Pedestrian Control Systems for Light-Rail Transit Operations in Metropolitan Environments

Hans W. Korve, José I. Farran, and Douglas M. Mansel, *Korve Engineering, Inc.*

Pedestrian considerations should be included with other considerations in the planning and design of light-rail transit (LRT) systems. If pedestrians' needs are inappropriately accounted for, the LRT agency could experience higher-than-average experience with collisions between light-rail vehicles (LRVs) and pedestrians, leading to necessary and expensive system retrofits or reduced LRV operating speeds, which would negatively affect LRT operations and potential ridership. Pedestrians interact with the LRT environment at stations and pedestrian crossings and in LRT-pedestrian malls. This interaction is unique in that (*a*) pedestrians are not always completely alert to their surroundings, (*b*) LRVs are unable to stop quickly or swerve to avoid colliding with a pedestrian, and (*c*) the injuries to the pedestrian are usually severe and often fatal. Thus, special pedestrian traffic control devices (including relevant pedestrian striping, signs, and signals) and pedestrian crossing control treatments (including pedestrian automatic gates, swing gates, Z-crossings, and bedstead barriers) are necessary to help pedestrians become alert to the dynamic LRT environment. Future research should be conducted to develop specific application guidelines for each of the pedestrian crossing control treatments. The potential methodology for selecting one or more pedestrian crossing control treatments for installation at a given pedestrian crossing location should be expanded and quantified through this research.

Light-rail transit (LRT) has become a reality in North America. Some 19 cities in the United States and Canada have systems in operation, in addition to several short starter-line segments (*1*). Because light-rail vehicles (LRVs) travel in a wide range of environments (both on street and in separate rights-of-way), attract passengers, and have large capacities, LRT is an increasingly viable public transportation option in many urban areas.

As new systems are planned and existing systems are extended, planning and design of LRT systems and extensions or retrofits to existing systems must consider the interaction of LRVs with motorists and pedestrians. Planning and design of new LRT systems (alignments, geometries, and traffic control devices) have traditionally focused on meeting only the minimum requirements for the interface between LRVs and motor vehicles. Pedestrian-related design issues in the vicinity of the LRT alignment have not received as much attention, sometimes leaving pedestrians exposed to potential accidents.

According to data obtained by the authors from 10 North American LRT agencies (Baltimore, Boston, Buffalo, Calgary, Los Angeles, Portland, Sacramento, San Diego, San Francisco, and San Jose) for the Transit Cooperative Research Program (TCRP), Project A-5 (Integration of Light-Rail Transit into City Streets), on average about 8 percent of all LRV collisions involve a pedestrian. Although this percentage is relatively small when compared with the percentage of LRV collisions involving motor vehicles, LRV-pedestrian collisions are usually more severe and often fatal. Therefore, it is critical that LRT agencies consider pedestrian movements and actions during the early stages of LRT system planning and design.

Further, interactions between pedestrians and LRVs are significantly different from those between motorists and LRVs. In general, as operators of motor vehicles, motorists tend to be more aware of their dynamic environment. Conversely, pedestrians, traveling largely in the relatively safe venue of protected sidewalk areas, do not routinely share the same continuous, attentive edge. When crossing the travel path of motor vehicles or LRVs, pedestrians should shift to a state of awareness similar to that exhibited by motorists. However, this shift does not always occur. Moreover, unlike motor vehicles, LRVs cannot swerve or stop quickly enough to compensate for pedestrians who are errant or disobedient of traffic control devices.

Accordingly, various pedestrian crossing environments and characteristics associated with each are described; then some recommended pedestrian traffic control devices for LRT systems are discussed along with some pedestrian design considerations and types of pedestrian crossing control treatments. Last, a possible approach to developing application guidelines for these pedestrian crossing treatments is presented.

Pedestrian Crossing Environment

Pedestrians interact with and cross LRT alignments at three distinct locations:

1. Pedestrian crossings of LRT semiexclusive, separate rights-of-way,
2. Mid-block or intersection crossings where LRVs travel in the median (or on the side) of a street, and
3. LRT-pedestrian mall environments.

At pedestrian crossings of semiexclusive, separate rights-of-way, LRVs usually operate through the crossing at speeds up to 90 km/hr (55 mph). Because of this relatively high crossing speed, these types of crossings are usually controlled by flashing-light signals (flashing red lights and bells), appropriate pedestrian warning signs and striping, and, in some instances, automatic gates. Examples of this type of pedestrian crossing can be found along the San Diego LRT system East Line to Santee, near Glen Burnie on the Baltimore LRT system, and along the Folsom Line on the Sacramento LRT system.

The second type of pedestrian crossing is perhaps the most common to existing LRT systems. Here, LRVs travel in the median or on the side of a parallel street. Pedestrians cross the LRT alignment either at mid-block locations or at street intersections. LRVs can operate through the crossing at speeds up to about 90 km/hr (55 mph) if the intersection uses motor vehicle automatic gates and up to about 55 km/hr (35 mph) if the intersection is controlled by standard traffic signals. These types of pedestrian crossings typically have pedestrian signals (displaying the Walk/Don't Walk aspects) and may also have flashing-light signals if LRVs operate at higher speeds (above 55 km/hr). This type of pedestrian crossing can be found at virtually all of the North American LRT systems.

In LRT-pedestrian malls, pedestrians may cross the LRT tracks at any location; therefore, LRV speeds in a mall-type environment are usually limited to about 25 km/hr (15 mph). The LRV dynamic envelope (the clearance on either side of a moving LRV in which no contact can take place from any condition of design wear, loading, end or middle ordinate overhang, or anticipated failure such as air-spring deflation or normal vehicle lateral motion) is typically delineated by contrasting pavement texture and color such as the tactile warning strip approved by the Americans with Disabilities Act (ADA). Examples of LRT-pedestrian malls can be found on North First and Second streets at the San Jose LRT system, on K Street at the Sacramento LRT system, and on First Avenue near downtown at the Portland LRT system.

Pedestrian Traffic Control Devices

As part of TCRP Project A-5 (Integration of Light-Rail Transit into City Streets) and ongoing participation on the National Committee on Uniform Traffic Control Devices (Highway-Railroad Grade Crossing Technical Committee, LRT Task Force), recommendations have been developed to aid traffic, safety, and LRT engineers in determining appropriate pedestrian traffic control devices for the three pedestrian crossing environments described in the previous section. The pedestrian traffic control devices presented here fall into two major categories: LRV dynamic envelope delineation and pedestrian signs and signals.

