

FINAL REPORT

DEVELOPMENT OF GUIDELINES FOR IN-ROADWAY WARNING LIGHTS

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ABSTRACT

An illuminated crosswalk is a relatively new traffic control device that is being used throughout the nation to alert approaching motorists to the presence of pedestrians in or about to enter the crosswalk. It consists of a series of lighting units encased in durable housings and embedded in the pavement parallel with the marked crosswalk. The lights are activated by a pedestrian, either by pushbutton or passive detection, and are aimed to flash toward approaching traffic. These light systems are known by many names. In deference to the terminology used in the *Manual on Uniform Traffic Control Devices for Streets and Highways*, this study refers to them as in-roadway warning lights (IRWLs).

The purpose of this research was to develop guidelines for IRWLs that the Virginia Department of Transportation (VDOT) could use statewide to ensure uniformity. The guidelines include both “planning” and “design” guidelines. Planning guidelines focus on when and where IRWLs are needed or justified. Design guidelines focus on design features of IRWLs and their components. The scope of the research was limited to a review of existing guidelines and of experiences with existing IRWLs.

Specific tasks undertaken for this research included a literature review, discussions on key issues involving IRWLs with practicing transportation engineering professionals via the Institute of Transportation Engineers’ traffic engineering Internet discussion group, and a review of the experiences with several IRWLs in Virginia. A task group of VDOT planners and traffic engineers from the central office and district offices provided oversight; guidance; and, as appropriate, approval of the developed draft guidelines.

Based on the findings and conclusions from these three tasks, draft guidelines for IRWLs were compiled and synthesized and then presented to the task group for review and discussion. Revised guidelines were then developed and recommended for pilot implementation.

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INTRODUCTION

An illuminated crosswalk is a relatively new traffic control device being used throughout the nation to alert approaching motorists to the presence of pedestrians in or about to enter the crosswalk. It consists of a series of lighting units encased in durable housings and embedded in the pavement parallel with the marked crosswalk. The lights are activated by a pedestrian, either by pushbutton or passive detection, and are aimed to flash toward approaching traffic. The lights serve essentially the same function as traditional overhead flashing beacons, with the major differences being the location of the lights and the pedestrian activation feature. These light systems are known by many names, including in-pavement flashers, in-pavement flashing lights, pedestrian crosswalk warning systems, pedestrian crosswalk lights, crosswalk pavement lights, in-roadway warning systems, in-roadway lights, in-roadway warning lights, SMART crosswalks, intelligent road studs, flashing crosswalks, lighted crosswalks, in-pavement flashers, and “Santa Rosa lights,” among others. In deference to the terminology used in the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), this study refers to them as in-roadway warning lights (IRWLs).¹

As with any traffic control device, IRWLs are associated with advantages and disadvantages, appropriate and inappropriate locations for their use, and preferred design features. The Virginia Department of Transportation (VDOT) has received requests to install IRWLs at several locations, and guidance is needed to address these issues.

PURPOSE AND SCOPE

The purpose of this research was to develop guidelines for IRWLs for statewide use and to ensure statewide uniformity. The guidelines include both “planning” and “design” guidelines. Planning guidelines focus on when and where IRWLs are needed or justified. Criteria such as accidents, traffic volumes, pedestrian volumes, and sight distance are used in developing these guidelines. Design guidelines refer to design features of IRWLs and their components, e.g., spacing and flashing rates of lights, width of crosswalks, and signing. Most of these features were taken directly from the MUTCD.

The scope of the research was limited to a review of existing guidelines and of experiences with existing IRWLs. A body of literature about IRWLs exists, including various sets of guidelines as defined previously. Likewise, there are many IRWL installations

throughout the nation, including several in Virginia. The researcher postulated that this information could be used to develop guidelines acceptable to VDOT, thus precluding the need for an extensive and costly field-based research effort. If this proved incorrect, then further research would be recommended and undertaken.

METHODS

A task group consisting of VDOT planners and traffic engineers from VDOT's central office and district offices was established to provide oversight; guidance; and, as appropriate, approval of the developed draft guidelines. The members of the task group are listed in Appendix A.

The following tasks were undertaken for this research:

1. *The pertinent literature on IRWLs was reviewed.* This included evaluation reports conducted under the auspices of the Federal Highway Administration, case study documentation, and current guidelines of state departments of transportation (DOTs). The literature was identified through a number of online databases and the resources of the Virginia Transportation Research Council library.
2. *A discussion of specific issues involving IRWLs on the Institute of Transportation Engineers' (ITE) traffic engineering list serve and a review of its archives were conducted.* The list serve is an Internet discussion group consisting for the most part of practicing transportation engineering professionals.
3. *The experiences with four IRWLs in Virginia were reviewed.* These IRWLs were selected based on a survey of VDOT's district traffic engineers and discussions with task group members. They are not the only IRWLs existing or being planned in the state.
4. *Based on the findings from the first three tasks, draft guidelines for IRWLs were compiled and synthesized and then presented to the task group for review and discussion.*
5. *Based on this review and discussion, revised guidelines were developed and recommended for pilot implementation.*

RESULTS

Literature Review

The literature was somewhat limited, as IRWLs are relatively new and have had fairly limited application. Thus, general findings may have been duplicated in several sources;

however, specific findings were mostly found in single sources and may have been based on limited data. A summary of the findings is presented here.

Effectiveness of IRWLs

Pedestrian Reaction

Installation of lighted crosswalks has a mixed effect on pedestrians. In some studies, on the positive side, the wait time for pedestrians at the curb was reduced by 51 percent² and the curb-to-curb duration of crossings was reduced by 19 percent² because pedestrians could cross the entire width at one time. Before installation of the lights, pedestrians frequently had to wait in the median for a gap in the traffic coming in the other direction. The percentage of pedestrians observed to run during some part of the crossing to avoid approaching traffic was reduced from 22 to 12 percent after the lights were installed.² Finally, the percentage of pedestrians who crossed entirely outside the marked crosswalk was reduced from 10 to 8 percent after the lights were installed.² Eighty percent of pedestrians interviewed were aware of the flashing lights.³

In some studies, on the negative side, the number of pedestrians crossing in the crosswalk and the locations where they entered the street did not substantially change.³ The number of times a pedestrian looked at oncoming traffic while crossing did not substantially change.³ There was essentially no change in the percentage of pedestrians who exhibited normal crossing behavior (defined as crossing at a steady pace).⁴ Of the 80 percent who were aware of the flashing lights, 23 percent said they relied on the lights to cause the driver to stop and give them the right of way.³ Finally, one study concluded that most people did not understand how the flashing crosswalk works, with several people saying that they did not know the flashers worked during the day.⁵

