CHAPTER 5

LITERATURE REVIEW

This task includes identification of suitable pedestrian safety countermeasures for research at high pedestrian crash sites in high risk zones.

Pedestrian Safety Countermeasures
The following pedestrian safety countermeasures were identified and selected for testing and evaluation at selected sites. A discussion on the identified pedestrian safety countermeasures is presented along with the identified countermeasure.

Pedestrian Channelization (Railings or Barriers)
Median barriers restrict pedestrians to use designated pedestrian crosswalks at two sites in Washington, D.C. and New York, NY [4]. More than 60 percent of pedestrians identified the presence of the barrier as the reason to use a crosswalk.

Minimizing Pedestrian Confusion
One of the five basic requirements for a traffic control device, as defined in the Manual on Uniformed Traffic Control Devices (MUTCD), is to "...convey a clear, simple meaning." The MUTCD allows practitioners to use words or symbols to convey the message. The symbols are the “walking person” for the WALK phase and the “upraised hand” for the DON'T WALK phases. A frequent complaint received by traffic engineers is that a pedestrian signal is either malfunctioning or improperly timed. However, investigations show that the signals in question are found to be operating as intended. The ultimate cause of the complaint is pedestrian confusion about the operation and meaning of the pedestrian signal indications [5]. The phase that is most misunderstood is the flashing DONT WALK [6]. Tidwell and Doyle [7] documented the extent of pedestrian confusion. Almost half of the survey participants incorrectly believed that the flashing DONT WALK or “upraised hand” indication meant that pedestrians should return to the curb if they have just begun to cross at an intersection. A comparable percentage of respondents incorrectly assumed that the display of a steady WALK symbol or word message indicated they could cross safely without conflicts with traffic that also had the right-of-way. Solutions to minimize pedestrian confusion include pedestrian signal countdown devices [8, 9].

Increase Motorist Awareness
The objective of this technology is to enhance visibility and minimize inappropriate perceptions between the pedestrian/bicyclist and the motorist. The MUTCD recommends the use of an advance pedestrian crossing sign (W11-2) in advance of locations where pedestrians may cross but may not be expected by the motorist [10]. An alternative approach to enhance safety is to install in-pavement lighting on both sides of a crosswalk to alert motorists about the presence of a pedestrian crossing or preparing to cross a street [11]. The lights flash when a pedestrian activates a pedestrian call button, thus providing information to the motorist in real-time. This is currently installed in a number of cities throughout the U. S. including Reno, NV, Kirkland, WA and Orlando, FL. The flashing lights can also be used in conjunction with automated pedestrian detection devices (instead of a pedestrian call button).
ITS Automatic Pedestrian Detection Devices
Beckwith and Hunter-Zaworski [11] researched the use of passive infrared, ultrasonic and microwave radar to detect pedestrians at unsignalized crossings. Tests have shown promising results for Doppler radar and especially for passive infrared sensors.

Hughes, Huang and Zegeer [12] evaluated whether automated pedestrian detectors, when used in conjunction with standard pedestrian push buttons, would result in fewer overall pedestrian/vehicle conflicts and fewer inappropriate crossings (i.e., beginning to cross during DONT WALK signal). Data were collected before and after the countermeasure installation at intersection locations in Los Angeles, CA (infrared and microwave), Phoenix, AZ (microwave), and Rochester, NY (microwave). The results indicated a significant reduction in vehicle-pedestrian conflicts as well as a reduction in the number of pedestrians beginning to cross during the DONT WALK signal. The differences between microwave and infrared detectors were not significant. Detailed field testing of the microwave equipment in Phoenix revealed that fine-tuning of the detection zone is still needed to reduce the number of false calls and missed calls.

Pedestrian Head Start Signal Timing
Pedestrian “head start” signal timing, also referred to as “leading pedestrian interval” or “early release timing”, is a way to improve pedestrian safety and comfort at busy intersections. The technique is to hold all cars for a few seconds while pedestrians are given a “Walk” symbol. This is based on the assumption that vehicles are less likely to try to preempt their right-of-way when making turns after pedestrians have entered the intersection. The strategy was implemented by the City and County of San Francisco, Department of Parking and Traffic (DPT) at two intersections with dual left-turn lanes in downtown San Francisco - 3rd and Folsom Streets and 3rd and Howard Streets. The signal timing changes at these intersections were based on requests from pedestrian groups and seniors in the area [13].

Regulatory Sign for Motorist
Huang, Zegeer, Nassi and Fairfax [14] evaluated the use of the following three types of devices which were used in conjunction with marked crosswalks in an attempt to improve pedestrian safety.
- An overhead CROSSWALK sign in Seattle, Washington
- Pedestrian safety cones (with the message, "STATE LAW - YIELD TO PEDESTRIANS IN CROSSWALK IN YOUR HALF OF ROAD") in New York State and Portland, OR, and
- Pedestrian-activated "STOP FOR PEDESTRIAN IN CROSSWALK" overhead signs in Tucson, Arizona.
The New York cones and Seattle signs were effective in increasing the number of motorists stopping for pedestrians. The signs in Seattle and Tucson were effective in reducing the number of pedestrians who had to run, hesitate, or abort their crossing. The study concludes that it is essential to use these devices together with education and enforcement.