LRV Dynamic Envelope Delineation

The dynamic envelope of an LRV should be delineated at all pedestrian crossings of semiexclusive, separate right-of-way and all pedestrian crossings where LRVs travel in the median (or on the side) of a street. The LRV dynamic envelope should also be delineated along the

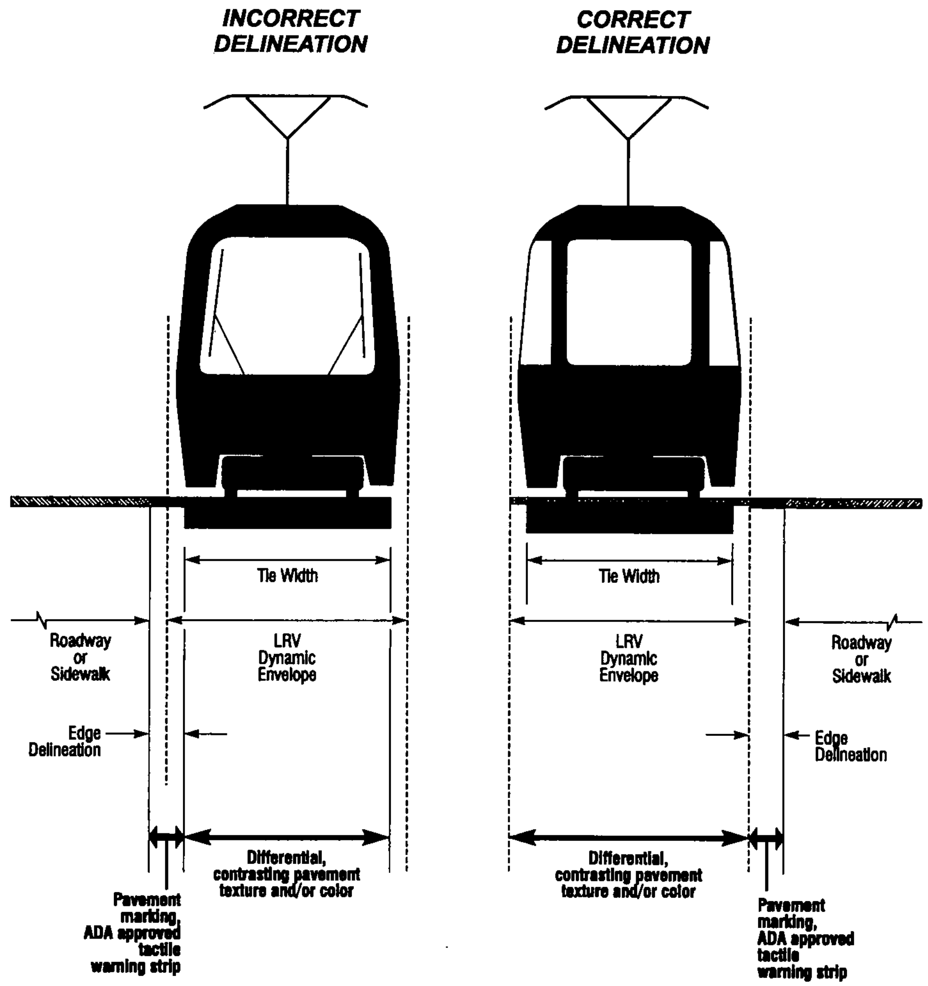


FIGURE 1 LRV dynamic envelope delineation.

entire length of LRT-pedestrian malls. Pavement markings that delineate the dynamic envelope of an LRV serve two purposes: to provide the LRV operator with the clearance limits for pedestrians and to indicate to pedestrians where the LRV may encroach on their path.

The preferred method of delineating the LRV dynamic envelope is by differential, contrasting pavement texture, color, or both. Alternatively, a solid line 100 mm (4 in.) wide may be used. Any crossing material or contrasting pavement texture or color used to delineate the track area should always encompass the LRV dynamic envelope. Further, as shown in Figure 1, where delineation (e.g., ADA-approved tactile warning strips) is used to mark the edge of the LRV dynamic envelope, it should always be completely outside of the envelope.

Pedestrian Signs and Signals

At crossings of LRT rights-of-way where pedestrian movements are controlled by pedestrian signals, the primary warning sign should be the W10-5 LRT crossing sign (see Figure 2). At unsignalized pedestrian crossings (crossings where pedestrians are not controlled by pedestrian signals) of semiexclusive, separate, LRT-only rights-of-way where LRVs operate in both directions, the W10-5a sign should be used. The pedestrian signal is the primary regulatory device, and the warning sign alerts the pedestrian of the increased risk associated with violating the pedestrian signal. According to the *Manual on Uniform Traffic Control Devices* (MUTCD) (2), Section 2A-13, an optional sign (educational plaque) displaying the legend TRAIN may be installed below the W10-5 or W10-5a signs.

When flashing-light signals (see Figure 3) serve as the primary warning device, that is, when the red signals are flashing alternately and the audible device is active, the pedestrian is required to remain clear of the track area (outside of the LRV dynamic envelope), as per the *Uniform Vehicle Code,* Section 11-513 (3).

At gated LRT-only crossings where LRVs operate in both directions, a flashing-light signal assembly should