Driver Reaction

Installation of lighted crosswalks generally had a much more positive effect on drivers than on pedestrians. With few exceptions, the following occurred after the lights were installed:

- The braking distance, i.e., the distance from the crosswalk at which the driver started applying the brakes, increased during both the day and night, ranging from 3 to 53 percent.^{3,6}
- Vehicle speeds decreased for essentially all measurements (maximum, average, and 85th percentile), with the decrease ranging from 7 to 44 percent.^{2,5,6}
- The percentage of drivers yielding to pedestrians increased, with the increase ranging from 26 to 162 percent under both day and night conditions.³⁻⁵
- The percentage of drivers who saw the crosswalk, saw a pedestrian, and accurately stated the position of the pedestrian increased by 13, 25, and 38 percent, respectively.³

- The percentage of drivers who saw the flashing lights was estimated at 77 percent.³
- The percentage of drivers who felt that the flashing lights had changed their driving habits was estimated at 62 percent.³
- The percentage of motorists who disregarded a pedestrian in the crossing decreased by 74 percent.²

Accident Analysis

Very few accident statistics were found in the literature, most likely because of the relatively short time IRWLs have been in use, the relatively small number of IRWLs, and the low incidence of pedestrian involvement in accidents. One study addressed the accident experience at lighted crosswalks by first assuming (based on previous experience) a pedestrian accident rate of 1 per 35 million vehicles at a typical marked crosswalk on a high-volume multi-lane street. Then, the expected number of accidents was calculated as 12.2 based on traffic volumes at the lighted crosswalks under study and compared to the actual number of accidents that occurred, i.e., 2. Thus, it was determined that the illuminated crosswalks reduced expected accidents by 83 percent. It was further suggested that the specific accidents that occurred would not have been prevented by crosswalk lights.³

Another study considered pedestrian-motor vehicle conflicts and found that the lighted crosswalk had a small positive effect on reducing conflicts. Forty percent of the pedestrians using the flashing crosswalk experienced no conflicts. In comparison, only 22 percent of the pedestrians who crossed within 30 ft of the flashing crosswalk and 13 percent who crossed even further away experienced no conflicts. Motorists were also more likely to stop or slow for pedestrians who crossed in or near the flashing crosswalk than those who crossed elsewhere.⁵

Effectiveness During Various Weather Conditions

Based on a survey of agencies and institutions that had deployed lighted crosswalks, one study found that lighted crosswalks are effective under all weather conditions; however, they are much more effective during adverse weather conditions such as darkness, fog, and rain. Sun glare diminishes their effectiveness during the day; on the other hand, they are particularly effective at night and during a heavy storm.³

Comparison with Similar Devices

The City of San Jose, California, compared the effectiveness of standard overhead flashing beacons and embedded crosswalk lights, both with passive activation, by evaluating particular performance measures before and after installation. The percentage of drivers yielding to a pedestrian in the crosswalk during both day and at night increased considerably more after installation of the lights than after installation of the flashing beacons. On the other hand, the distance from the crosswalk at which brakes were applied after a pedestrian stepped into the crosswalk was different for day and night conditions. During the day, the distance increased more with the flashing beacons than with the embedded lights. During the night, however, the

distance increased more with the embedded lights than with the flashing beacons. Based on a survey of drivers, more drivers noticed the crosswalk, the pedestrian, and the lights at the location with embedded lights for both day and night conditions. In addition, considerably more drivers thought the embedded lights were effective. Finally, the initial effects of the embedded lights diminished somewhat over time; however, they were still generally much more effective than the overhead flashing beacons.⁷

The City of Boulder, Colorado, studied motorist compliance at crosswalks for five treatments, including pedestrian activated in-pavement lights and pedestrian-activated flashing lights embedded in a pedestrian walk sign mounted on poles on the roadside and in the median. The in-pavement lighting was not continued as the sign-mounted lights were more effective and less costly to install and maintain.⁸

Some studies suggested that continuously flashing beacons at urban crosswalks do not increase driver awareness since these passive applications eventually become part of the background scenery.^{9,10}

Specific Issues Regarding the Use of IRWLs

Four specific issues regarding the use of IRWLs were addressed frequently in the literature: method of activation, liability, maintenance, and costs.

Method of Activation

There are two methods of activating an IRWL: by pushbutton and by passive detection of the pedestrian. Pushbuttons are identical with traffic signal pedestrian pushbuttons. Passive detection is done using microwaves, motion sensors, video detection, light trip beams, and pressure pads. Table 1 lists the advantages and disadvantages of each.

Liability

There seemed to be three liability issues for those responding to questions on the ITE's Traffic Engineering List Serve:

1. liability associated with giving the pedestrian a false sense of security in that a right of way and/or that the motorist will stop may be assumed
2. liability associated with maintenance
3. liability associated with a dilemma zone for motorists approaching a lighted crosswalk and suddenly confronted with flashing lights.

No specific cases regarding liability and legal actions were found in the literature review, but the reader must remember that this is a relatively new technology. However, all three potential areas of liability are not new to traffic engineering operations. Although there are

Table 1. Advantages and Disadvantages of Activation Methods

Type of Activation	Advantages	Disadvantages
Pushbutton	<ul style="list-style-type: none"> • Familiarity with detection device.⁹ • Generally more reliable, less expensive, and easier to maintain than passive detection.¹⁰ 	<ul style="list-style-type: none"> • Unfamiliarity with detection device because expected pedestrian signals are not present.⁹ • May be interpreted as giving right of way.⁹ • May be interpreted as causing approaching motorists to stop.⁹ • Difficult to determine duration of crossing time accurately.¹⁰
Passive	<ul style="list-style-type: none"> • Since IRWLs warn drivers, it is considered better not to have a visual indication of IRWLs for pedestrians. Passive detection generally provides this feature.⁹ • 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.⁹ • Makes pedestrians more responsible for their actions.¹⁰ • Less disruptive to traffic, as pedestrians typically wait until there is a natural gap in traffic before stepping off curb and activating device • Since the device is activated exactly when pedestrians need it (compared to some distance away from the crosswalk at the location of the pushbutton), the duration of the flashing interval can be set more accurately.¹⁰ 	<ul style="list-style-type: none"> • Some systems are prone to false activations because of inclement weather, swaying trees, turning vehicles, pedestrians passing nearby, etc.⁹ • Generally less reliable, more expensive, and more difficult to maintain than pushbutton detection.¹⁰

certainly no guarantees, it is suggested by transportation engineers that driver and pedestrian education and appropriate maintenance measures will address any liability issues that arise.

