to implement the different types of crosswalk treatments. The type of treatment depends on several factors including pedestrians' crossing volumes, vehicular traffic volumes, number of lanes, traffic speed, and sight distance.

- Whenever the above-ground flashing beacons are to be considered, their effectiveness has to be reviewed over time, since studies have indicated that the above ground-flashing beacons lose its effectiveness over time when drivers tend to ignore it, as it becomes part of the everyday seen.
- It will be more helpful to consider additional treatment at the crosswalk such as warning signs, textured pavement, and bright markings to increase the effectiveness of the flashing lights. Also, attention has to be given to make sure that the above-ground flashing beacons are effective in urbanized areas where drivers can be distracted by other sources of lights.
- The embedded flashing lights can always be considered as a better alternative for the above-ground flashing. Studies have indicated that when everything else is equal, the embedded flashing lights tend to outperform the above-ground flashing beacons. However, traffic engineers should make sure that they will work effectively when they are covered by snow and not destroyed by snowplowing activities.
- Passive activation of the crosswalk flashing beacons is more promising that the manual (push-button) activation. Pedestrians might not realize or notice that they have to push a button before crossing the street to activate the crossing warning system. Also, they sometimes feel that if they push the button, vehicular traffic will always stop for them to cross. However, more attention has to be considered to select the type and location of pedestrian sensing and pedestrian-detection technology.

1. INTRODUCTION

Problem Statement:

The Alaska Department of Transportation & Public Facilities lacks conclusive data and information on the effectiveness and economics of lighted uncontrolled crosswalks.

Background:

Pedestrian crossings at uncontrolled locations are risky and unsafe for pedestrians, especially at night and during adverse weather conditions involving rain, snow and fog. Recent results from a study that analyzed pedestrian fatality accidents indicate that about 78% of accidents occurred at non-intersection locations. Statistics also indicate that pedestrians are more unsafe during the night time, when about 68% of the fatalities occur (Shanker 2003). An earlier study shows that about 26.4% of accidents occur in the street midblock. Results are based on a sample of over 5,000 pedestrian crashes drawn from six states and reported by police (Hunter et al. 1996).

In an effort to improve pedestrian safety while crossing at uncontrolled locations, several countermeasures have been developed and implemented to warn motorists on pedestrian crossing activities. A common adopted countermeasure is to use flashing lights at the crosswalk to warn drivers on pedestrian's presence. The goal is to make drivers alert such that they yield to crossing pedestrians. These flashing lights are either in the form of above-ground (overhead) flashing beacons, in-pavement (in-road) flashing lights, or a combination of both. The overhead flashing beacons are first introduced in England in the thirties and named *Belisha Beacons*, following the name of minister of transport Leslie Hore-Belisha who devised them. It is usually placed at zebra pedestrian crossings and in the form of black and white stripy poles with the flashing yellow balls on top. In-road flashing crosswalk lights were created in response to high incidence of pedestrian crashes in Santa Rosa, CA in 1993. The system was invented by an airline pilot whose friend was involved in a pedestrian-vehicle crash. He suggested that a row of lights in the pavement along the crosswalk (similar to runway lights at an airport) would give drivers an advanced warning of crossing pedestrians. The lights shine towards the coming vehicular traffic. In both cases, the lights are activated either manually by pedestrians via a push button or automatically via automated pedestrian detection techniques such as infrared detection devices and similar sensing devices.

Flashing beacons (sometimes called flashers or flashing lights) are frequently requested in the belief that they will slow down traffic. However, the real purpose of flashers is to attract attention to unexpected hazards. A flashing beacon is most effective as a warning of unexpected or hazardous conditions not readily visible to drivers. One of the more common locations where a flashing beacon is effective is at a stop sign controlled intersection located just beyond a curve that is hidden from the view of approaching motorists. Immediately after seeing a flasher, drivers must consistently see an unusual condition, which requires special attention. The condition also must be viewed as serious enough to justify having been alerted. For any traffic control device to be effective and it must command the respect of motorists, if it seems arbitrary or unnecessary, drivers tend to ignore it. When flashing beacons are used where not warranted, they soon lose much of their effectiveness. After continually being alerted to a condition which does not appear to be truly unusual, research and experience has shown that drivers actually stop "seeing" a flashing light. This can result in a disregard for all beacons, even those that are truly needed.

There has been a wide disagreement on the effectiveness of the different crosswalk flashing warning devices in reducing pedestrians' accidents and increasing their safety and comfort under the different operation conditions. For instance, above-ground and overhead flashing lights might not be noticeable and effective in urban areas, where regular traffic signals and other lighting sources are more common. Crosswalk flashing lights might lose their effectiveness over time, when drivers become accustomed to seeing them. Similarly, in-pavement crosswalk flashing lights might not be effective in areas with heavy-snowfall, where these in-pavement flashers could be covered by snow or ice. Also, the in-pavement flashers could be damaged by snowplows during snowplowing activities, increasing the effort of their maintenance.

2. OBJECTIVES

The main objective of this research is to determine the effectiveness of crosswalk flashing lights to justify its use. It reviews studies that investigate and document the effectiveness of crosswalk flashing lights as a measure to improve pedestrian safety at uncontrolled crosswalks. The focus will be given to the above-ground flashing lights, which seem to be more plausible option for areas with heavy-snow participations. The goals of the research are as follows:

- Review and identify the economics of the overhead crosswalk flashing lights in increasing the percentage of drivers yielding to pedestrians and reducing vehicular speed, conflicts and accidents at uncontrolled crosswalks.
- Compares the effectiveness of the above-ground flashing beacons against the in-pavement flashing lights as a safety measure at uncontrolled crosswalks.
- Review the main operational warrants, precautions and guidelines need to be considered with using the overhead crosswalk flashing lights.
- Study the cost effectiveness of the overhead crosswalk flashing lights with the different implementation of activation and pedestrian detection devices.
- Identify a set of recommendations for the implementation of the overhead crosswalk flashing lights and identify the topics that need further research.

3. SCOPE

There has been a significant amount of studies that investigate a wide variety of measures, devices, and treatments that improve pedestrian safety at different locations (sidewalks, intersection crossing, and midblock crossing). These measures are can be classified into three main categories:

1- Physical separation

Physical separation includes the cases where the conflicts between vehicular traffic and pedestrian traffic are eliminated by overpasses or underground tunnels. This separation is usually warranted at locations with high vehicular/pedestrian traffic volumes or at high speed routes where pedestrian traffic is noticeably frequent.

2- Time separation

Traffic signals are used to allocate the right of way to the different maneuvers of the vehicular and pedestrian traffic such that the conflicts between vehicles and pedestrians are eliminated or minimized. Traffic signals are widely used at traffic intersections, where a pedestrian phase is sometimes considered. It is also used at midblock sections, where pedestrian and vehicular traffic are high. In these traffic signals, the pedestrian phase is usually activated either manually or automatically at pedestrian presence.

3- Warning and Traffic Calming Measures

In the case of no physical or time separation between the vehicular and pedestrian traffic, other measures are used to warn vehicular traffic on the possible existence of pedestrians' activities. The main objective of these measures is to warn the drivers that such they reduce their speed and yield to possible conflicting pedestrian traffic. Examples of these measures include fluorescent signs, road marking, textured pavement, speed humps, above-ground and in-pavement flashing lights.

The focus of this study is limited to investigating the effectiveness of flashing lights in increasing pedestrian safety and reducing traffic accidents at uncontrolled pedestrian crossing, as indicated in the blue shaded blocks of Figure 1. This study reviews the experimental research and test cases that investigate the effectiveness of the above-ground flashing beacons as a warning device at uncontrolled crosswalks. In particular, it investigate the usefulness of the above-ground flashing beacons in reducing traffic speeds at pedestrians crosswalks, increasing the percentage of motorists that are yielding to pedestrians, reducing conflicts between motorists and pedestrians, reducing accidents, and increasing pedestrians safety. This study also reviews the comparisons between the effectiveness of the above-ground flashing beacons and the in-pavement flashing lights as warning devices for motorists at uncontrolled crosswalks.