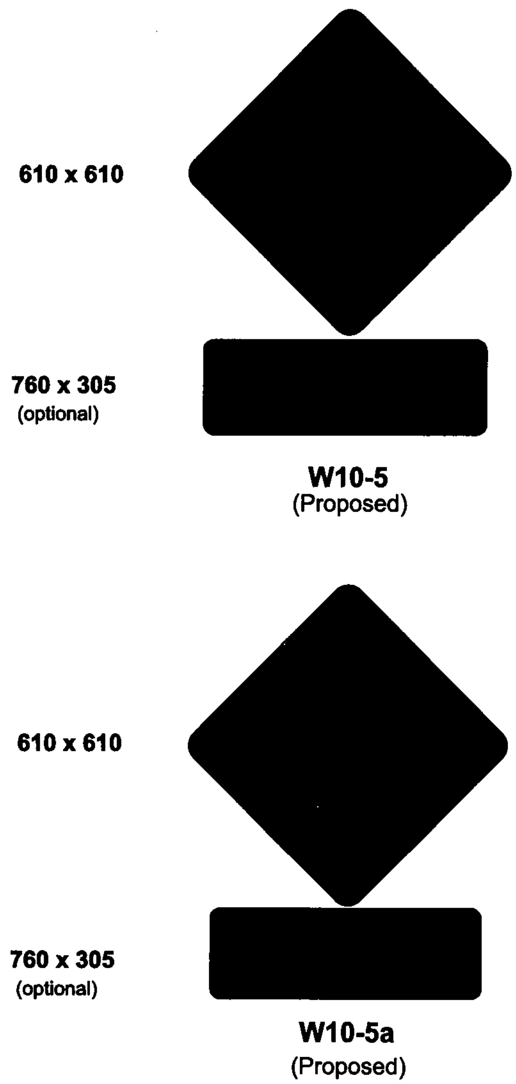


FIGURE 2 LRT crossing signs [colors: symbol, arrow, legend, and border—black (nonreflecting); background—yellow (reflective); dimensions in millimeters; 25.4 mm = 1 in.].

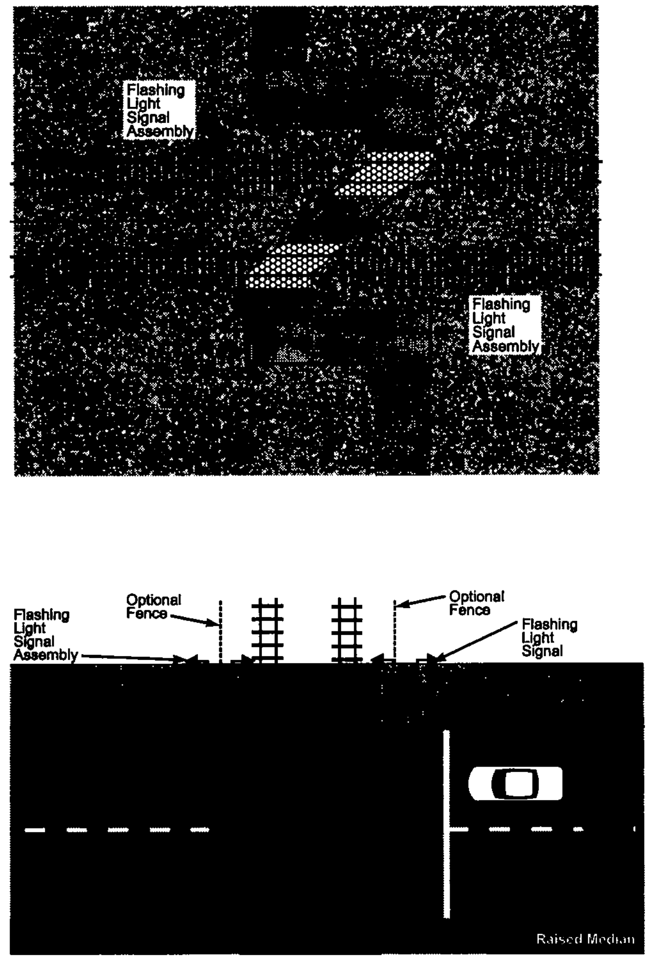


FIGURE 3 Typical placement of flashing-light signal assemblies: ***top,*** isolated pedestrian-only crossing of LRT-only right-of-way; ***bottom,*** pedestrian crossing of LRT-only right-of-way.

also be installed adjacent to the pedestrian path (e.g., the sidewalk) in the two quadrants without vehicle automatic gates, as shown in Figure 3.

At nongated, unsignalized pedestrian crossings where LRVs operate in both directions in the median (or on the side) of a street, the W10-5a sign should be the primary pedestrian warning.

An LRV-activated, internally illuminated matrix sign displaying the pedestrian crossing configuration with multiple tracks may be used as a supplement to the W10-5 sign to warn pedestrians of the direction from which one or more LRVs may approach the crossing, especially at locations where pedestrian traffic is heavy (e.g., near LRT stations). This active matrix sign (see Figure 4) should animate the pedestrian to look both ways as LRVs are approaching the crossing. Further, the relative speed of all LRVs (or railroad trains) as they approach the pedestrian crossing should be depicted. This sign should be used in combination with the W10-5 sign in lieu of the W10-5a sign. It should not be used with the W10-5a sign since it permanently displays a double-headed arrow and the legend LOOK BOTH WAYS.

Alternatively, an LRV-activated, internally illuminated flashing sign displaying the legend SECOND TRAIN—LOOK LEFT (or RIGHT) may be used as a supplement to the W10-5 to alert pedestrians that a second LRV is approaching the crossing from a direction that might not be expected (see Figure 5). The sign warns pedestrians that, although one LRV has passed through the crossing, a second LRV is approaching and that other active warning devices (e.g., flashing-light signals and a bell) will remain active until the second LRV has cleared the crossing.