Maintenance

There is not a lot of experience with maintenance issues reported in the literature. Maintenance issues with the earliest designs were addressed and the latest prototypes have been superior in terms of durability. There have been several instances of devices being damaged by street sweepers, logging trucks, and snowplows. Lights may become scratched; however, this does not noticeably reduce the visual effect of the device. Replacement, when needed, is reportedly accomplished very easily. Problems caused by vehicle impact are minimized since most of the lights are not placed in the direct path of vehicle tires. Pavement maintenance activities (sealing and repaving) are a problem for a flashing light system, just as for any device located on the roadway.^{7,9}

Costs

Costs for installing lighted crosswalks obviously vary depending on the location, the number of lanes and the manufacturer of the equipment being key variables. Based on

information in the literature reviewed, the cost to install lights on a crosswalk (without accounting for inflation, i.e., the year of the installation) are estimated as follows:

- two-lane crosswalks: \$9,000 (equipment only)⁹
- four-lane crosswalks: \$20,000 to \$26,000^{5,6,9}
- five- to seven-lane crosswalks: \$20,000 to \$24,000; \$22,000 to \$29,000; or \$28,000 to \$37,000 (depending on the manufacturer).³

Existing Guidelines for Installation

Guidelines in the literature were of two basic types: planning and design. Planning guidelines focused on when and where IRWLs were needed or justified and how proposed installations could be prioritized. Key components included the following:

- An engineering study was typically required.¹²
- Specific conditions at the proposed crossing were considered, including the following:
 - *Characteristics or type of pedestrian crossing.* These included whether the crossing was at mid-block or at an intersection, whether the crosswalk was marked, and whether the crosswalk was controlled by signals, yield signs, or stop signs or was uncontrolled.^{1,3,9,12,13}
 - *Speed on the street being crossed.* The commonly cited threshold speed was 45 mph; however, sources varied as to whether this was the average speed, 85th percentile speed, or posted speed limit.^{3,9,12-14}
 - *Traffic volumes on the street being crossed.* The criteria varied between average daily traffic and hourly volumes.^{3,9,14}
 - *Safe stopping distance.* Either the criteria were specific to a speed on the street or there was a general statement that current engineering standards should be applied.^{3,9,13,14}
 - *Pedestrian volume.* The criteria considered either average daily traffic or hourly volumes.^{3,9,14}
 - *Adjacent crosswalks or traffic control.* This referred to the distance to the nearest marked crosswalk or controlled intersection and was cited as either 250 or 300 ft.^{3,9}
 - *Roadway cross section.* This referred to the number of lanes on the roadway being crossed.^{3,9}

- *Other treatments considered.* One study recommended that treatments other than IRWLs be considered and that IRWLs be used only if found to be the most appropriate for site conditions.³
- Two prioritization methodologies were reported in the literature: one used in Fountain Valley, California,³ and one used in Kirkland, Washington.¹⁵

Design guidelines referred to design features of IRWLs and their components. The only guidelines of interest were directly from the MUTCD.¹

Key Points from the ITE Traffic Engineering List Serve Discussion

The discussion on ITE's traffic engineering list serve raised several key points with regard to the use of IRWLs. Although the discussion was anecdotal (although sometimes references to specific documentation were made), potentially biased, and generally not comprehensive in its coverage of the issues, it provided examples and was indicative of actual field experiences with IRWLs. The information can offer valuable insight if these limitations are kept in mind.

Effectiveness

- One discussant noted amazement at the lights' effect on motorists; i.e., all of them stopped.
- One discussant cautioned that although the lights may initially be quite effective, their impact might diminish over time as their use becomes common.
- One discussant observed that even though the system works well, driver compliance is very low and most drivers do not stop and yield to pedestrians.
- One discussant indicated that motorists could not see the flashers on heavily congested streets because the lights were blocked by slow-moving vehicles.
- One discussant felt that the lights are very difficult to see in bright sunlight.

Activation

- Two discussants preferred passive detection/activation because pedestrians' prior experiences with pushbuttons could result in a false sense of security because of an expectation that motorists will stop (i.e., a pushbutton call for a pedestrian signal).
- One discussant preferred pushbutton activation because pedestrians must stop and think about crossing the street rather than just walk into the street.

Maintenance

- One discussant reported the necessity of constantly cleaning the lights because dust and debris clog them consistently and of repairing them because of the damage done by snowplows.
- Several discussants mentioned the need for good preventative maintenance and a quick response to failures to mitigate potential liability issues.
- One discussant discouraged the use of devices embedded in pavement unless there is an overriding safety concern because pavement deterioration caused by improper installation, truck traffic, and general aging will ultimately cause the system to fail and add to maintenance difficulty.

Alternative Devices

- Several discussants recommended the use of other similar devices, specifically overhead flashing warning signs and side-mounted flashing beacon displays.

Experiences with IRWLs in Virginia

The information obtained was generally anecdotal and had the same limitations as the discussion on the ITE's list serve. However, it offers valuable insight if the aforementioned limitations are kept in mind.

Table 2 provides summary information on four IRWL installations in Virginia. Further details about these installations are provided in Appendix B.

The two older installations on Route 57 and in Blacksburg generally performed much worse than the two newer ones in Arlington and Fairfax counties. The older units have had serious maintenance problems, and no further installations are being planned in those localities. The system on Route 57 is being replaced with a more traditional actuated system. The newer units have proven to be much more reliable, with minimal maintenance problems. Both counties plan on installing more IRWL systems. It appears, therefore, that later generations of IRWL systems are better.

Development of Guidelines

Draft guidelines were developed and presented to the task group for review and comment. After the guidelines were revised based on the recommendations of the group, a stand-alone document entitled *Guidelines for the Installation of In-Roadway Warning Lights* was developed and is provided in Appendix C.