In-Pavement Lighting (Illuminated Overhead Crosswalk)
Nitzburg and Knoblauch [15] evaluated the effect of a novel illuminated overhead crosswalk sign and high visibility ladder style crosswalk markings on driver and pedestrian behavior at

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non-signalized intersections in Clearwater, FL. The following scenarios were studied.

- If pedestrians were more likely to cross where there was an illuminated overhead crosswalk sign and ladder crosswalk markings,
- If drivers would yield more often to pedestrians using this novel pedestrian facility, and,
- If pedestrians use more, less, or the same amount of caution as well as whether they cross more aggressively, forcing drivers to yield.

Nighttime observation sessions were conducted in order to better evaluate the effectiveness of the illuminated overhead crosswalk sign.

Other Pedestrian Safety Countermeasures

Literature has limited documentation on other pedestrian safety countermeasures such as countdown timers, enlarged pedestrian signal heads, animated eyes pedestrian signal heads, animated eyes alerting drivers to the direction of a crossing pedestrian, smart lighting, Danish offsets, symbol signs alerting pedestrians, advance stop / yield lines, flashing beacons activated by speeding trailers, and portable speed trailers. A short discussion on these potential pedestrian safety countermeasures is presented in the following.

Pedestrian Countdown Timers

The use of countdown timers is part of the FHWA Notice of Proposed Amendment (NPA) for inclusion in the MUTCD. The countdown timer displays the time left to cross the intersection safely and helps to clarify the message of the flashing “DON’T WALK”.

Enlarged Pedestrian Signal Heads

The use of enlarged signal heads is beneficial especially at wide intersections. This also would help vision impaired pedestrians.

Animated Eyes Pedestrian Signal Heads

The use of animated eyes is part of the FHWA NPA for inclusion in the MUTCD. The animated eyes address the problem of a WALK signal not being clear about the possibility of conflicts with turning vehicles. It can also be seen 50 percent farther by vision impaired pedestrians.

Animated Eyes ITS Warning Signs That Show Drivers the Direction Pedestrians Are Crossing

The animated eyes ITS warning sign is mounted overhead in advance of marked pedestrian crossing locations. This sign indicates that a pedestrian is crossing the street at an uncontrolled location, the direction the pedestrian is crossing the street, and the moving eyes display remind the motorist to look for the crossing pedestrian. The sign could be activated by a pedestrian call button or using pedestrian detection devices.

Smart Lighting to Warn Drivers That Pedestrians are Crossing under Dark Light Conditions

The objective of the smart lighting strategy is to increase the intensity of illumination at the crosswalk when a pedestrian is detected in the crosswalk. The sudden increase in lighting intensity alerts motorists that pedestrians are in crosswalk more so than when continuous intensity light is used in the crosswalk. Note that high intensity lighting will remain only when pedestrians are present in the crosswalk.
**Danish Offset**
The use of an offset at the middle of a multilane crossing to ensure pedestrians are facing the next half of traffic being crossed will be evaluated. In addition, it also provides a median refuge.

**Turning Vehicles Yield to Pedestrian Sign**
“TURNING VEHICLES YIELD TO PEDESTRIANS” is a symbol sign to remind motorists that turning vehicles must yield to pedestrians at traffic signals. These signs would be placed next to the traffic signal or mounted on in-roadway knockdown signs located at the centerline (or the lane divider marking closest to the curbside lane).

**High Visibility Crosswalk Treatment (Marked Crosswalks)**
Knoblauch, Nitzburg and Seifert [16] studied the effect of crosswalk markings on driver and pedestrian behavior at unsignalized intersections. The following three cases were analyzed.
- If pedestrians were more likely to cross a street within a marked crosswalk,
- If drivers drove slower and/ or yielded more often to pedestrians crossing at a marked location, and
- If pedestrians use more, less, or the same amount of caution when crossing at a marked pedestrian crosswalk as compared to an unmarked location.

Observations showed drivers approached the pedestrian in a crosswalk at somewhat slower speeds. The study also showed an increase in the usage of crosswalk after the installation of a crosswalk. It appears that marking pedestrian crosswalks at relatively low-speed, low volume, unsignalized intersections is a desirable practice.

Sisiopiku and Akin [17] state that marked midblock crosswalks are attractive crossing locations for pedestrian users. Approximately 83% of survey respondents indicated that the presence of midblock crossings influenced their decision to cross at the specific location and over 71 percent of pedestrians crossed properly at such crossings. The study also concluded that, though signalized crossings attract pedestrians crossing points, they are not always effective in protecting pedestrians from interactions with moving traffic.

Knoblauch and Raymond [18] studied the effect of crosswalk markings on vehicles speeds in Maryland, Virginia and Arizona. Six uncontrolled intersections were evaluated before and after crosswalks were installed. Observations showed a reduction in vehicle speeds under both the no pedestrian and the pedestrian not looking conditions. However, none of the approaching vehicles actually stopped and yielded to the pedestrian.