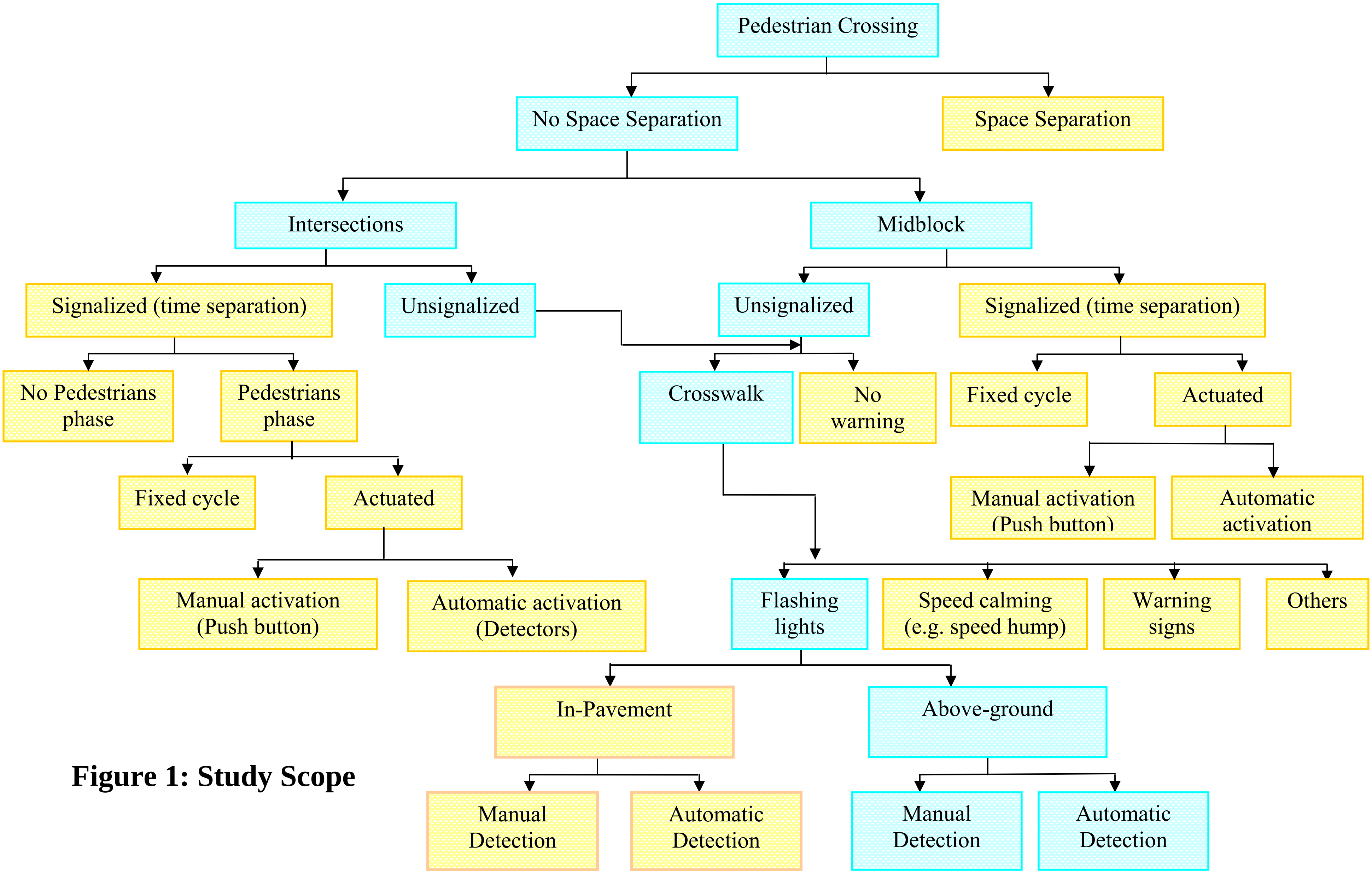

Figure 1: Study Scope

4. EFFECTIVENESS OF THE OVERHEAD CROSSWALK FLASHING LIGHTS

It has been noticed that there is general disagreement on the effectiveness of the above-ground crosswalk warning flashing lights. In the following subsections, conclusions of several studies about the effectiveness of these warrant systems are presented. Next, an overall summary is given regarding the impact of flashing lights with respect to several functional measures including crash reduction, percentage that yield, and maintenance.

Dartmouth, Nova Scotia (Van Houten et al. 1998)

This study evaluated two strategies for increasing the percentage of motorists yielding to pedestrians at crosswalks equipped with pedestrian-activated flashing beacons. One method involved adding an illuminated sign, with the standard pedestrian symbol next to the beacons. The second method involved erecting signs 50 m before the crosswalk that displayed the pedestrian symbol and requested motorists to yield when the beacons were flashing. Two crosswalk sites are selected for the study. One site was located at an intersection and the other is at midblock. The two crosswalks link a major community recreation facility with a convention center. Both crosswalks traversed three lanes of traffic in each direction separated by a concrete median strip. Flashing amber beacons were suspended over the crosswalk on a cable. Pedestrians activated the flashing beacons by pressing a button located on a pole at each end of the crosswalk. A sign placed on the pole contained the message “Press Button” to alert pedestrians. The beacons continued to flash 35 seconds once activated.

Data were scored manually from 48 pedestrians per day, between the hours of 9:00 AM and 5:00 PM, Monday through Friday over a 10-week period. Observers scored (a) whether the pedestrian activated the flashing beacons, (b) the yielding behavior of the drivers, and (c) motor vehicle—pedestrian conflicts. Yielding behavior was scored in the following manner. Whenever a pedestrian approached the crosswalk and was facing the crosswalk within approximately 0.5 m from the edge of the road, the observer scored the behavior of motorists in the three adjacent lanes but did not score the behavior of motorists on the far side of the median strip. Once the pedestrian entered the last lane before the median, the yielding behavior of the motorists in the remaining three lanes was scored. Motorists were scored as yielding to the pedestrian if they stopped before the crosswalk or slowed sufficiently to allow the pedestrian to cross. Motorists were scored as not yielding if they proceed through the crosswalk, provided that they were at least 50 m before the crosswalk when the pedestrian was positioned within 30 cm of the crosswalk for the first three lanes, or the pedestrian had started crossing the final lane before reaching the median strip for the last three lanes. A motor vehicle—pedestrian conflict was scored whenever (a) a motorist had to engage in abrupt audible braking, or had to change lanes abruptly to avoid striking a pedestrian, and (b) a pedestrian had to jump or suddenly step back to avoid being stuck by a vehicle.

Tables 1 and 2 present the results of the experiments at the intersection and the midblock crosswalk sites, respectively. The baseline represents the case when only the flashing beacons are used with no additional signs. In the baseline case, the percentages of pedestrians that activated the beacons are 57.3 and 71.7 in the two sites, respectively. These percentages increase at the intersection crosswalk to 55.5 and 66.4 when pictograph and pictograph plus yield signs are used, respectively. Similarly, it increased to 69.3 and 72.3 at the midblock crosswalk. The percentage of motorists yielding to pedestrians when the beacons were activated during the baseline condition averaged 67.6 percent at the intersection crosswalk and 67.5 at the midblock crosswalk. The modification of the pedestrian signal to include a pictograph of a pedestrian increased the percentage yielding at the intersection crosswalk to 78.0 percent, and the introduction of the pictograph at the midblock crosswalk increased the yielding percentage to 76.3. The introduction of both interventions at each site was associated with respective increases to 86.7 percent and 87.1 percent.

Generally, there is no significant reduction in the percentages of yielding motorists, when the beacons are not activated. There is significant percentage of motorists yielding to pedestrians at both crosswalks when beacons are not activated. For example, during the baseline case, the percentage of yielding motorists, when the beacons are not activated, declined by about 4% at the midblock crosswalk and counter-intuitively increased by about 2% at the intersection crosswalk. This might be raising a question regarding the incremental impact of the flashing beacons in alerting motorists to yield to pedestrians at intersections. In other words, the “baseline” yielding behavior of motorists at these sidewalks could be contributed to some other measure in the crosswalk setting and not to the flashing beacons.

The number of conflicts recorded in each session when the flashing beacons were activated averaged 1.0 per session at the intersection crosswalk and 3.0 per session at the midblock crosswalk during the baseline conditions. The introduction of a modified signal at the intersection crosswalk was associated with a small decline in the number of conflicts to 0.91 per session, but the introduction of the “Stop When Flashing” sign at the midblock crosswalk was associated with a marked reduction in conflicts to 0.37 per session. The addition of the “Stop When Flashing” sign at the intersection crosswalk was associated with a marked decline in conflicts to 0.25 per session, and the introduction of the modification to the pedestrian signal at the midblock crosswalk was associated with a small increase in conflicts to 0.67 per session.