Table 2. Summary Information on Four IRWL Installations in Virginia

Issue/Location	Route 57	Blacksburg	Arlington County	Fairfax County
How long installed	3 years	4 years	2 years	2 ½ years
Cross section	Wide 2-lane, small median	4-lane divided, with median	4-lane divided, 10-ft median	Wide 2-lane, no median
Detection	Pushbutton	Passive, microwave (pushbutton initially)	Passive, bollards with light beam	Pushbutton
Pedestrian counts	200-300 peak at shift change	30-40 at bus discharge	200 in peak hour	200 peak school crossing, 75-100 football games
Cost	\$15,000	\$10,000	\$20,000	\$20,000
Effectiveness	Yes, when working	Questionable at this location	Yes	Yes
Maintenance problems	Significant: water leakage, road salt, snowplow damage	Significant: debris collects, requiring hand cleaning; frequent bulb burnout; repaving issues	Minimal: have survived 2 severe winters with snow	Minimal: have survived snowplowing
Liability issues	None	None	None	None
Supplementary special devices	None	None	Standard pole-mounted ped/xwalk signs with flashing beacons also activated upon detection	Standard pole-mounted ped/xwalk signs with flashing beacons also activated upon detection
Future plans	Remove lights, replace with pushbutton-actuated ped/xwalk signs with beacons	None	Add curb extensions, also consider lights for more crossings	Consider lights at two more crossings

CONCLUSIONS

Based on findings from the literature review, anecdotal information gleaned from ITE’s traffic engineering list-serve discussions, and experiences with four installations in Virginia, the following points should be addressed in any proposed guidelines for the installation of IRWLs:

General

- *IRWLs should typically be considered for use only after other more traditional measures have been tried and proven unsuccessful.*
- *IRWLs should be used judiciously.* Although IRWLs have been shown to have positive impacts on pedestrian safety, they are costly relative to more traditional warning devices and serious maintenance problems have occurred with existing installations. (Some of these problems have probably been addressed with the newer generations of these devices.) If a

need arises to install IRWLs at multiple locations, it may be necessary to prioritize the order of installations due to budgetary, personnel, or time constraints.

- *Precautions should be taken to address the two basic liability issues associated with IRWLs: (1) the issue associated with pedestrians having a false sense of security because they believe that they have the right-of-way or that motorists will stop and, (2) the issue associated with maintenance.*
- *Engineering judgment should be used to select the type of IRWL for each location and situation, i.e., either pushbutton or passive. Each has associated advantages and disadvantages.*
- *Regardless of how comprehensive the guidelines are, the final decision as to whether to install an IRWL should be based on engineering judgment since there will be locations and situations that are not covered by the guidelines.*

Location

- *The location being considered for an IRWL must have an identified associated pedestrian safety problem (pedestrian accidents, near misses, high pedestrian volumes, a sight distance problem, excessive speeding, etc.).*
- *IRWLs should be installed only at marked crosswalks; therefore, guidelines for IRWLs should be used in conjunction with existing VDOT guidelines for marked crosswalks.*
- *Specific conditions should be considered at the site of the proposed IRWL, including characteristics of or type of pedestrian crossing, vehicle speed on the street being crossed, traffic volumes on the street being crossed, safe stopping distance, and pedestrian volume.*

Design

- *Design guidelines should be based on the guidance provided in the MUTCD since design features should be consistent throughout the state and, for that matter, from state to state.*

RECOMMENDATIONS

1. *VDOT district traffic engineering staff should conduct a 1-year pilot test of the guidelines outlined in Appendix C. This time frame may need adjustment depending on the number of cases in which the guidelines are employed.*

2. *After the pilot, members of the project task force and appropriate VDOT central office and district personnel should undertake another round of review and comment as a means of further refining the guidelines where needed and developing the final guidelines.*

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APPENDIX A

TASK GROUP FOR THE DEVELOPMENT OF IN-ROADWAY WARNING LIGHTS

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APPENDIX B

EXPERIENCES WITH IN-ROADWAY WARNING LIGHTS IN VIRGINIA

Route 57 Near Bassett

This IRWL is located just east of Bassett, Virginia, on State Route 57. The flashers were installed about 3 years ago at the crosswalk that connects a parking lot on the south side of Route 57 with the Stanley Furniture Company. The crosswalk is located on a section of roadway transitioning between a four-lane divided section and a three-lane section. The crossing itself is marked on a two-lane section and has a small median island. The lights were installed by VDOT at the request of Stanley Furniture to address safety concerns about employees having to cross Route 57 to reach the parking lot. Although there were no accidents, there were apparently several near misses. It is estimated that between 200 and 300 pedestrians use the crossing. Activation is by a standard pushbutton, and there are advance crosswalk ahead signs. The installation cost was approximately \$15,000.

There have been no evaluations undertaken; however, both VDOT personnel and Stanley Furniture employees feel that the lights are effective. The biggest issue has been maintenance of the halogen lights. A VDOT representative reported the following:

They (the crosswalk lights) are a maintenance nightmare. We are going to take them out and go back to more conventional means – signs and flashers. The set we have in service has been trouble from the start. Even though it was properly assembled, every time it rains, the lights fill up with water. The control system sometimes just stops working. Snow plows tear them up. They are deteriorating because of road salt. When they work, they look good. But they have only worked for short periods of time between failures. Source: Email with subject *RE: In-Roadway Warning Lights*, from Bobby Purdue, Traffic Technician, VDOT Salem District, July 16, 2004.

Because of the maintenance experience, VDOT is going to take out the lights and put in standard pole-mounted flashing beacons mounted on a pedestrian crosswalk sign. The flashers will be pushbutton actuated using the same equipment currently on site.

University City Boulevard in the Town of Blacksburg

In July 2000, the transit director of the Town of Blacksburg installed flashing lights on a crosswalk on University City Boulevard in response to a request from Virginia Tech and shopping center management to solve a “safety problem.” There was no accident history; shopping center management simply did not want to bring the buses onto the parking lot. The crossing is on a major bus route, which is a four-lane divided collector roadway with a speed limit of 25 mph that is located at the entrance to two shopping complexes. One of the buildings is an old department store that houses Virginia Tech’s math lab, and a majority of students arrive by bus. The bus from the central campus stops across the street from the shopping complex and discharges upward of 30 to 40 students, who cross the street and walk through the parking lot to the math lab.

The initial installation was pushbutton activated; however, due to minimal calls for the lights, a microwave detector was installed later to trigger the system upon arrival of the bus. Crosswalk warning signs with high-intensity sheeting were also installed, and several public information sessions were held when the lights were first turned on. The cost was approximately \$10,000 for the equipment and installation.