Miller [19] states that marked locations are not safer than unmarked locations for any similar traffic volumes range. Raised medians and new treatments such as actuated warning systems may improve safety at marked locations.

ITE [20] states that providing crosswalks at uncontrolled locations resulted in increased pedestrian collisions compared with not providing marked crosswalks on multilane roads and roads with average daily volumes of 10,000 or more vehicles per day. On roads with one-lane in each direction and less than 10,000 vehicles per day, the study found no difference in pedestrian collisions between marked crosswalks and unmarked crosswalks.
Malenfant, McCusker and Van Houten [21] studied the effect of an advanced yield marking and a symbol sign prompting motorists to yield to pedestrians at the marking on the motor vehicle-pedestrian conflicts. Observations show a decrease in the number of conflicts on the uncontrolled approach.

Crosswalks on multilane roads and uncontrolled approaches do not produce a false sense of security but increased yielding can place pedestrians at risk when vehicles stop for pedestrians too close to crosswalks [22]. Motorists yielding too close not only block the view of approaching traffic in the next travel lane but also block the pedestrian’s view of traffic approaching in the lane. Observations indicate that signs such as “Yield Here for Pedestrians”, placed 10 to 15 meters in advance of the crosswalk and used in conjunction with a yield line can produce a marked reduction in multiple threat conflicts. Other effective treatments are: use of an intelligent transportation systems (ITS) animated light emitting diodes (LED) signal designed to alert drivers; use of raised pedestrian crossing islands; and the use of curb extensions or bulbouts.

Zegeer, Stewart, Huang and Lagerway [23] studied five years of pedestrian crashes at 1,000 marked crosswalks and 1,000 matched unmarked comparison sites at uncontrolled locations. The study revealed no difference in pedestrian crash rate on two-lane roads or multi-lane roads with traffic volumes above 12,000 vehicles per day. Raised medians provided significantly lower pedestrian crash rates on multi-lane roads, compared to roads with no raised median.

**Advance Stop Line and Offset Stop Lines at Traffic Signal Locations**
The use of advance stop lines and offset stop lines produce a clear zone for pedestrians. This is expected to reduce the threat of vehicles turning right on red and the percentage of vehicles stopping in the crosswalk. Research has shown that moving these lines 15 to 30 feet upstream (in advance) of the crosswalk line could reduce conflicts and enhance pedestrian safety.

**Advance Yield Markings (Yield Bar)**
Installation of advance yield markings 30 to 50 feet in advance of crosswalks at uncontrolled locations could also enhance pedestrian safety. These markings produce a clear zone for pedestrians to reduce conflicts and crashes caused by the screening effect of vehicles on multilane roadways.

**ITS Speed Warning Signs**
Vehicles exceeding the school zone speed limit or vehicles speeding in high pedestrian crash zones would activate flashing beacons mounted on SPEEDING SLOW DOWN signs. The “device” used for this treatment would include a post mounted radar gun (or similar device) to measure vehicular speed, and display systems to indicate that the motorist is exceeding the speed limit.

**Portable speed trailer with Fine Info**
The use of a traditional portable speed trailer which only provides feedback on vehicle speed will be compared to a speed trailer that also informs the driver of the size of the fine associated with their speed.
Alternative Technologies Related to ADA
Evaluate the use and effectiveness of technologies such as vibro-tactile pedestrian call buttons, illuminated pedestrian call buttons, and audible signals for pedestrians.

Other pedestrian safety countermeasures include eliminating permissive left turns at high pedestrian crash signalized locations, signs that prohibit drivers from turning right on red when a pedestrian is crossing, pedestrian channelization using protective fences or barriers along the curbside or along medians, development of median refuges, and reduction of turning radius especially for right turning vehicles.

Graphical illustrations of the countermeasures are included in the form of photographs, or photographs with animated or mock-up representations (Figures 43-61, pages 5-7 through 5-16).
FIGURE 43 Pedestrian Channelization (Railings or Barriers)

FIGURE 44 Pedestrian Countdown Signal
FIGURE 45 Advanced Warning for the Motorists

FIGURE 46 ITS Automatic Pedestrian Detection Devices
FIGURE 47 Regulatory Sign for Motorist

FIGURE 48 In-Pavement Lighting (Illuminated Crosswalk)
FIGURE 49 Enlarged Pedestrian Signal Head

FIGURE 50 Animated Eyes Pedestrian Signal Heads
FIGURE 51 Animated Eyes ITS Warning Signs for Drivers

FIGURE 52 Smart Lighting to Warn Drivers That Pedestrians are Crossing under Dark Light Conditions
FIGURE 53 Danish Offset

FIGURE 54 Turning Vehicles Stop/Yield for Pedestrians
FIGURE 55 Advanced Stop Line and Offset Stop Lines at Traffic Signal Locations

FIGURE 56 Advanced Yield Markings
FIGURE 57 Portable Speed Trailer

FIGURE 58 Dynamic Signals Restricting RTOR
FIGURE 59 High Visibility Cross Walk Treatment

FIGURE 60 Median Refuge
FIGURE 61 Pedestrian Activated Signal Heads