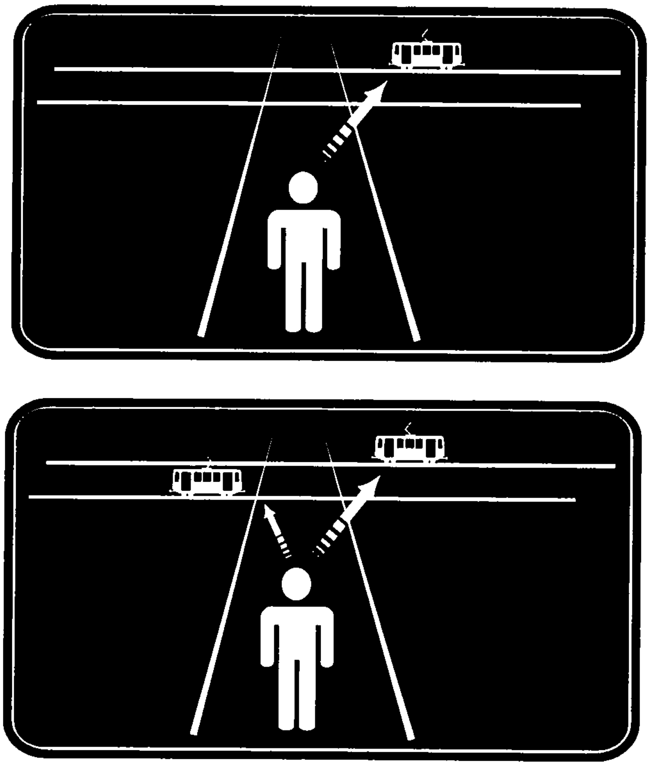
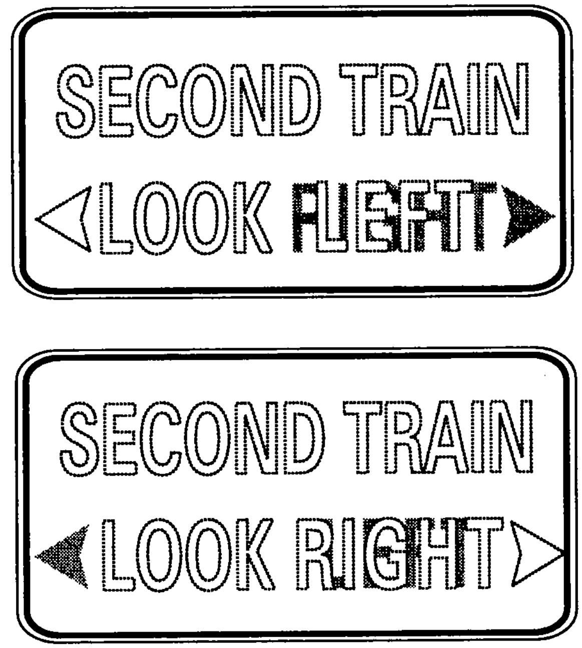


FIGURE 4 Active matrix train-approaching sign (approximately 760 by 460 mm): *top,* one LRV approaching pedestrian crossing; *bottom,* multiple LRVs approaching pedestrian crossing [colors: pedestrian, crossing, rail, and LRV—amber (active matrix); background—black (nonreflective); 25.4 mm = 1 in.].

When this sign is activated, only one direction is illuminated at any time and only one arrow (to the left of LOOK or to the right of RIGHT) is illuminated at any time, the arrow that points in the direction of the approaching second LRV. If two LRVs are very closely spaced so that they will pass through the pedestrian crossing almost simultaneously, this sign should not be activated since there would be no opportunity for pedestrians to cross between the successive LRVs.

These LRV-activated warning signs should be placed on the far side of the crossing (and also on the near side of the crossing if necessary for added pedestrian visibility), especially when the crossing is located near an LRT station, track junction, or multiple-track alignment (more than two tracks). All pedestrian warning signs should be mounted as close as possible to the minimum height above the ground set by the MUTCD (2), Section 2A–23 [1.5 or 1.8 m (6 or 7 ft)], or pedestrians will often not see or simply ignore them. They should be mounted lower than the minimum height only if pedestrians are restricted from entering the area where the signs are installed. Usually, the W10-5 or W10-5a sign should be mounted so that the clearance to the bottom



W10-7
(Proposed)

FIGURE 5 "Second Train" internally illuminated sign (760 by 460 mm) [colors: legend—amber (fiber-optic illumination); background—black (nonreflective); only one direction illuminated at any time; 25.4 mm = 1 in.].

of the sign is 1.8 m (7 ft). If a supplemental active matrix sign or SECOND TRAIN—LOOK LEFT/RIGHT sign is used below the W10-5 sign, the bottom of the supplemental sign should be at least 1.5 m (6 ft) above the ground.

Pedestrian Crossing Design Considerations

At pedestrian crossings of semiexclusive, separate right-of-way and at mid-block or intersection pedestrian crossings where LRVs travel in the median (or on the side) of a street, adequate, safe queueing areas for pedestrians should always be provided. These areas should be clearly marked (with contrasting pavement texture and color or striping) on both sides of the tracks between the parallel roadway (if present) and LRT tracks. Where the pedestrian crossing is wide (e.g., more than two track alignments) and LRVs or other trains operate in multiple directions, a clearly designated area between the sets of tracks should be provided (if space is available) as a safe place to queue in case multiple LRVs or trains approach the crossing while pedestrians are within the rail alignment.

Furthermore, if these safe queueing areas are not provided and pedestrians are not adequately channeled across the LRT tracks at designated locations (along separate rights-of-way or the median or side of the street alignments), LRV speeds through the crossings would have to be substantially reduced, forcing LRVs to operate as if they were in an LRT-pedestrian mall environment.

Possible treatments for the channelization and control of pedestrian crossings of LRT separate rights-of-way or median or side-of-street alignments include

- Grade separation or crossing closure,
- Pedestrian automatic gates,
- Swing gates,
- Z-crossings, and
- Bedstead barriers.

The last four pedestrian crossing control systems, as well as appropriate application of each, are described in the following sections.

Pedestrian Crossing Treatments

One possible solution to address pedestrian crossing concerns is to either grade separate or close the crossing. Although grade separation (e.g., a pedestrian-only tunnel under or a bridge over the LRT alignment) may completely solve the conflict between pedestrians and LRVs, it is not always feasible for LRT agencies because of economic, construction, security, or environmental reasons.

Further, closing the pedestrian crossing may, in some instances, make the potential for an LRV-pedestrian collision greater. One of the overriding planning principles developed by TCRP Project A–5 suggests that LRT system planning and design should respect the urban environment that existed before LRT implementation. Because pedestrians (and motorists) grow accustomed to their urban environment, LRT systems that operate in these environments should conform as much as possible to the behaviors (and pedestrian movements) that have already been established. Accordingly, unless a specific urban design change is desired (e.g., changing a street into an LRT-pedestrian mall), pedestrian traffic and travel patterns should be maintained. If pedestrian crossings are simply closed without considering impacts on out-of-direction travel patterns, pedestrians may attempt to cross the LRT alignment despite fences and other barriers that discourage these actions.

Because grade separation and pedestrian crossing closure are not usually feasible, for economic and safety reasons, respectively, the other pedestrian crossing control treatments listed earlier, which are designed to warn, channelize, or block pedestrians from crossing the tracks when LRVs are or may be approaching the crossing, have proven effective for both controlling and channeling pedestrians across the LRT track environment.

Pedestrian Automatic Gates

Pedestrian automatic gates are the same as standard automatic crossing gates except that the arms are shorter. They are used to physically discourage pedestrians from crossing the LRT tracks when the automatic gates are activated by an approaching LRV. When LRV stopping sight distance is inadequate, these gates should always be used.