No before or after studies were done to measure the light's effectiveness, but lights were not installed at the next two planned sites. The biggest maintenance problem has been trash, leaves, and snow accumulating in the lights. The street sweeper will not adequately clean them out so someone has to go out to the site, close the lanes, and then hand sweep them out. There is also a bulb or two that burns out each year. This requires crews to close the lane, take the unit completely apart, replace the bulb, and then close the unit. It takes about 1 to 1½ hours for one bulb. Other issues came up when repaving was scheduled. There was no money for the cost of risers for the lights and thus the pavers had to grind around them in preparation for repaving. Source: Email with subject *RE: In-Roadway Warning Lights*, from Barry Cross, Traffic Engineering/Operations, Town of Blacksburg, June 29, 2004.

Wilson Boulevard in Arlington County

In October 2002, Arlington County installed IRWLs to pilot the “new technology” on a four-lane divided (with an approximate 10-ft median) section of Wilson Boulevard. The lights were placed at an existing mid-block crosswalk that had a shopping mall on one side and mixed high-density residential and office development on the other. The system uses passive detection via a light beam between bollards. In addition to the typical bollards at each end of the crosswalk, there are also bollards in the median that activate the specific directional roadway being used. In other words, each direction is activated separately from either the end of the crosswalk or the median. There are also standard pole-mounted crosswalk/pedestrian signs with flashing beacons in the median that provide additional warning to motorists. These are connected into the bollard activation and thus flash only when the crosswalk is in use. The crossing is used by an estimated 200 pedestrians in the peak hour. The IRWLs cost approximately \$20,000 to install.

The county studied motorist compliance with yielding to the flashing lights after installation and found a very high percentage of compliance. Based on anecdotal information, reaction to the lights has generally been positive, though there has been some negative feedback. There have been no liability issues or concerns and no significant maintenance problem, and the lights survived the snowplowing during two rather severe winters.

The county is pleased with the lights and will likely install more. There are also plans to add curb extensions on both ends of the Wilson Boulevard lighted crosswalk to enable more visibility for pedestrians as they step into the street between parked cars.

Old Lee Highway in Fairfax City

Fairfax City has had flashing lights installed on a crosswalk at Fairfax High School on Old Lee Highway near Cornell Road for about 2½ years. The roadway is very wide (approximately 70 ft) at the crossing and is marked for only two lanes with no parking and no median. The high school is on one side, and housing developments are on the other. A pushbutton activates the crossing lights as well as standard pole-mounted pedestrian/crosswalk signs with flashing beacons. A special external box with a combination lock and switch has been installed that allows a school crossing guard to override the pushbutton manually and turn on the flashing lights for continuous operation in cases of poor visibility conditions. The installation cost approximately \$20,000, which included labor and equipment. It is estimated that up to 200 students use the crossing during peak school hours and between 75 and 100 pedestrians use the crossing during night football games.

Anecdotal information indicates that citizens and crossing guards like the system and that motorists generally slow down when the lights are flashing. County staff is pleased with the effectiveness and performance of the lights. There is some concern that pedestrians might have a false sense of security due to associating a pushbutton with motorists having to stop; however, no issues or incidents have occurred. Maintenance has not been a problem: the lights do not collect debris, have stayed bright, and have survived snowplowing. The one light (LED) that burned out was easily replaced.

The county has plans to install IRWLs at two more locations and thinks that they might have applicability at downtown urban locations.

APPENDIX C

GUIDELINES FOR THE INSTALLATION OF IN-ROADWAY WARNING LIGHTS

Virginia Department of Transportation Mobility Management Division

I. INTRODUCTION

An illuminated crosswalk is a relatively new traffic control device that is being used throughout the nation to alert approaching motorists to the presence of pedestrians in or about to enter a marked midblock crosswalk or at a marked crosswalk on an uncontrolled approach at an intersection. It consists of a series of lighting units encased in durable housings and embedded in the pavement parallel with the marked crosswalk. The lights are activated by a pedestrian, either by pushbutton or passive detection, and are aimed to flash toward approaching traffic. They serve essentially the same function as traditional overhead flashing beacons, with the major differences being the location of the lights and the pedestrian activation feature. These light systems are known by many names, including in-pavement flashers, in-pavement flashing lights, pedestrian crosswalk warning systems, pedestrian crosswalk lights, crosswalk pavement lights, in-roadway warning systems, in-roadway lights, in-roadway warning lights, SMART crosswalks, intelligent road studs, flashing crosswalks, lighted crosswalks, in-pavement flashers, and “Santa Rosa lights,” among others.

In deference to the terminology used in the *Manual on Uniform Traffic Control Devices* (MUTCD), these guidelines refer to them as In-Roadway Warning Lights (IRWL).¹ They are formally defined in Section 4L.01 of the MUTCD as follows:

In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes, but is not necessarily limited to, situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabout intersections as described in Sections 3B.24 and 3B.25, and other roadway situations involving pedestrian crossings.¹

As with any traffic control device, IRWLs are associated with advantages and disadvantages, appropriate and inappropriate locations, and preferred design features. IRWLs have been shown to have positive impacts on pedestrian safety; however, they are costly relative to more traditional warning devices and early installations have been associated with serious maintenance problems. (Some of these problems may have been addressed with the newer generations of these devices.) Therefore, it is important that they be installed judiciously and at locations where their effectiveness is maximized. Further, IRWLs should typically be considered only after other more traditional measures have been tried and proven unsuccessful. Finally, design guidelines should be based on guidance in the MUTCD.

The following guidelines are based on these principles and provide the Virginia Department of Transportation (VDOT) with guidance on when and where IRWLs should be considered for installation and on appropriate design details. IRWLs should be installed only at

marked midblock crosswalks or *marked* crosswalks on uncontrolled approaches to intersections; therefore, these guidelines should be used in conjunction with existing VDOT guidelines for marked crosswalks.²

II. APPROPRIATE LOCATIONS TO INSTALL IN-ROADWAY WARNING LIGHTS

The location being considered for an IRWL must have an identified pedestrian safety problem (pedestrian accidents, near misses, high pedestrian volumes, a sight distance problem, excessive speeding, etc.). The location must have a marked crosswalk with applicable warning signs.¹ It may be at either an intersection or mid-block. IRWLs shall not be used at crosswalks controlled by a yield or stop sign or traffic control signal.¹ If these criteria are met, further consideration of IRWLs should be based on the following step-by-step analysis:

1. *If the location does not currently have a marked crosswalk*, VDOT's most recent *Guidelines for the Installation of Marked Crosswalks*² shall be applied. See Attachment A.