In general, the results of these experiments indicate that adding the pedestrian symbol next to the flashing beacons and adding a sign promoting motorist to stop when the amber beacons are flashing are both effective in increasing the percentage of drivers yielding to pedestrians when the flashing beacons are activated. The data also indicate that conflicts are reduced by the sign prompting motorists to stop when the amber beacons are flashing but not by adding the pedestrian pictograph to the amber beacon. One reason why the Yield When Flashing signs may have been effective is that they removed the dilemma of whether the motorist could safely stop for a pedestrian. If the motorist was behind the sign when the beacons began to flash, they were at a safe distance to stop for the pedestrian providing they were complying with the speed limit. Without the sign, motorists considering whether they should stop for a pedestrian might lose the opportunity to do so if they took too long to make their decisions. The addition of the pedestrian symbol beside the flashing amber beacons probably increased yielding behavior because the pictograph was so similar to the crosswalk sign currently in use in

North America and likely made the crosswalk more salient to the drivers by prompting them to look for pedestrians.

Table 1: Beacon activation and percentage of motorists yielding to pedestrians at the intersection site (Van Houten et al. 1998)

criteria	Baseline		Beacon and Pictograph		Yield Sign plus Beacon and Pictograph	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Percentage of pedestrians activated beacons	**57.3**	8.8	**55.5**	9.4	**66.4**	6.1
Percentage of motorists yielding when beacon activated	**67.7**	6.4	**78.0**	5.9	**86.7**	7.2
Percentage of motorists yielding when beacon not activated	**69.9** (+2.2)	6.5	**61.6** (-16.4%)	13.0	**70.9** (-15.8%)	15.3

Table 2: Beacon activation and percentage of motorists yielding to pedestrians at the midblock site (Van Houten et al. 1998)

Criteria	Baseline		Beacon and Pictograph		Yield Sign plus Beacon and Pictograph	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Percentage of pedestrians activated beacons	**71.7**	6.9	**69.3**	7.0	**72.3**	5.2
Percentage of motorists yielding when beacon activated	**67.5**	6.3	**76.3**	6.3	**87.1**	5.3
Percentage of motorists yielding when beacon not activated	**63.5** (-4%)	14.8	**62.4** (-13.9%)	14.4	**75.8** (-11.3%)	13.9

Phoenix, Arizona (Sparks and Cynecki 1990)

The City of Phoenix has experimented with advance warning flashing beacons in conjunction with several pedestrian locations (all on major streets) near schools. Summary of the main related findings at three locations are given below.

Arcadia High School Flasher:

The first use of pedestrian flashers in Phoenix was part of an effort to reduce speeds and increase driver awareness of pedestrians near Arcadia High School. The flashers were installed at 4700 East Indian School Road, a six-lane, high volume major street. This experiment involved flasher operation during school hours (6:00 AM to 3:35 PM). Overhead flashers were installed with supplemental "SCHOOL" warning signs. Simultaneous with flasher installation, the speed limit was reduced from 40 mph to 35 mph. Before-and-after radar speed studies collected in 1975 indicated that the flashers and lower speed limit did not result in lower vehicle speeds. In fact, both the average speed and the 85th percentile speeds increased slightly after flasher installation. In early 1989, another study was conducted to measure any possible long term impact of the flashers. Radar speed data were gathered near 44th Place and Indian School Road, which is outside the flasher influence area, and were compared with speeds at 4700 East Indian School Road, directly at the flasher. Flashers presence did not reduce speeds, despite the flasher roadway section having a posted speed 5 mph lower than the roadway section without flashers.

Cortez High School:

The second experiment with pedestrian flashers was conducted at Cortez High School, 3300 West Dunlap, in 1976. The school is on the south side of a six-lane major street and had a split campus with Cortez Park on the north side of the street, which generated considerable pedestrian crossings. A traffic signal was recommended and implemented for the school driveway. However, the school staff was concerned that because no local street existed, drivers may not perceive this signal as a logical stopping point. This concern was due to previous experience with a similar midblock school traffic signal. Flashers were therefore added to advance warning signs (about 250 feet up-stream) in conjunction with the new traffic signal. The flashers are actuated by pedestrians at the signal. A study was performed to determine if the flashers were successful in reducing run-red violations. In summary results have indicated that flashers were ineffective in reducing run-red violations when vehicle movements at a midblock pedestrian signal with flasher were compared with vehicle movements at similar midblock pedestrian signal without flashers.

Sunnyslope High School

This experiment with flashers occurred in Central Avenue, a median-divided major street with two lanes in each direction. Central Avenue has a posted speed limit of 35 mph. Townley is a local street that T-intersects with Central Ave. The crosswalk on Central at Townley is 1/8 mile south of a signalized major street intersection (Dunlap), which served as one of two access points to the Sunnyslope High School parking lot. Pedestrian-actuated (push button) flashers were installed on October 9, 1987. The pedestrian-actuated flashers were mounted with oversized, advance pedestrian warning signs and a 30-mph advisory speed sign. When activated, the advance beacons flash for 25 second allowing sufficient time to cross Central Ave. There are also supplemental advance warnings signs with advisory speed signs installed in the median island without flashers. Specialty warning signs advising pedestrians to "Use Caution When Entering the Street" were installed to compensate for a possible "false sense of security" the flashers may give to pedestrians.

Radar speed studies taken a short time after flasher installation revealed a slight speed reduction (2 to 3 mph) during flasher actuation. However, driver speeds were slightly above the 35-mph posted speed limit and well above the 30-mph advisory speed posted at the flasher. The study highlighted that other national studies have repeatedly found that drivers have a natural tendency to reduce speeds when pedestrians are present. Since pedestrian-actuated flashers only operate when pedestrians are present, even the minimal 2-3 mph speed reduction may not be attributable to the flasher. The presence of pedestrians may have caused the lower speeds. Long term speed studies were conducted in February 1989. Findings indicated no flasher effectiveness, with virtually identical vehicle speeds when the flasher is operating compared with the non-flashing conditions. Furthermore, the minor impact found after the first four months had virtually eroded, with speeds during flashing operation increasing to become identical to the before condition. Observations of pedestrians at the crosswalk indicated that only one third of the pedestrians crossing Central Ave bothered to push the flasher button. The high number of pedestrians unwilling to push the buttons reflects poorly on the flasher's value.

In summary, the study concluded that local experience in Phoenix, Arizona, shows that flashers offer no benefit for intermittent pedestrian crossings in an urban environment. In addition, the longer the flasher operates, the more it becomes part of the scenery and eventually loses any effectiveness. Flashing beacons may be ineffective in an urban environment because intersections are encountered frequently by motorists and pedestrians; flashers therefore provide no additional information to pedestrians. Additionally, most major streets in Phoenix are flat, straight and allow no parking, thus offering consistent and predictable driving conditions. It is recognized that actuated flashers may possibly be beneficial in a high-speed, rural environment with unusual geometrics, high pedestrian crossings, and unfamiliar drivers. The use of actuated flashers raises concerns about pedestrians expecting drivers to slow down when the flashers are activated. As a result, pedestrians could relax their guard while crossing, resulting in a less safe condition. Another major concern with the use of flashing beacons for any jurisdiction is uniformity. The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD 2003) highlights the need for uniformity and caution about the overuse of traffic control devices. Overuse and inconsistent use of traffic control devices lead to noncompliance and a general lack of effectiveness. Even more important, overuse of traffic control devices diminishes their effectiveness at locations where they are truly warranted. Finally, a lack of uniformity can expose a jurisdiction to liability, allowing attorneys to "point their fingers" at non-standard flasher locations or at locations that are similar but not equipped with flashers. Finally, it was concluded that flashers evaluations in Phoenix have clearly suggested that the use of flashers in an urban environment for intermittent conditions does not add to traffic safety and should not be a recommended or encouraged practice.