The preferred method for pedestrian automatic gate installation is to provide them in all four quadrants; where right-of-way conditions permit, the vehicle automatic gate should be located behind the sidewalk (on the side that is away from the curb), so that the gate arm will extend across the sidewalk, blocking the pedestrian crossing in two of the four pedestrian quadrants (see Figure 6, Option A, and Figure 7, Option A). Longer and lighter gate arms make this installation feasible. However, experience suggests a maximum gate arm length of 11.5 m (38 ft) for practical operation and maintenance. At those crossings requiring the gate arm to be longer than 11.5 m, a second automatic gate should be placed in the roadway median. To provide four-quadrant protection, two single-unit pedestrian automatic gates should also be installed behind the sidewalk across the tracks opposite the vehicle automatic gates. This option is preferred to the option described next because it keeps the pedestrian path clear and minimizes roadside hazards for motorists.

Alternatively, the pedestrian automatic gate may share the same assembly with the vehicle automatic gate (near the curb of the sidewalk), as shown in Figure 6, Option B, and Figure 7, Option B. In this case a separate driving mechanism should be provided for the pedestrian gate so that if it fails, it will not affect the vehicle automatic gate operations. To provide four-quadrant protection, two single-unit pedestrian automatic gates should also be installed on the curbside of the sidewalk across the tracks opposite the combination vehicle-pedestrian automatic gates.

The possibility of trapping pedestrians in the LRT right-of-way when four-quadrant pedestrian gates are installed should be minimized. Clearly marked pedestrian safety zones and escape paths within the crossing should be established.

Pedestrian automatic gates have been successfully installed on the St. Louis Metrolink LRT system, the Chicago Transit Authority "Skokie Swift" electrified passenger rail line, the CalTrain commuter railroad line from San Jose to San Francisco, the Long Island commuter railroad line in New York, the Southeastern Penn-

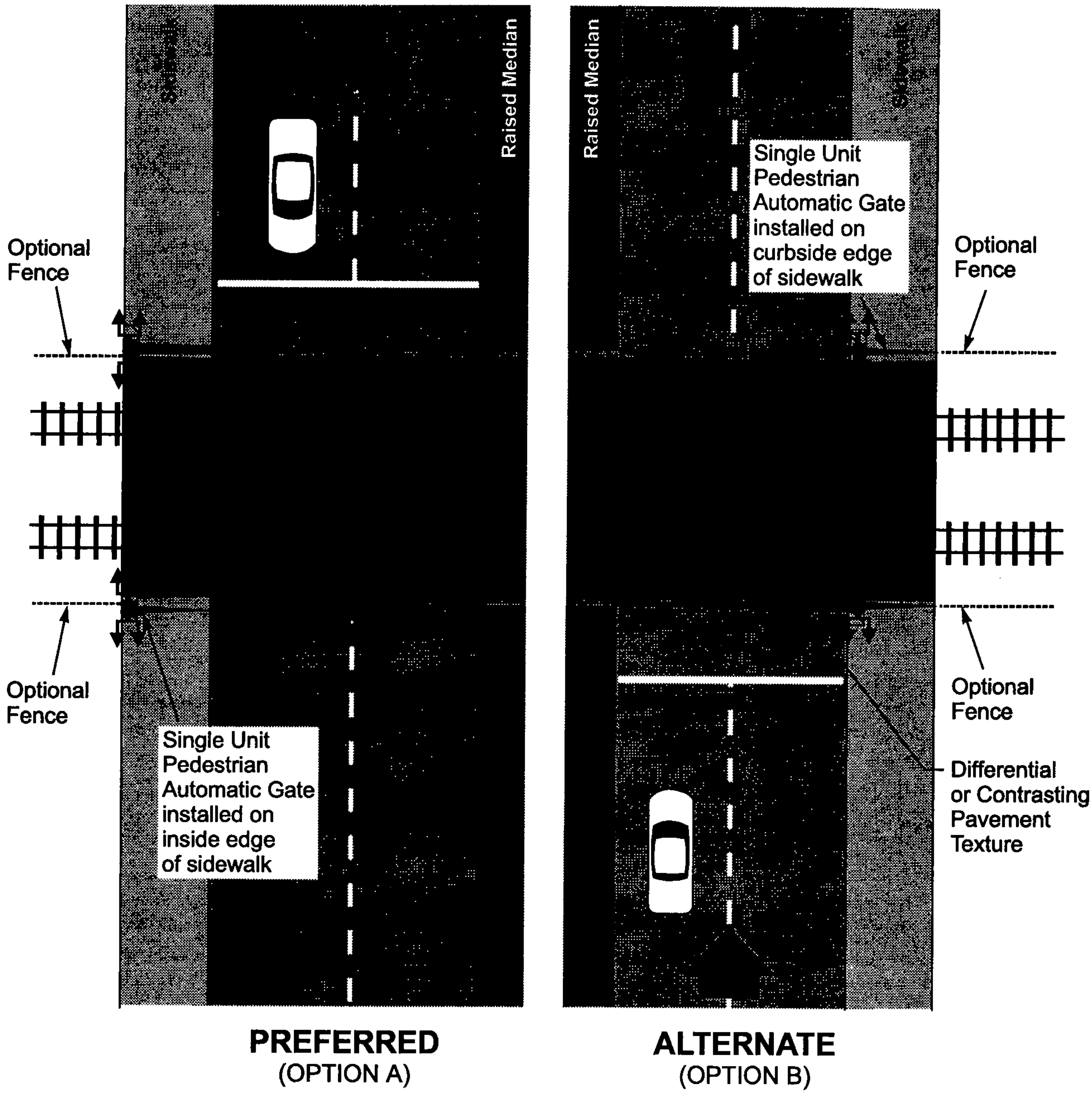


FIGURE 6 Placement of pedestrian automatic gates: Option A—gates installed on inside of sidewalk extending across sidewalk and roadway; Option B—gates installed on curbside of sidewalk with separate pedestrian gate arm.

sylvania Transportation Authority commuter railroad line, the Santa Fe railroad through Holbrook, Arizona, and the Southern Pacific railroad through Reno, Nevada.