- *If a marked crosswalk is not justified* according to Figure B3 in Attachment A, do not consider an IRWL.
- *If a marked crosswalk is justified*, Table B1 in Attachment A must identify an IRWL (a Level 4 device) as a potential special treatment at the crossing.

2. *If the location currently has a marked crosswalk*, VDOT's most recent *Guidelines for the Installation of Marked Crosswalks*² shall be consulted to determine if the crosswalk is justified. See Attachment A.

- *If the existing marked crosswalk is not justified*, do not consider an IRWL.
- *If the marked crosswalk is justified*, Table B1 in Attachment A must identify an IRWL (a Level 4 device) as a potential special treatment at the crossing.

3. If the *Guidelines for the Installation of Marked Crosswalks*² identify an IRWL as a potential special treatment at the crossing, the following additional guidance is suggested.

- *Alternative measures to mitigate the pedestrian safety problem should have been tried and proven unsuccessful or engineering judgment should have determined that other alternative measures are not feasible.* A typical example is some arrangement of the standard flashing beacon, either on continuous flash or pedestrian actuated.
- *The 85th percentile speed of vehicles approaching the crosswalk from either direction should not be more than 45 mph.*^{3,4}
- *The average daily traffic (ADT) on the street being crossed should be between 5,000 and 30,000 vehicles per day,*^{3,5} *or vehicular volume through the crossing should*

exceed 200 vehicles per hour in urban areas or 140 vehicles per hour in rural areas during peak-hour pedestrian usage.⁴

- *The daily pedestrian crossing volume should be at least 100 pedestrians per day^{3,5} or at least 40 pedestrians should regularly use the crossing during each of any 2 hours (not necessarily consecutive) during a 24-hour period.⁴*
- *The existing stopping sight distance from both directions should not be less than the minimums shown here.*

Stopping Sight Distance (Feet)
(Height of Eye 3.5 ft; Height of Object 2.0 ft)

Design Speed* (mph)	25	30	35	40	45	50	55	60	65	70
Minimum Sight Distance	155	200	250	305	360	425	495	570	645	730

*If the design speed is unknown, it may be assumed to be the posted speed limit unless the operating speed is lower at that point.

Source: *Sight Distance*, Appendix C, Design Data, Vol. 1. Virginia Department of Transportation, Richmond, p. C-11, Revised 10/02.

4. *Although these guidelines were crafted to be as comprehensive as possible, they do not address all situations.* Therefore, the final decision as to whether to install an IRWL should be left to engineering judgment, and this decision should most likely be made by the district traffic engineer.

III. DESIGN GUIDELINES

Information in the MUTCD, Chapter 4L, In-Roadway Lights, provides the basis for the IRWL design guidelines.¹ The chapter is reproduced here for the convenience of users.

MUTCD – 2003 EDITION CHAPTER 4L. IN-ROADWAY LIGHTS

Section 4L.01 Application of In-Roadway Lights

Support:

In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn road users that they are approaching a condition on or adjacent to the roadway that might not be readily apparent and might require the road users to slow down and/or come to a stop. This includes, but is not necessarily limited to, situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabout intersections as described in Sections 3B.24 and 3B.25, and other roadway situations involving pedestrian crossings.

Standard:

If used, In-Roadway Lights shall not exceed a height of 19 mm (0.75 in) above the roadway surface.

Option:

The flash rate for In-Roadway Lights may be different from the flash rate of standard beacons.

Section 4L.02 In-Roadway Warning Lights at Crosswalks

Standard:

If used, In-Roadway Warning Lights at crosswalks shall be installed only at marked crosswalks with applicable warning signs. They shall not be used at crosswalks controlled by YIELD signs, STOP signs, or traffic control signals.

If used, In-Roadway Warning Lights at crosswalks shall be installed along both sides of the crosswalk and shall span its entire length.

If used, In-Roadway Warning Lights at crosswalks shall initiate operation based on pedestrian actuation and shall cease operation at a predetermined time after the pedestrian actuation or, with passive detection, after the pedestrian clears the crosswalk.

If used, In-Roadway Warning Lights at crosswalks shall display a flashing yellow signal indication when actuated. The flash rate for In-Roadway Warning Lights at crosswalks shall be at least 50, but not more than 60, flash periods per minute. The flash rate shall not be between 5 and 30 flashes per second to avoid frequencies that might cause seizures.

If used on one-lane, one-way roadways, a minimum of two In-Roadway Warning Lights shall be installed on the approach side of the crosswalk. If used on two-lane roadways, a minimum of three In-Roadway Warning Lights shall be installed along both sides of the crosswalk. If used on roadways with more than two lanes, a minimum of one In-Roadway Warning Light per lane shall be installed along both sides of the crosswalk.

If used, In-Roadway Warning Lights shall be installed in the area between the outside edge of the crosswalk line and 3 m (10 ft) from the outside edge of the crosswalk. In-Roadway Warning Lights shall face away from the crosswalk if unidirectional, or shall face away from and across the crosswalk if bidirectional.

Guidance:

If used, the period of operation of the In-Roadway Warning Lights following each actuation should be sufficient to allow a pedestrian crossing in the crosswalk to leave the curb or shoulder and travel at a normal walking speed of 1.2 m (4 ft) per second to at least the far side of the traveled way or to a median of sufficient width for pedestrians to wait. Where pedestrians who walk slower than normal, or pedestrians who use wheelchairs, routinely use the crosswalk, a walking speed of less than 1.2 m (4 ft) per second should be considered in determining the period of operation. Where the period of operation is sufficient only for crossing from a curb or shoulder to a median of sufficient width for pedestrians to wait, additional measures should be considered, such as median-mounted pedestrian actuators.

If used, In-Roadway Warning Lights should be installed in the center of each travel lane, at the centerline of the roadway, at each edge of the roadway or parking lanes, or at other suitable locations away from the normal tire track paths.

The location of the In-Roadway Warning Lights within the lanes should be based on engineering judgment.

Option:

In-Roadway Warning Lights at crosswalks may use pedestrian detectors to determine the duration of the operation instead of ceasing operation after a predetermined time.

On one-way streets, In-Roadway Warning Lights may be omitted on the departure side of the crosswalk.

Based on engineering judgment, the In-Roadway Warning Lights on the departure side of the crosswalk on the left side of a median may be omitted.