Camas, Washington (City of Camas and Washington State Department of Transportation 1999)

The City of Camas, Washington, was considering enhancing one of its sidewalks that is extensively used by students from local neighborhoods when traveling to and from school. The crosswalk is located on Everett Street which carries vehicular traffic of about 7,400 vehicles per day with an 85^{th} percentile speed of 32 to 34 mph. One of the main pedestrian routes crossing Everett Street is at 19^{th} Avenue which has 82 pedestrians per day crossing Everett Street when school is in session. Most of pedestrian crossings take place the hour prior to the start and the hour after release of students from school at the northbound of Everett Street. At the project outset, the intersection included a market (striped) school crossing with advance “School Crossing” warning signs. Traffic on 19^{th} Avenue was stop sign controlled and Everett Street traffic was uncontrolled. To help increase the visibility and safety of this crossing, local agencies wanted a crossing treatment, such as traffic signal or the use of other traffic calming techniques, to assist pedestrians cross Everett Street. Gap studies along Everett Street showed that traffic control was warranted only during the time children were traveling home from school in the afternoons.

The City of Camas undertook an exhaustive public involvement process to insure the needs of all stakeholders affected by the crossing treatment would be addressed. The stakeholders involved included the City of Camas, Washington State Department of Transportation, local police and fire departments, the local school district, City Council, and neighborhood citizens. Several options are discussed and the stakeholders considered the option of adding a median island and flashing beacons with passive infrared detection (19^{th} Avenue to remain stop sign controlled and Everett Street to remain uncontrolled). This option uses passive infrared sensors to detect when pedestrians are present at the landing of the crosswalk. Once the pedestrian is detected, flashing beacons (located above the crosswalk) are activated to alert motorists that pedestrians are at the crosswalk. The pedestrians are then monitored as they are crossing the street by a second set of infrared sensors. Once the pedestrian has crossed the street and left the landing area, the beacons are deactivated by the use of a gap timer until another pedestrian comes up to the crossing landing. In addition to the infrared detection, a raised island was constructed in the middle of the Everett Street to provide a storage area for pedestrians as they cross and to constrict vehicle travel lanes to encourage lower speeds through the crossing area. Curb cuts were provided in the median to allow bicycle and wheelchair access across the street, and to direct pedestrians and bicyclists so they face the direction of oncoming traffic before continuing across the street.

With the addition of traffic calming elements and the use of passive detection to activate supplemental warning devices at this crosswalk, the new system was evaluated to determine if any of the treatments changed motorist or pedestrian behaviors within the crossing area. Three different surveys were conducted before and after the addition of the crossing treatment to evaluate its effectiveness. These surveys include Speed Survey, Pedestrian Crossing Count Survey, and Video Tape Survey. The results of these surveys are given below:

Speed Surveys:

Speed surveys were conducted to evaluate if lane width restrictions and the addition of overhead pedestrian crossing signs with supplemental warning beacons activated only when pedestrians are in the vicinity of the crossing changed motorists behavior within the crossing area. Speed surveys were conducted at two locations for both southbound and northbound vehicles (100 feet and 500 feet north and south of crossing). The results of the speed survey are given in Table 3. Results generally show slight or no reduction in speed due to the crosswalk improvement.

Pedestrian Crossing Counts Survey

Pedestrian counts were conducted at the intersection of Everett Street and 19th Avenue, midblock locations north and south of the intersection, and adjacent intersections (17th Avenue and 21st Avenue) before and after the pedestrian crossing improvements. Before counts show where pedestrians were crossing Everett Street prior to the pedestrian crossing improvements. After counts make it possible to determine if modifications to the existing crosswalk encouraged pedestrians to use the crosswalk, cross at other locations, if pedestrian behaviors remain unchanged. The results of the before and after surveys, shown in Table 4, indicate that with crossing improvements in place, crosswalk pedestrian traffic increased by about 5%. Also, crossings outside the crosswalk have decreased by about 2% and midblock crossings have decreased by about 6%.

Table 3: Speed Survey (City of Camas and Washington State Department of Transportation 1999)

Survey Location	85% speed Before (mph)	85% speed After (mph)	Percent Change
Northbound			
100’ South of Crossing	29.0	29.6	+2%
500’ South of Crossing	28.0	28	0%
Southbound			
100’ North of Crossing	32.0	29.4	-8%
500’ North of Crossing	33.0	30.6	-7%

Table 4: Pedestrian Crossing Count Survey (City of Camas and Washington State Department of Transportation 1999)

Crossing Location	Percent of Pedestrians Crossing Everett St.	
	Before	After
19th Ave/Everett St (within crosswalk)	78%	83%
19th Ave/Everett St (outside crosswalk)	9%	7%
Everett St: Midblock (17th to 19th and 19th to 21st)	9%	3%
Everett St: Adjacent Intersections (17th and 21st)	4%	7%

Video Tape Surveys:

Video tape surveys were conducted on both approaches of Everett Street at its intersection with 19th Avenue. Cameras were placed in advance of the crosswalk (approximately 200 to 300 ft in inconspicuous locations) at a position that allows for the monitoring of the deceleration and braking of vehicles, which can indicate the drivers' reaction to pedestrians at the crossing. The results from the video tape surveys provide the most obvious effect of the pedestrian crossing improvement on motorists' behavior. Three categories of motorists' behavior were analyzed. These included motorists that showed no apparent slowing when pedestrians were present at the crossing, those that slowed for pedestrians, and those that stopped for pedestrians at the crossing. Table 5 summarizes the before and after analysis.

Table 5: Video Tapping Survey (City of Camas and Washington State Department of Transportation 1999)

Motorist Behavior	NB		SB	
	Before	After	Before	After
No apparent slowing for pedestrian	49%	10%	58%	20%
Slowed for pedestrian	25%	33%	19%	43%
Stopped for pedestrian	26%	57%	23%	37%

Chattanooga, Tennessee (Van Winkle 1997)

In order to better identify midblock crosswalks, the City of Chattanooga for several years has been using pedestrian-actuated flashing beacons for midblock crosswalks on arterial streets. By flashing only when the crosswalk is actually in use, these installations are more effective in alerting drivers to the crosswalk and hence in protecting pedestrians. The technical design consists of overhead signs with the message "Yield to Pedestrians – 25 MPH When Flashing" with dual 8-inch beacons mounted approximately 300 feet in advance of the crosswalk in both directions. Push buttons are mounted on pedestal poles on both sides of the crosswalk, along with auxiliary flashers that confirm to the pedestrian that the overhead beacons have been activated. Advisory signs are also posted instructing the pedestrians in the use of the flashers. Once activated, the beacons are controlled by a timer housed in the flasher cabinet. The duration for each activation is dependent on the width of the street, usually 20-30 seconds. The first pedestrian actuated crosswalk flashing beacons was installed in 1987 in response to a request from a retirement home for an unwarranted standard traffic signal. Field studies determined that the installation is effective in reducing pedestrian/vehicle conflicts. Since the initial installation, three other crosswalks have been equipped with these devices.

Boulder, Colorado (City of Boulder 2002)

In 1998, Boulder's city staff began an outreach effort with the community to identify needed pedestrian facilities. This included missing sidewalks, current social trails and needed pedestrian crossing improvements. Requests for a pedestrian crossing treatment were placed on a list for evaluation. From this list, staff identified 47 locations that required further study. Then, most of the identified treatments were constructed. The construction of new pedestrian crossing treatments was beneficial to the city's goal of promoting the pedestrian mode; however, several issues still remain. The city realized that at uncontrolled crossing locations, drivers were not yielding to pedestrians as required by law. Also, there was concern that pedestrians crossing multiple lanes in the same direction were exposed to a multiple threat scenario, where one vehicle stops and yields but that vehicle shields the pedestrian's line of sight to a second vehicle that does not yield. To address these issues, staff began researching non-standard pedestrian crossing treatments or enhancements, being used in other communities.