Swing Gates

The swing gate (usually used in conjunction with flashing-light signals and bells) is a pedestrian crossing control treatment that alerts pedestrians to the LRT tracks to be crossed and forces them to pause, thus preventing pedestrians from running freely across the LRT tracks and restricting the exit from the LRT right-of-way (see Figure 8). The swing gate requires pedestrians to pull the gate in order to enter the crossing and to push the gate to leave the protected track area; therefore, a pedestrian cannot enter the track area without pulling and opening the gate. Swing gates should be designed to return to the closed position after passage of the pedestrian but should never lock in the closed position to avoid potentially trapping a pedestrian within the LRT right-of-way.

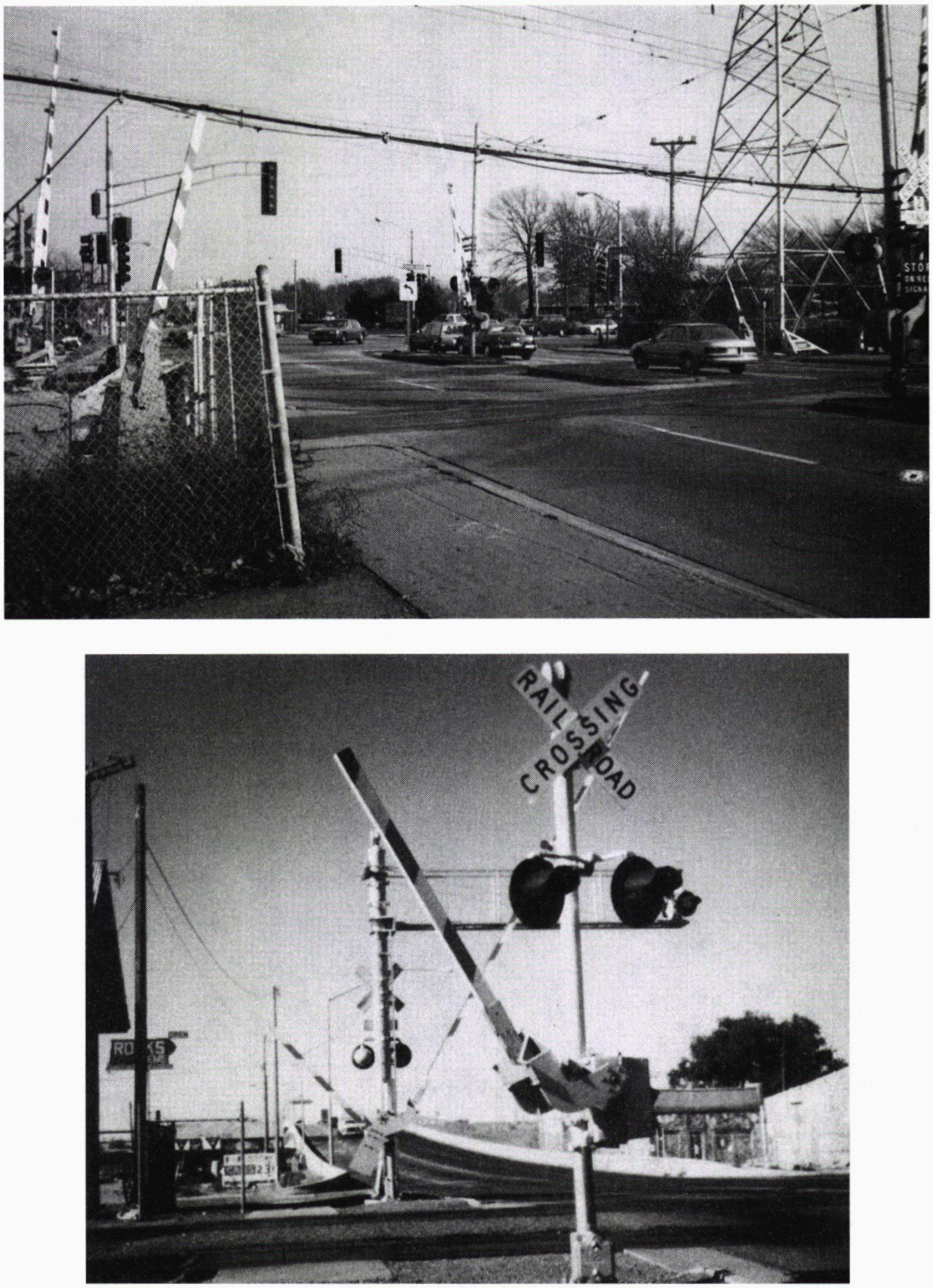


FIGURE 7 Pedestrian automatic gate examples: *top,* Option A, Skokie, Illinois; *bottom,* Option B, Holbrook, Arizona.

Swing gates may be used at pedestrian-only crossings, on sidewalks, and near stations (especially if the station is a transfer point with heavy pedestrian volumes). They may be used at pedestrian crossings of either single-track (one-or two-way operations) or double-track alignments.

Although initially there were some concerns about the potential to trap pedestrians (especially those with disabilities) on the trackway, research conducted by the authors as part of TCRP Project A–5 (which included interviews with safety officers from three LRT agencies that have installed swing gates) suggests that swing gates not only have not increased the risk of accidents at those crossings where they have been installed but also have proved effective in reducing collisions between pedestrians and LRVs. They are currently installed at various locations on the Calgary LRT system, especially at stations; on the San Jose LRT system (at the Ohlone-Chynoweth Station); and on the Los Angeles LRT system (at the Imperial Transfer Station). In fact, the Los

FIGURE 8 Pedestrian swing gate examples: *top,* Los Angeles LRT system; *bottom,* San Jose LRT system.

Angeles County Metropolitan Transportation Authority (LACMTA), operating agency of the Los Angeles LRT system, recently conducted a survey of swing gate users at the Imperial Transfer Station in which it was indicated that pedestrians found the swing gates easy to use and appreciated the barrier between them and the fast-moving LRVs and railroad trains.

Z-Crossings

The Z-crossing channelization controls movements of pedestrians who are approaching the LRT tracks. Its design and installation turn pedestrians toward a potentially approaching LRV before they cross each track, forcing them to look in the direction of oncoming LRVs (see Figure 9, *top*).

Z-crossing channelization may be used at crossings where pedestrians are likely to run unimpeded across the tracks, such as isolated mid-block, pedestrian-only crossings. Z-crossing channelization used with pedestrian signals creates a safer environment for pedestrians than when Z-crossings are used alone. This type of channelization device may also be used in conjunction with pedestrian automatic gates and bedstead barriers if LRVs operate at high speeds or the pedestrian volumes are heavy.