Unidirectional In-Roadway Warning Lights installed at crosswalk locations may have an optional, additional yellow light indication in each unit that is visible to pedestrians in the crosswalk to indicate to pedestrians in the crosswalk that the In-Roadway Warning Lights are in fact flashing as they cross the street. These lights may flash with and at the same flash rate as the light module in which each is installed.

IV. OTHER CONSIDERATIONS

A. Detection of Pedestrians and Activation of Lights

The two methods of detecting a pedestrian and activating an IRWL are via pushbutton and passive detection. The former requires a pedestrian to push a button to activate the lights; the latter is automatic and requires no action by the pedestrian. Passive detection is done using microwaves, motion sensors, video detection, light trip beam, and pressure pads. Based on experiences to date, a light trip beam between bollards seems to operate the best.

Engineering judgment should be used to select the method of activation at each location and situation; however, the advantages and disadvantages listed on the next page should be considered.^{5,6}

B. Liability

There are two primary liability issues associated with IRWLs:

1. liability associated with giving the pedestrian a possible false sense of security in that a right-of-way and/or that the motorist will stop may be assumed
2. liability associated with maintenance.

No specific cases regarding liability and legal actions are known, but IRWLs are relatively new; however, these issues of liability are not new to transportation engineers. It is suggested that driver and pedestrian education be provided prior to installation of IRWLs at a new location to ensure that both understand what is expected when the lights begin to flash. Because of the documented maintenance problems with IRWLs (some of which may have been addressed with the newer generations of these devices), particular attention should be paid to routine maintenance activities.

Advantages and Disadvantages of Pushbutton and Passive Activation of IRWL

Type of Activation	Advantages	Disadvantages
Pushbutton	<ul style="list-style-type: none"> • Familiarity with detection device. • Generally more reliable, less expensive, and easier to maintain than passive detection. • Few false calls. 	<ul style="list-style-type: none"> • Non-familiarity with detection device because expected pedestrian signals not present. • May interpret as giving right of way. • May interpret as causing approaching motorists to stop. • Difficult to determine duration of crossing time accurately.
Passive	<ul style="list-style-type: none"> • Since IRWLs warn drivers, it is considered better that pedestrians not have visual indication of device. Passive detection generally provides this feature. • 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. • Makes pedestrians more responsible for their actions. • Less disruptive to traffic, as pedestrians typically wait until there is a natural gap in traffic before stepping off curb and activating device. • Since device is activated exactly when pedestrian needs it (as compared to some distance away from crosswalk at location of pushbutton), duration of flashing interval can be set more accurately. 	<ul style="list-style-type: none"> • Some systems prone to false activations due to inclement weather, swaying trees, turning vehicles, pedestrians passing nearby, etc. Bollard gateway system using light beams seems to be best. • Generally less reliable, more expensive, and more difficult to maintain than pushbutton detection.

C. Use of Bollards

If a bollard detection system is used, the bollards should be placed along the same line as each row of flashers, i.e., not inside the crosswalk marking lines. This will ensure that a pedestrian entering anywhere in the crosswalk will be detected.⁷

D. Use of Supplementary Signs

Supplementary signs that educate the motorist and pedestrian about the use of IRWLs should be considered. Examples are⁷:

- Yield To Pedestrians
- Flashing Crosswalk—Walk Between Posts To Activate (if bollards are used)
- Watch for Cars—Cross Only When It Is Safe To Do So.

REFERENCES

1. Federal Highway Administration. *Manual on Uniform Traffic Control Devices*, Chapter 4L, Part 4: Highway Traffic Signals, In-Roadway Lights. Washington, D.C., 2003.
2. Dougald, L. *Development of Guidelines for the Installation of Marked Crosswalks*. VTRC 05-R18. Virginia Transportation Research Council, Charlottesville, 2004.
3. Katz, Okitsu & Associates. *Illuminated Crosswalks: An Evaluation Study and Policy Recommendations*. Prepared for the City of Fountain Valley, California. Tustin, Calif., 2000.
4. California Department of Transportation. *MUTCD 2003 California Supplement, Part 4: Highway Traffic Signals, Section 4L.02 In-Roadway Warning Lights at Crosswalks*. Sacramento, 2004.
5. Whitlock & Weinberger Transportation. *An Evaluation of a Crosswalk Warning System Utilizing In-Pavement Flashing Lights* (Executive Summary). Prepared for the State of California Office of Traffic Safety and the Federal Highway Administration. Santa Rosa, Calif., 1998.
6. Miller, R., and Dore, G. *In-Pavement Flashing Crosswalks: State of the Art*. Article based on Fountain Valley Study conducted by Katz, Okitsu & Associates. <http://www.katzokitsu.com/peds.htm#articles>. Accessed September 5, 2003.
7. California Department of Transportation, Traffic Operations Program. *Interim Guidelines for Experimental Crosswalk Pavement Lights*. Sacramento, 2000.

ATTACHMENT A

KEY PAGES FROM GUIDELINES FOR THE INSTALLATION OF MARKED CROSSWALKS

Key pages from *Guidelines for the Installation of Marked Crosswalks*² are provided here for the user's convenience. The flowchart is used to determine the justification for marking a crosswalk. The table then identifies possible alternative enhancement measures to consider at the crossing. These measures are categorized into five levels, and an IRWL (a Level 4 device) should be identified as an appropriate enhancement measure in order for the step-by-step progression in Section II of the IRWL guidelines to proceed.