In 2000, city staff began demonstrating two new pedestrian crossing treatment enhancements. The first demonstration was a new sign saying "State Law – STOP for pedestrians in crosswalk" placed on an orange barrel on the lane line and on the side of the street. The other device was the "in-pavement lighting", which involves placing lights into the pavement and connecting the lights to a pedestrian actuation button. When the pedestrian pushes the button, the lights begin to flash, long enough for the pedestrian to cross the street. Flashing yellow beacons were also placed in the median island and on the curb ramp, at the crosswalk location. These beacons flashed when a pedestrian pushed the button and flashed long enough for them to cross the street. Later in 2000, staff began to extend these demonstrations to other locations within the city. The “State Law” signing was used with barrels and added to median refuge island to create “gate-posting” effect. The in-pavement lighting aspect of the second demonstration was not repeated; rather this treatment relied on the above-ground pedestrian actuated flashing beacons which bracketed the crossing area. Over about two years, staff placed these demonstrations devices at 12 locations. In addition, staff studied these devices and made determinations on their relative effectiveness, safety and impact to the roadway system, for different conditions. Table 6 presents the vehicular volume, pedestrian crossing volume and “yielding to pedestrians” compliance, before and after the installation of the pedestrian activated flashing beacons. The results suggest that in all locations where this demonstration device was installed, there were significant increase in “yielding to pedestrians” compliance. The single factor that seemed to most influence these results was the amount of pedestrian crossing activity. Locations that had high pedestrian crossing volumes, also had very high compliance percentages, regardless of other factors such as roadway volumes. Likewise, low pedestrian crossing volumes typically resulted in low compliance percentages. In all cases, the compliance increased significantly after the demonstration devices were provided.

Table 6: Compliance results at crosswalks with pedestrian actuated flashing beacons (City of Boulder 2002)

Location	Vehicle volume per day	Pedestrian volume (3 hours)	Compliance (before)	Compliance (after)
Canyon & 11th	20,000	460	38%	74%
2900 Pearl Street	22,000	70	26%	54%
Broadway & 18th	35,000	330	23%	70%
Broadway & Pleasant	35,000	500	16%	70%

Staff also reviewed accident reports for a number of these demonstration locations. Two types of accidents seemed to be associated with the crossing area and these demonstration devices. One type of accident was a vehicle failing to yield to a pedestrian or bicyclist and hitting them in the crosswalk. Fortunately, these types of accidents were very rare, and there was not a significant increase in these types of accidents as a result of any of the demonstration devices. The other type of accident occurred when a vehicle stopped to yield to a pedestrian and was hit from behind (rear-end collision) by another vehicle that did not stop in time. Unfortunately, this type of collision was much more common. In most locations, there were very similar numbers of these types of collisions, before and after the placement of these demonstration devices. The one notable exception is the crossing treatment on Broadway and Pleasant Avenue. At this location, there were almost four times as many of these types of collisions after the placement of the pedestrian actuated flashing beacons.

During this study, some concern was expressed about the impacts these crossing demonstrations have on vehicular delay and congestion. The study notes that none of the pedestrian crossing treatment "demonstration" devices actually change the rules of the road at any of these crossing locations. So any impact on vehicular delay or congestion would be the result of more pedestrians taking their right-of-way at these crossings and/or more vehicles stopping to yield to these pedestrians. In April 2002, staff conducted a drive-time survey on one of the corridors on which the devices are installed to attempt to quantify the delay occurring from the demonstration devices. Staff drove through the corridor during peak traffic periods, noting the time it took to get from one point to another through the demonstration devices. The data for trips in which a pedestrian caused delay in the crosswalk was compared to data for which no pedestrian was encountered in the crosswalk. In summary, there was between 5 to 15 seconds of average additional delay for trips in which a pedestrian was encountered. The results suggested that delay to motor vehicle traffic in the studied corridor as a result of these demonstration devices is not a significant factor.

San Jose, California (Malek 2001)

A study was performed in San Jose, California, to compare the effectiveness of overhead yellow flashing beacons against an experimental embedded pavement light system. To avoid repetition, the details of the effectiveness of the overhead yellow flashing lights and results of the comparison will be given in the next section. Based on before and after studies at the locations where these two devices are installed, it was concluded that although the above-ground flashing beacons were found to be effective at uncontrolled crosswalks, the embedded pavement light system was found to be more effective at alerting motorists of pedestrian presence in the crosswalk than the standard overhead yellow flashing beacons, particularly at night. This was also validated by pedestrians and drivers surveys. It appears that drivers more easily observe the experimental embedded pavement lights rather than the standard overhead yellow flashing beacon installation. The study recommended that these devices should be evaluated under adverse weather conditions and overtime, as motorists become accustomed to the system. The study also reported that there were maintenance issues with the experimental embedded pavement lights and its activation system during the six-month test period. These issues included moisture penetration in the fixture housing, vandalism and malfunction of the detection/activation system. The experimental embedded pavement flashers appear to prone to more maintenance needs, particularly at the time of pavement resurfacing and other maintenance activities.

Copenhagen, Denmark (The Danish Road Directorate 1998)

The installation of better lighting at zebra crossings, i.e., the so-called "Copenhagen system", has been estimated to give a 30% reduction in the number of pedestrian accidents occurring in darkness. This system can help to make pedestrians more visible and can induce them to cross the road at a zebra crossing, in preference to a point elsewhere in the immediate vicinity. The system consists of road markings, a flashing amber light, internally-illuminated zebra-crossing-signs and illumination of the crossing with two 1,000 W lamp suspended about six meters above the carriageway.

Perth, Australia (Zeeger and Zeeger, 1988)

The installation of floodlights at 63 zebra crossings in Perth, Australia, resulted in a significant drop in the number of pedestrian accidents in darkness, from 39 in the before period to 15 in the after period, i.e. a 62% reduction. The installation did not affect the number of pedestrian accidents occurring in daylight and neither did it affect the number of other accidents. The Perth system consists of a 100 W sodium-vapour lamp, suspended about five meters above the carriageway, on either side of the zebra crossing.

5. ABOVE-GROUND VS IN-PAVEMENT CROSSWALK WARNING FLASHING LIGHTS

There is a single comprehensive study (Malek 2001) that compares the effectiveness of the two warning systems at uncontrolled crosswalks, which was conducted in San Jose, California. The purpose of this study is to examine the effectiveness of experimental embedded pavement lights against the standard overhead yellow flashing beacons, where both systems are activated automatically by motion detectors that sense the movement of pedestrians into the crosswalk. While the focus of this study is at crosswalks at intersections, it is believed that many of its conclusions are very much related to the objectives of this study, which focus of midblock crosswalks.

The study concluded that the embedded pavement light system was found to be more effective at alerting motorists of pedestrian presence in the crosswalk than the standard overhead yellow flashing beacon, particularly at night. Furthermore, , based on driver surveys, that drivers observe the embedded pavement lights more easily rather than the standard overhead yellow flashing beacon installation. The study recommended that these devices should be evaluated under adverse weather conditions (i.e. rainy days, fog, and other wet conditions). In addition, the effectiveness of the devices should be evaluated over time, as motorists become accustomed to the system.

It is also indicated that there were some maintenance issues with the experimental embedded pavement lights and the bollard activation system during the six-month test period. These issues included moisture penetration in the fixture housing, vandalism and malfunction of the bollard detection system. Generally, the experimental embedded pavement flashers appear to be prone to more maintenance needs, particularly at the time of pavement resurfacing and other maintenance activities. In the next few subsections, the study settings, methodology, and main findings are presented.

Study Settings:

1- System configuration:

As mentioned earlier the effectiveness of two crosswalk warning systems are compared. These systems are the standard overhead warning flashing beacons and the embedded pavement light system. The standard overhead yellow flashing beacon system consists of a (California Department of Transportation) Caltrans standard mastarm with 12-inch yellow flashing beacon heads per direction and one W-54 sign placed in between the two heads. This system is activated when a pedestrian passes through a set of bollards that has an optical beam running between them.

The embedded pavement light system utilizes a series of lighting emitting diodes (LEDs) in a housing embedded in the roadway, which flashes to warn approaching motorists that a pedestrian is entering or is in the crosswalk. The lights shine out towards the oncoming vehicular traffic to warn drivers and flash for a set period of time before automatically turning off. The system also activates when a pedestrian breaks an optical beam by passing through a set of bollards.

2- Experimental Location:

The city of San Jose selected intersections with existing uncontrolled crosswalks to conduct the study. The first intersection, in which the overhead yellow flashing beacon is installed, represents a T-intersection in which a two lane residential street (36 ft curb to curb) is teeing into a four lane east-west major collector street (70 ft wide curb to curb). The major collector street has a left turn lane on each approach and carries approximately 10,000 vehicles per day with speed limit of 30 mph. It also has no on-street parking and continuous sidewalk on both sides of the street. The residential street is controlled by a one-way stop sign and has a speed limit of 25 mph. The intersection serves the traffic to a nearby hospital and a senior living facility. It also connects the hospital to residential and medical facilities on the other side of the intersection. The standard overhead yellow flashing beacon was installed at the existing crosswalk on the east legs of the major collector.