The Z-crossing channelization should not be used where LRVs operate both ways on a single track because pedestrians may be looking the wrong direction in some instances. In a double-track alignment during reverse-

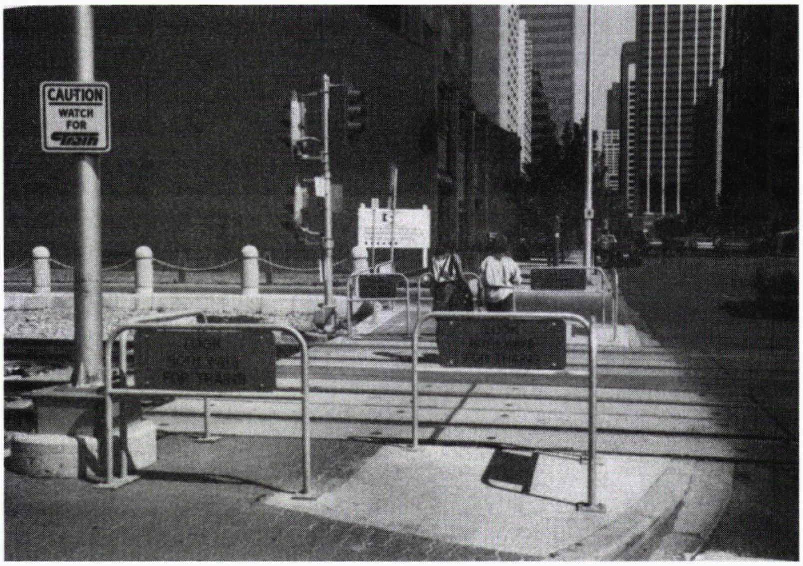


FIGURE 9 ***Top:*** **Z-crossing, San Diego LRT system, East Line to Santee;** ***bottom:*** **bedstead barrier, Calgary, Alberta, LRT system, Seventh Avenue transit mall.**

running situations, pedestrians may also look in the wrong direction; however, because reverse-running is performed at lower speeds, it should not be a deterrent to installing this channeling approach.

Z-crossing channelization is currently being used by the Portland LRT system along East Burnside Street, by the San Diego LRT system on the East Line to Santee, and by the San Francisco LRT system on the South Embarcadero MUNI Metro Extension.

Bedstead Barriers

Bedstead barriers may be used in tight urban spaces where the LRT right-of-way is not fenced in, such as a pedestrian crossing at a street intersection. The barriers are placed in an offset, mazelike manner that requires pedestrians moving across the LRT tracks to navigate the passageway through the barriers, which should be designed and installed to turn pedestrians toward the potentially approaching LRVs before they cross each track, forcing them to look in that direction (see Figure 9, *bottom*). These barriers should also be used to delineate the pedestrian queueing area on both sides of the track area. These same effects could be accomplished by using bollards and chain.

Bedstead barriers may also be used in crossings where pedestrians are likely to cross the tracks unimpeded, such as at stations or transfer points. The barriers should be used in conjunction with one or all of the following:

flashing-light signals, pedestrian signals, and appropriate signing. Bedstead barriers may also be used in conjunction with pedestrian automatic gates.

Bedstead barriers should not be used where LRVs operate both ways on a single track because pedestrians may be looking in the wrong direction in some instances. In a double-track alignment during reverse-running situations, pedestrians also look in the wrong direction; however, because reverse-running is performed at lower speeds, it should not be a deterrent to installing this channeling approach.

Bedstead barriers are used at numerous locations on the Calgary LRT system at or near station locations and intersection crosswalks.

Combined Pedestrian Crossing Control Treatments

The pedestrian crossing control treatments described in the foregoing sections may be used in combination, as shown in Figure 10, depending on the level of risk of a collision between a pedestrian and an approaching LRV at the crossing. Moreover, pedestrian safety and queueing areas should always be provided and clearly marked.

Pedestrian Crossing Control Treatment Applications

To date, no guidelines have been developed for determining when to use one or more of the pedestrian crossing control treatments as a function of the level of risk for pedestrians at a crossing. Theoretically, selecting the most appropriate pedestrian crossing control treatment would follow the conceptual process shown in Figure 11. First the level of risk should be established, typically as a function of pedestrian volumes, LRV speed, crossing configuration, stopping sight distance, adjacent land use (e.g., schools, senior citizen facilities, etc.), existence of passenger transfers to other modes, and other factors that may affect pedestrian safety. A potential risk value could be determined as a function of the foregoing factors (f_i) weighted according to their relative importance (w_i):

$$R = \Phi\,(w_i\,, f_i) \tag{1}$$

Once the potential risk value is determined and the cross street traffic control device is established, the appropriate pedestrian crossing treatment can be selected as per Figure 11. Further research is needed to quantify pedestrian risk values and develop the best equations