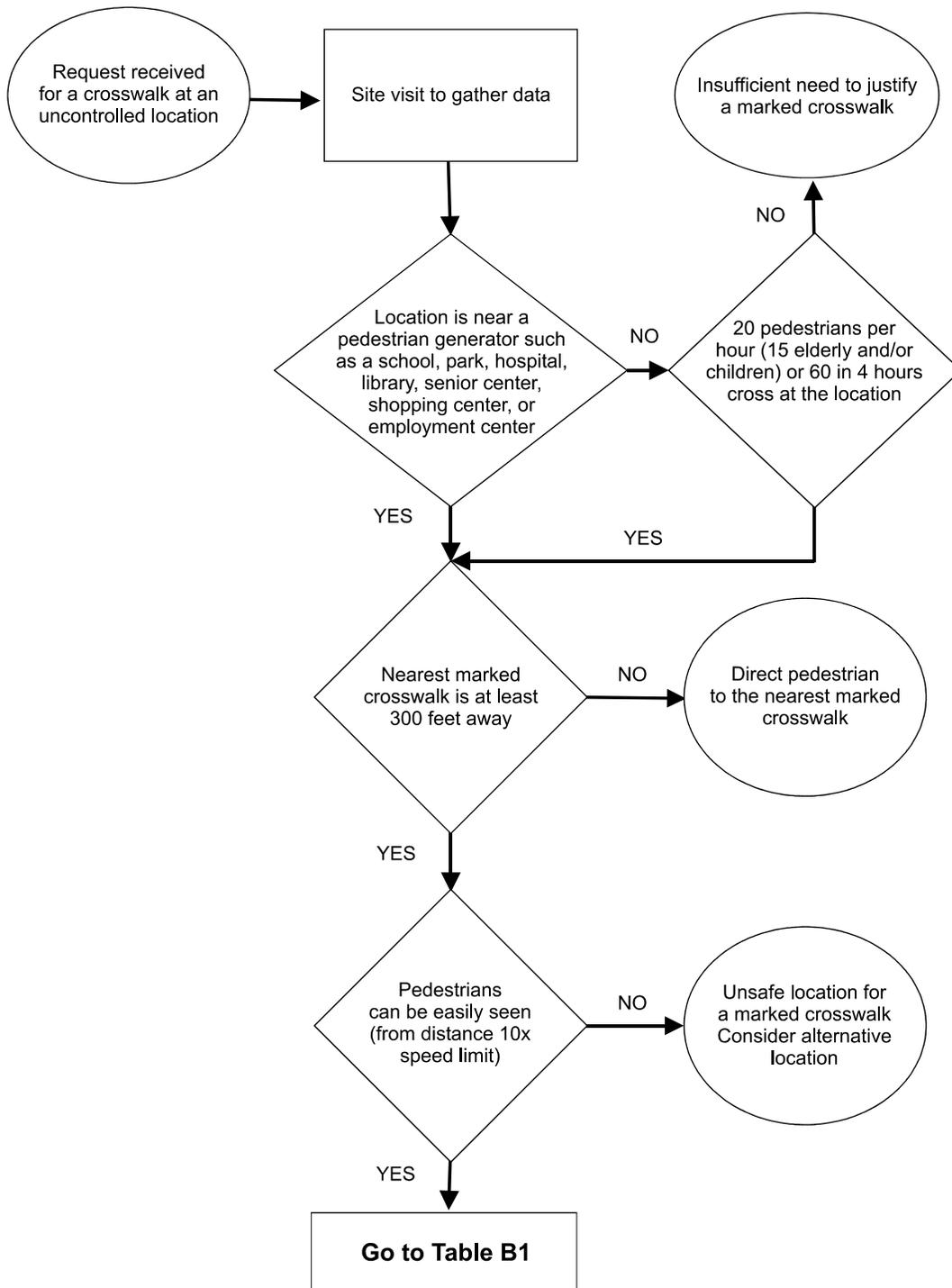


Figure B3. Flowchart for Justifying Installation of Marked Crosswalks at Uncontrolled Intersections.

Table B1. Recommendations for Considering Marked Crosswalks and Other Needed Pedestrian Improvements at Uncontrolled Locations^a

	≤ 9,000 ADT			> 9,000 ADT to ≤ 12,000 ADT			> 12,000 ADT to ≤ 15,000 ADT			> 15,000 ADT		
	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph ^b
2 lanes												
3 lanes												
+ + 4 lanes, raised median ^c												
+ + 4 lanes, no median												

 **Candidate sites for marked crosswalks.** Marked crosswalks must be installed carefully and selectively. First, an engineering study is needed to determine whether the location is suitable for a marked crosswalk. For an engineering study, a site review may be sufficient at some locations, but a more in-depth study of pedestrian volume, vehicle speed, sight distance, vehicle mix, etc., may be needed at other sites. If the speed limit is less than or equal to 30 mph, use **Level 1** or **Level 2** devices. If the speed limit exceeds 30 mph, use **Level 2** devices. *Refer to Level 1 and Level 2 devices in the Special Treatments section.*

 **Probable candidate sites for marked crosswalks.** Pedestrian crash risk may increase if marked crosswalks are added without other pedestrian facility enhancements. Add **Level 3** or **Level 4** devices if feasible. *Refer to Level 3 and Level 4 devices in the Special Treatments section.*

 **Marked crosswalks alone are insufficient, since pedestrian crash risk may increase if only marked crosswalks are provided.** Consider using **Level 5** devices if feasible. If not feasible, use multiple treatments from **Level 2**, **Level 3**, or **Level 4** devices. *Refer to Level 5 devices in the Special Treatments section.*

^aThese guidelines include intersection and mid-block locations with no traffic signal or stop sign on the approach to the crossing. They do not apply to school crossings. A two-way center turn lane is not considered a median. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians, such as where there is poor site distance, complex or confusing designs, substantial volumes of heavy trucks, or other dangers, without first providing adequate design features and/or traffic control devices. Adding crosswalks alone will not make a crossing safer or necessarily result in more drivers stopping for pedestrians. Whenever marked crosswalks are installed, it is important to consider other pedestrian facility enhancements, as needed, to improve the safety of the crossing (for example, raised median, traffic signal, roadway narrowing, enhanced overhead lighting, traffic calming measures, curb extensions). **These are general recommendations; an engineering study should be performed to determine where to install marked crosswalks.**

^bWhere the posted speed limit or 85th percentile speed exceeds 40 mph, marked crosswalks alone should not be used at uncontrolled intersections with an ADT greater than 15,000.

^cThe raised median or refuge island must be at least 4 feet (1.2 meters) wide and 6 feet (1.8 meters) long to adequately serve as a refuge area for pedestrians.

Special Treatments

There are a number of innovative treatments for pedestrians at uncontrolled crossing locations. Level 1 devices are typically less costly to install and are found at locations with potentially lower levels of vehicle/pedestrian conflict. Level 2 through 5 devices can be more costly to install and are used at locations with an ascending order of potential vehicle/pedestrian conflicts.

Level 1 Devices

- Standard Crosswalk
- Raised Mid-Block Crosswalk
- Rumble Strips

Level 2 Devices

- High Visibility Crosswalks

Level 3 Devices

- Refuge Islands
- Split Pedestrian Crossover (SPXO)
- Bulbouts

Level 4 Devices

- Overhead Signs and Flashing Beacons
- In-Roadway Warning Lights (IRWLs)

Level 5 Devices

- Pedestrian-Actuated Signals
- Grade-Separated Crossings