The embedded pavement flashing light system was installed at another intersection where a north-south major collector intersects with a two lane residential street. The major collector consists of two lanes, bike lane, and left turn lane (65 ft curb to curb). It carries about 6,000 vehicles per day with speed limit of 35 mph. It has a continuous sidewalk of both sides and parking is removed in the vicinity of the intersection. The residential street (36 ft curb to curb) is controlled by a two-way stop sign on each of its approaches and has a speed limit of 25 mph and has a continuous sidewalk of one side (the north side). The embedded pavement flashing lights are installed on the existing crosswalk on the major collector at the north side. This intersection connects the residential area to the vicinity of a park area.

Methodology:

A before-after study was performed at both installations. The study focused on the reaction of drivers to a pedestrian waiting to cross the street as well as driver and pedestrian perceptions of the system.

Driver Reaction:

At both locations, driver reaction was measured with a pedestrian waiting to cross the street. Using a staged pedestrian, the following driver reaction parameters were evaluated at each location for conditions both before and after installation:

- Approach speed of vehicles (from 500 to 300 ft in advance of the crosswalk)
- Travel time of the vehicles (from 500 to 100 feet in advance of the crosswalk)
- Distance prior to the crosswalk at which brakes were applied (if any)
- Reaction of driver to the pedestrian waiting to cross (did the driver brake or yield?)

Data was collected manually during the daylight and nighttime conditions using visual observations, stop watches, and two-way radios. The weather was clear and the pavement was dry during the testing periods. The staged pedestrian stood on the curb, preparing to cross, for half of the data samples, and stepped out into the roadway for the other half of the data samples. The staged pedestrian never directly challenged the vehicles during the study. Data was collected on random chosen vehicles, typically the first in a platoon to ensure good potential for eye contact between driver and pedestrian. During the after-study, the pedestrian activated the flashing lights (or flashing beacon) by walking through the bollards as the vehicles approached. There were two after-studies conducted for both daylight and nighttime conditions. The first after-study occurred one month after installation and results were compared with six-month after-study data.

Driver Survey:

Six months after the installation of the devices, randomly selected drivers were interviewed after passing through the activated crosswalk warning systems. Drivers were flagged to the side of the road by City of San Jose police officers and the following straightforward questions were asked.

- Did you notice the crosswalk in which you passed in the last block?
- Did you notice any pedestrians in or near that crosswalk?
- Did you notice the flashing lights at the crosswalk?
- Are the warning devices are effective?

Pedestrian Survey:

Pedestrian interviews were randomly taken and the data was collected before, as well as one month and six months after, the installation of the crosswalk warning devices. Eleven pedestrians were surveyed at the first intersection and 10 pedestrians were surveyed at the second intersection during the day time. Pedestrians were asked the following questions:

- Did you feel safe crossing at this location?
- Are you aware of the flashing lights?
- Do you rely upon the lights to stop drivers to give you the right-of-way?

Main Findings:

Drivers Reaction:

Standard Overhead Yellow Flashing Beacons (Table 7):

<u>Eastbound</u>

- Drivers yielding for pedestrians during the day increased from 1% in the before conditions to 4% and 2% for one month and six months after installation, respectively. Braking distance during the day increased from 63 feet in the before condition to 133 feet and 243 feet for one month and six months after installation, respectively.

- Drivers yielding for pedestrians during the dark hours of the night increased from 0% in the before condition to 5% and 8% for one month and six months after installation, respectively. Braking distance during the night increased from none in the before condition to 175 feet and 190 feet for one month and six months after installation, respectively.

Westbound

- Drivers yielding for pedestrians during the day increased from 5% in the before condition to 14% and 8% for one month and six months after installation, respectively. Braking distance during the day increased from 87 feet in the before condition to 165 feet and 266 feet for one months and six months after installation, respectively.
- Drivers yielding for pedestrians during the night increased from 2% in the before condition to 5% and 8% for one month and six months after installation, respectively. Braking distance during the day increased from 87 feet in the before condition to 200 feet and 228 feet for one month and six months after installation, respectively.

Table 7: Standard Overhead Yellow Flashing Beacons (Malek 2001)

Criteria	Before	After	
		One month	Six months
Eastbound			
Drivers yielding for pedestrians during the day	1%	4%	2%
Braking distance during the day	63 ft	133 ft	243 ft
Drivers yielding for pedestrians during the night time	0%	5%	8%
Braking distance during the night time	0 ft	175 ft	190 ft
Westbound			
Drivers yielding for pedestrians during the day for	5%	14%	8%
Braking distance during the day	87 ft	165 ft	266 ft
Drivers yielding for pedestrians during the night time	2%	5%	8%
Braking distance during the night time	87 ft	200 ft	228 ft

Experimental Embedded Pavement Light System (Table 8):

<u>Northbound</u>

- Drivers yielding for pedestrians during the day increased from 10% in the before condition to 44% and 46% for one month and six months after installation, respectively. Braking distance during the day increased from 143 feet in the before condition to 245 feet and 232 feet for one month and six months after installation, respectively.
- Drivers yielding for pedestrians during the night increased from 5% in the before condition to 64% and 80% for one months and six months after installation, respectively. Braking distance during the night increased from 148 feet in the before condition to 329 and 352 feet fro one month and six months after installation, respectively.

<u>Southbound</u>

- Drivers yielding for pedestrians during the day increased from 12% in the before condition to 54% and 52% for one month and six months after installation, respectively. Braking distance during the day decreased from 214 feet in the before condition to 186 and 192 feet for one month and six months after installation, respectively.
- Drivers yielding for pedestrians during the night increased from 5% in the before condition to 68% and 72% for one month and six months after installation, respectively. Braking distance during the day increased from 105 feet in the before condition to 324 feet and 286 feet for one month and six months after installation, respectively.

Table 8: Embedded Pavement Light System (Malek 2001)

Criteria	Before	After	
		One month	Six months
Northbound			
Drivers yielding for pedestrians during the day	10%	44%	46%
Braking distance during the day	143 ft	245 ft	232 ft
Drivers yielding for pedestrians during the night time	5%	64%	80%
Braking distance during the night time	148 ft	329 ft	352 ft
Southbound			
Drivers yielding for pedestrians during the day for	12%	54%	52%
Braking distance during the day	214 ft	186 ft	192 ft
Drivers yielding for pedestrians during the night time	5%	68%	72%
Braking distance during the night time	105 ft	324 ft	286 ft

Driver Survey:

Standard Overhead Yellow Flashing Beacons (Table 9):

- The six-month after study of the drivers during the day revealed that 50% of the surveyed drivers noticed the crosswalk. Fifty percent of the drivers surveyed noticed a pedestrian, and of those, 17% noticed the flashing lights. Only 4% of the surveyed drivers thought the device was effective.
- The six-month after study of the drivers during the night revealed that 50% of the surveyed drivers noticed the crosswalk. Sixty percent of the drivers surveyed noticed a pedestrian, and of those, 5% noticed the flashing lights. Only 5% of the surveyed drivers thought the device was effective.

Table 9: Standard Overhead Yellow Flashing Beacons (Six-month after study) (Malek 2001)

Criteria	Day time	Night time
Noticed the crosswalk	50%	50%
Noticed a pedestrian	50%	60%
Out of which noticed the flashing light	17%	5%
Thought the device was effective	4%	5%

Experimental Embedded Pavement Light System (Table 10):

- The six-month after study of the drivers during the day revealed that 71% of the surveyed drivers noticed the crosswalk. Eighty-nine percent of the drivers surveyed noticed a pedestrian, and of those, 42% noticed the flashing lights. Sixty-nine percent of the surveyed drivers thought the device was effective.
- The six-month after study of the drivers during the night revealed that 71% of the surveyed vehicles noticed the crosswalk. One hundred percent of the drivers surveyed noticed a pedestrian, and of those, 91% noticed the flashing lights. Sixty-six percent of the surveyed drivers thought the device was effective.