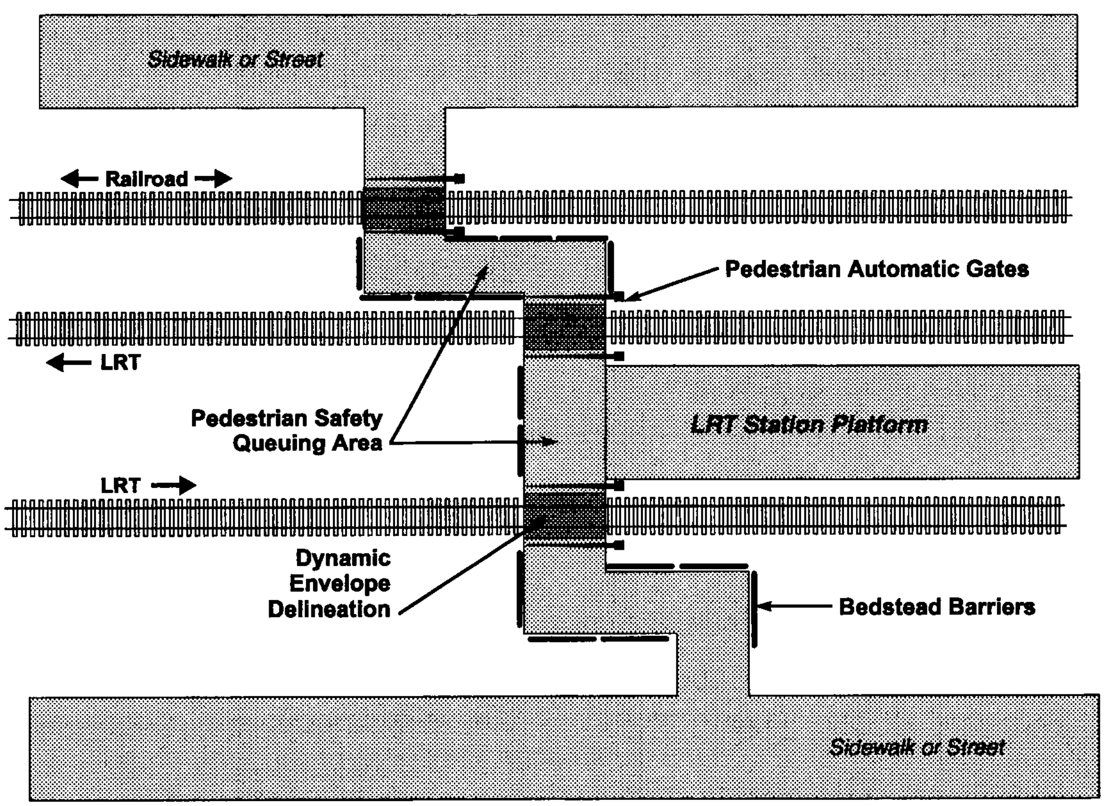


FIGURE 10 Illustrative pedestrian treatment in combined railroad and LRT corridor (not to scale).

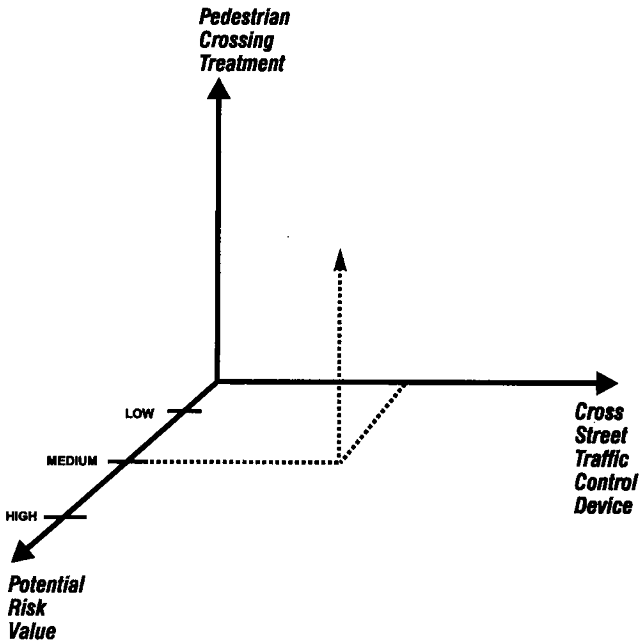


FIGURE 11 Conceptual process for selecting pedestrian crossing treatment.

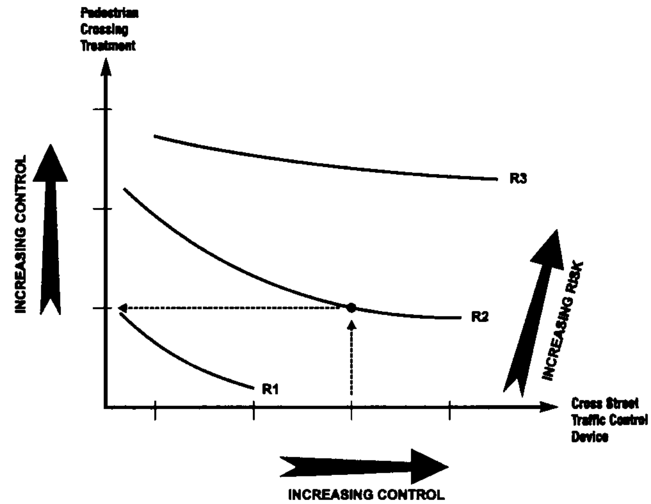


FIGURE 12 Pedestrian crossing treatment selection diagram.

and appropriate weights for each safety factor. Moreover, through additional research each pair of risk value and cross street traffic control devices has to be related to the most appropriate pedestrian crossing treatment.

In practice, to simplify this process for possible inclusion in LRT design or traffic engineering manuals, a pedestrian crossing treatment selection diagram (Figure 12) could be developed. Once the risk value has been determined using Equation 1 and the cross street traffic control device has been selected, the most appropriate pedestrian crossing treatment can be selected by means of the discrete risk value curves ($R1$, $R2$, $R3$, . . . in Figure 12). The shape of the risk value curves would be determined as a function of the research described above.

Conclusions and Recommendations

Each of the gate and channelization devices described above should be used with appropriate signaling (flashing-light signals, pedestrian signals, or both), signing, and pavement markings. As described, the dynamic envelope of the LRV should be clearly delineated by contrasting pavement texture and color (or alternatively by striping) at every pedestrian crossing. Further, the LRV dynamic envelope should be continuously delineated in an LRT-pedestrian mall (by contrasting pavement texture and color, ADA-approved tactile warning strips, or other approved pavement marking).

The gate and channelization devices presented in this paper should be used to alert pedestrians of the increased risk associated with crossing an LRT track alignment. Future research is needed to develop specific application guidelines and an appropriate selection methodology for each pedestrian crossing control treatment or combination of treatments.

Last, pedestrian considerations should be included with other considerations in LRT system planning and design. If pedestrians' needs are inappropriately accounted for during system planning and design, the LRT agency could experience a higher-than-average rate of collisions between LRVs and pedestrians (leading to necessary and expensive system retrofits) or reduced LRV operating speeds, which would negatively affect LRT operations and potential ridership.

References

1. Booz, Allen & Hamilton, Inc. *Transit Cooperative Research Program Report 2: Applicability of Low-Floor Light Rail Vehicles in North America.* TRB, National Research Council, Washington, D.C., 1995, pp. 161–168.
2. *Manual on Uniform Traffic Control Devices for Streets and Highways.* FHWA, U.S. Department of Transportation, 1988.
3. *Uniform Vehicle Code.* Article V, para. 11–513(b), 1992 edition. National Committee on Uniform Laws and Ordinances, Evanston, Ill.