Table 10: Embedded Pavement Light System (Six-month after study) (Malek 2001)

Criteria	Day time	Night time
Noticed the crosswalk	71%	71%
Noticed a pedestrian	89%	100%
Out of which noticed the flashing light	42%	91%
Thought the device was effective	69%	66%

Pedestrian Survey (Tables 11 and 12):

Overall, pedestrians were receptive to the new devices, however, several pedestrians thought that both systems were a poor use of funds and felt a standard traffic signal with a pedestrian push button would be more effective.

Table 11: Standard Overhead Yellow Flashing Beacons (Six-month after study) (Malek 2001)

Criteria	Day time	Night time
Felt comfortable crossing at the crosswalk	50%	N/A
Out of which were aware of the flashing lights	80%	N/A
Rely upon the lights to stop drivers to give them the right of way	0%	N/A

Table 12: Embedded Pavement Light System (Six-month after study) (Malek 2001)

Criteria	Day time	Night time
Felt comfortable crossing at the crosswalk	81%	N/A
Out of which were aware of the flashing lights	91%	N/A
Rely upon the lights to stop drivers to give them the right of way	18%	N/A

6. MAIN FINDINGS:

Based on the review of the experiments related to crosswalk flashing lights presented above, several findings regarding the impact of the flashing lights at midblock crosswalks can be summarized as follows:

- Most of the flashing light systems are adopted with non-passive activation system (push buttons), where pedestrians at the crosswalk might press a button to activate the flashing lights. Pedestrians might feel that it is unnecessary to push the button and they can cross, while the flashing lights are not active. The percentage of pedestrians who activate the flashing lights differed among the studies that reported this number, ranging from 33% of crossing pedestrians to 71.3%. Nonetheless, it was not possible to explain the reason behind this variation at the different locations.
- Studies that considered studying the impact of crosswalk above-ground flashing lights in reducing traffic speeds at midblock crosswalks have found that flashing lights have no or slight (2-3 mph) impact on reducing traffic speed near the crosswalk.
- Most of the studies have reported that considerable percentage of vehicles yield to crossing pedestrians at midblock crosswalks with flashing lights (ranging from 10% to 74%). However, the results were sometimes misleading since it did not consider the fact that vehicles are yielding anyway even when the flashing lights

are not activated. Drivers might yield when they notice an activity on the crosswalk, even when the flashing lights are not available.

- Several studies have reported results from before-and-after analysis that investigated the yielding behavior of traffic at crosswalks before and after installing flashing lights. Most of the studies have indicated that flashing lights increase the percentage of vehicles that yield to crossing pedestrians (average of about 100%). However, the range of this increase was significantly different from a study to another, raising questions regarding the possible existence of other factors that might impact the yielding behavior of vehicles. One of the results have indicated that the impact of the flashing lights at crosswalks tend to decline with time.
- Two non-U.S. studies have indicated that above-ground flashing lights tend to reduce accidents during nighttime. About 30% and 62% reduction in accidents have been reported in the two studies.
- Only one study considered studying the impact of the flashing lights at midblock crosswalk in reducing conflicts between vehicles and crossing pedestrians. In this study, it is reported that conflicts are reduced by about 66%, when flashing lights are implemented at the crosswalk.
- As reported by one study, the existence of the above-ground flashing beacons encouraged more pedestrians to use the crosswalk. Results indicated that there is about 5% increase in pedestrians' activities after installation of the above-ground flashing lights at the crosswalk.
- Finally, it is indicated that flashing lights at pedestrians' crosswalk might not be effective in urbanized areas, where drivers might be distracted by many lighting sources including traffic signals. However, it can be more effective in dark places where the existence of the flashing lights can better get the attention of drivers for possible activities on crosswalks.
- Embedded flashing lights are generally more effective than the above-ground flashing lights at midblock crosswalks. They also tend to remain effective for longer periods.

- Studies have indicated that embedded flashing lights might require more consideration for its maintenance, raising questions about is reliability. However, it has been observed that over the last few years new systems have been developed which tend to be more reliable and requires less maintenance.
- No studies have indicated the impact of existence of snow on the top of the embedded flashing lights on its effectiveness.

7. GUIDELINES AND RECOMMENDATIONS

As presented in the different case studies and demonstrations presented in the previous two sections, there has been general disagreement regarding the effectiveness of the above-ground flashing beacons as a tool to alert motorists at uncontrolled crosswalks. In addition, in the cases that the above-ground flashing beacons are identified to be effective in increasing pedestrian safety, there has been wide differences in reporting and quantifying the impact of these devices at the uncontrolled crosswalks. Generally, these disagreements can be contributed that these demonstrations are performed under different conditions, which significantly affect the resulted performance of these warning devices. There could be significant number of factors that affect the effectiveness of the above-ground flashing beacons in increasing pedestrians' safety at uncontrolled intersections. These factors include:

- Vehicular traffic volume, speed, and composite,
- Pedestrian/bicyclists traffic volumes,
- Geometric design
  - ⇒ Number of lanes
  - ⇒ Midblock or intersection location
  - ⇒ Distance to the nearest intersection
  - ⇒ Speed limits
- Dominant weather conditions
  - ⇒ Dry, rain, fog, or snow
- Time of the day,
- Area type,
  - ⇒ Rural, or urban
- Pedestrians' characteristics
  - ⇒ School children, elderly, or others
  - ⇒ Commuters or unfamiliar
- Motorists' characteristics
  - ⇒ Commuters or unfamiliar

- System configuration
    - ⇒ Type of activation (automatic or manual)
    - ⇒ Locations of the beacons (overhead or on side poles; at the crosswalk or at upstream locations)
    - ⇒ Surrounding lighting conditions
- Additional supporting treatments,
    - ⇒ Road marking, supporting signs, etc.
- System lifetime
    - ⇒ New or old

A recent study was performed by the City of Stockton, California to identify the main guidelines for pedestrian safety and crosswalk installation (City of Stockton 2003). The study describes best practices related to numerous pedestrian treatments, including: pedestrian signals, pedestrian refuge islands, compact intersections, sidewalks, and crosswalks. The study guides the City in making decisions about where basic crosswalks (two stripes) can be marked; where crosswalks with special treatments, such as high visibility crosswalks, flashing beacons and other special features. The City of Stockton, California, had a policy of prohibiting new crosswalks at uncontrolled locations (intersections and midblock locations without a signal or stop sign), unless approved by City Council action, and they needed additional study to establish criteria for considering crosswalks at unsignalized or midblock locations.

The study presented a framework for choosing the right treatment for crosswalks at uncontrolled locations (See Figure 2 and Table 13). The framework considered several factors among those given above to warrant the use of the different crossing treatments appropriate for uncontrolled crossing locations. The main guidelines for using overhead flashing beacons can be summarized as follows:

- The crossing location is close to a major pedestrian destination such as school, hospital, mall, etc. Otherwise, the location should have more than 20 pedestrians crossing per hour or 60 pedestrians in four hours. This is also supported by the demonstration conducted at Boulder, Colorado, which found that motorists are more likely to yield at crosswalks that have high pedestrian activities (City of Boulder 2002).

- There is no other close crosswalks that can be used by pedestrians (within 300 feet)
- The location insures that pedestrians can be seen by motorists from a distance long enough to allow motorists to yield and stop safely to pedestrians crossing at the crosswalk. This distance depends on vehicular speed in the road of the crosswalk. Otherwise, the location is to be considered as an unsafe location for pedestrians crosswalk
- Given the above conditions are satisfied, based on the number of lanes of the street on which a crosswalk is proposed, vehicular traffic volumes per day, and traffic speed, the use of above-ground flashing beacons can be warranted (as given in Table 13).
- Generally, above-ground flashing beacons are not warranted when traffic volumes are low (less than 9000 cars per day) and speed limit are less than or equal 30 mph). However, in scenarios that include higher traffic volumes and higher speed limits, above-ground flashing beacons can be used. Nevertheless, as traffic volume and speed limit increase (more than 15,000 cars per day and 40 mph, respectively), the use of above-ground flashing beacons may be unsafe and other more effective tools such as pedestrian traffic signals should be used.
- The lighting condition around the crosswalk at which the above-ground flashing beacons are proposed is to be considered. Studies have found that the above-ground flashing beacons might not be effective in urban areas where too many light sources can distract drivers and reduce the effectiveness of the flashing beacons at the crosswalk during the night (Sparks and Cynecki 1990).
- Flashing beacons should not be operated continuously all day. It should only be used during pedestrians crossing activities. Supporting tools to enable activation/deactivation of the flashing beacons should be provided.

Two main types of activation methods are commonly used which are manually through pushing buttons or automatically through pedestrian detection technologies. Unfortunately, the difference between effectiveness of the methods is not documented in the literature when used with above-ground flashing beacons. However, a study with in-pavement flashing beacons at crosswalks in Santa Rosa, California (Whitlock & Weinberger Transportation, Inc, 1998) has concluded the following "Considering the experience at all of the test sites which have included both manual activation (push button) and automatic activation (overhead ultrasonic and overhead video imaging), an automatic detection system seems to be more appropriate than a manual push button activation. This recommendation is based on the following considerations:

⇒ Historically, the pedestrian push button has been used almost exclusively as part of a standard traffic signal installation, which includes pedestrian signal heads. Pedestrians who encounter a pedestrian push button without the associated traffic signal equipment are unlikely to expect it and may not understand what it is for. Worse, they may interpret a push button as giving them the right of way.

⇒ Since this application is considered a warning system to the driver, no visual indication should be given to the pedestrian.

⇒ The public may perceive the act of pushing a button as a way to cause approaching vehicles to stop.

⇒ Based on field observations of several push button operated crosswalks warning systems, the frequency with which pedestrians used the push buttons varied with the volume of traffic. During off-peak periods when traffic volumes were lower, approximately one-third of the pedestrians activated the system. During peak periods when traffic volumes required the crossing pedestrian to wait for a gap, the use of the push button increased up to approximately two-thirds of the time.

⇒ An automatic detection system should be less confusing to pedestrians because it does not require them to act in any way other than crossing the street with caution and at their own discretion. It also makes the pedestrian more responsible for their actions and causes less confusion."

The study also noted that the ultrasonic detection system which has been used to date has not performed satisfactorily. In general, the lights have activated 60 to 70 percent of the time when a pedestrian uses the crosswalk. Periodically, a turning vehicle or swaying trees have activated the lights with no pedestrians present. The video imaging detection system which was installed by the City of Petaluma seems to be a superior system but still has occurrences of false and non-activations. A recent demonstrated "bolland gateway system" which utilizes two parallel modulated visible red beams seems to be the most promising technology. When pedestrians break the two beams in succession while walking into the street, the system activates 100 percent of the time. The system does not activate when a pedestrian breaks the beam in the reverse order leaving the street.

- In case a push-button technique is used to activate the flashing beacons, the location of the beacons should be very clear and handy to pedestrians. Also, clear signs should be used inform pedestrians that they can push buttons to activate the system to warn motorists while they are crossings. Furthermore, warning signs should be given to pedestrians to warn them that even if they push the button to activate the system, they have to use caution while crossing, since vehicular traffic might not yield for them.
- Studies have found that above-ground flashing beacons usually lose some of its effectiveness as time elapses and the flashing beacons become part of the everyday seen of the motorists. Accordingly, the effectiveness of the above-ground flashing beacons should be investigated and measured periodically to insure continuous safety of pedestrians.

- Whenever possible additional treatments such as road markings, textured pavement, road signs, and traffic calming techniques are to be implemented with the above-ground flashing beacons. These treatments can increase the effectiveness of the warning system at the midblock crosswalk.

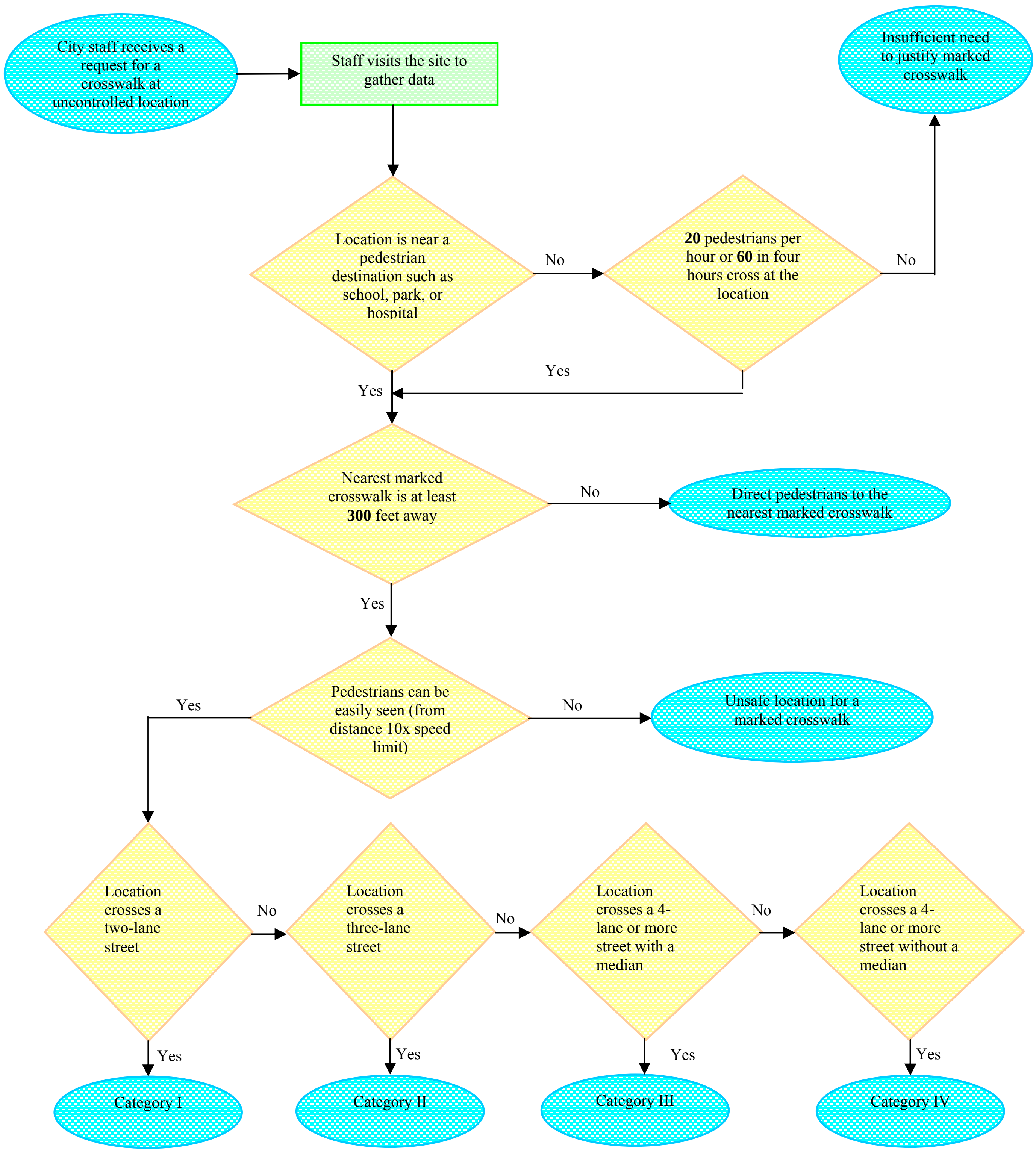

Figure 2: Crosswalk Placement Flowchart for Uncontrolled Locations (Source: The City of Stockton 2003)

Table 13: Summary of the Type of Crossing Treatments Appropriate for Uncontrolled Crossing Locations (Source: The City of Stockton 2003).

Category	No of lanes	Raised Median?	9,000 cars or fewer per day			9,000-12,000 cars per day			12,000-15,000 cars per day			15,000 cars or more per day		
			Speed Limit (MPH)											
			≤30	35	≥40	≤30	35	≥40	≤30	35	≥40	≤30	35	≥40
I	2	No	A	B	C	A	B	C	B	B	C	B	C	D
II	3	No	B	B	C	B	C	C	C	C	D	C	D	D
III	≥ 4	Yes	B	B	C	B	C	D	C	C	D	D	D	D
IV	≥ 4	No	B	B	C	B	C	D	C	C	D	D	D	D

Standard crosswalk

High visibility crosswalk (double stripes, textured pavement crosswalk, etc)

High visibility crosswalk (double stripes, textured pavement crosswalk, etc) plus a pedestrian refuge, Split pedestrian crossover, Bulbouts, **overhead flashing beacons**, in-pavement flashing lights

Pedestrian signal or bridge

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