TCRP

REPORT 175

TRANSIT
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Guidebook on Pedestrian Crossings of Public Transit Rail Services

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TRANSIT COOPERATIVE RESEARCH PROGRAM

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Guidebook on Pedestrian Crossings of Public Transit Rail Services

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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THE NATIONAL ACADEMIES

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Photos included in this *Guidebook* were taken by Kay Fitzpatrick, Jeff Warner, Billie Louise Bentzen, Marcus Brewer, Brian Gilleran, Kurt Wilkinson, Robert Pitts, and Abdul Zohbi.

FOREWORD

By Dianne S. Schwager
Staff Officer
Transportation Research Board

TCRP Report 175: Guidebook on Pedestrian Crossings of Public Transit Rail Services presents a wide array of engineering treatments to improve pedestrian safety for three types of public transit rail services: light rail, commuter rail, and streetcar. The *Guidebook* is a resource that addresses key pedestrian safety issues associated with public transit rail services; presents pedestrian crossing issues associated with the National Environmental Policy Act of 1969 and the Americans with Disabilities Act; summarizes readily available decision flowcharts used to make decisions regarding pedestrian treatments at rail crossings; presents information for 34 pedestrian treatments used at rail crossings, grouped into eight appropriate categories; and includes four case studies that examine specific decisions with respect to pedestrian-rail crossings. The *Guidebook* is supplemented by a final research report, *TCRP Web-Only Document 63: Treatments Used at Pedestrian Crossings of Public Transit Rail Services* (available on the TRB website). This report presents the methods and results from the detailed literature review, data analysis, industry survey, interviews, and site visits.

The research deliverables will be useful to transit agencies that provide light rail, commuter rail, and streetcar services; local departments of transportation; and urban planners seeking to improve the safety of pedestrians who use transit services, as well as others crossing public transit rails who are not transit patrons.

Pedestrian safety at rail public transit crossings is critically important. Improved treatments and guidance for safe and effective pedestrian crossings are needed since there is a lack of consistency for rail transit crossing treatments; rail transit services (light rail, commuter rail, and streetcar) are being added in many areas; the number of pedestrians has increased; and the ubiquitous use of cell phones and other electronic devices distracts pedestrians or limits their ability to hear audible warnings.

TCRP Project A-38, which was conducted by the Texas A&M Transportation Institute, was undertaken to develop a guidebook for safe and effective treatments for pedestrian crossings for rail public transit services, including light rail, commuter rail, and streetcar services. The treatments are effective options considering rail vehicle speed and frequency, geometry of the crossing, sight lines for pedestrians and rail vehicle operators, operating environment, and characteristics of pedestrians, including pedestrians with disabilities.

The contractor's final report (*TCRP Web-Only Document 63*) presents the research activities conducted to develop the *Guidebook* including a literature review, an investigation of online transit crash databases, an online survey of practitioners, telephone interviews to obtain further details, and site visits. The key research activity was visiting several public transit rail services crossings within select regions. These visits provided the opportunity to observe the challenges faced by pedestrians at public transit rail crossings and included observations made during site visits to Boston, Massachusetts; Portland, Oregon; and Los Angeles, California.

CONTENTS

SUMMARY

Guidebook on Pedestrian Crossings of Public Transit Rail Services

There is a natural interaction between pedestrians and public transit rail services. Rail transit services provide a high-capacity travel option for trips between major origin-destination pairs in an urban area, allowing pedestrians to travel to many more places than otherwise feasible on foot. Improving pedestrian access to rail transit stations obviously benefits the pedestrian by providing a safer and more usable route. Improving pedestrian access also benefits rail transit by resulting in a more attractive service and improved consistency at crossings.

To compile the guidance from other existing resources into one document and to supplement that guidance with observations of existing pedestrian rail treatments, *TCRP Report 175: Guidebook on Pedestrian Crossings of Public Transit Rail Services* (*Guidebook*) was developed under TCRP Project A-38. The *Guidebook* discusses issues associated with pedestrian crossing of public transit rail services and provides examples of treatments in use. Included within the *Guidebook* are summaries of rail transit service options, safety and accessibility issues related to pedestrians and rail crossings, and methods of selecting appropriate treatments for a given crossing. A collection of existing treatments is described, and case studies provide additional insight on the process for identifying and implementing pedestrian crossing treatments.

The following pedestrian treatments are discussed within the *Guidebook*:

- Channelization
- Barriers
  - General
  - Offset pedestrian crossing
  - Maze fencing
  - Pedestrian fencing
  - Between-car barriers at transit platform edges
  - Temporary
- Design
  - Clearly defined pedestrian crossing
  - Smooth and level surface
  - Sight distance improvements
  - Stops and terminals
  - Illumination
  - Flangeway filler
  - Pedestrian refuge
  - Sidewalk relocation
  - On-road bollards

- Signs
  - Passive
  - Unique warning messages
  - Signs for enforcement
  - Blank-out warning
- Signals
  - Timing considerations near railroad crossings
  - Flashing-light signal assembly
  - In-pavement flashing lights
- Pavement markings
  - Pedestrian stop lines
  - Detectable warnings
  - Word or symbol
  - Dynamic envelope markings
- Infrastructure
  - Audible crossing warning devices
  - Pedestrian automatic gates
  - Pedestrian automatic gates with horizontal hanging bar
  - Pedestrian swing gates
- Operations
  - Required stop
  - Reduced train speed
  - Rail safety ambassador program

Case studies were developed on the following topics:

- Case Study A: Review of Sound Wall
- Case Study B: Location of Station Entrance
- Case Study C: Consideration of Visually Impaired Pedestrians When Designing a Station Entrance to a Platform Located Between Tracks
- Case Study D: Control of Pedestrian Path

CHAPTER 1

Introduction

Overview

There is a natural interaction between pedestrians and rail transit services. Rail transit services provide a high-capacity travel option for trips between major origin-destination pairs in an urban area, allowing pedestrians to travel to many more places than otherwise feasible on foot. Improving pedestrian access to rail transit stations obviously benefits the pedestrian by providing a safer and more usable route. Improving pedestrian access also benefits rail transit by resulting in a more attractive service and improved consistency at crossings. In addition, pedestrians not accessing transit frequently need to cross public transit rail services. It is important that these pedestrians are provided with information and treatments to maximize their safety.

Current Resources

Previous TCRP research (*1*, *2*, *3*, *4*) has advanced the safety of light-rail transit (LRT) systems in particular contexts. The FRA completed two studies on pedestrian safety for commuter-rail services, one focusing on safety devices (*5*) and another on pedestrian crossing issues around station areas (*6*). The FHWA also has guidance on pedestrian safety for transit agencies (*7*). Another key FHWA document is the *Manual on Uniform Traffic Control Devices* (MUTCD) (*8*), which provides guidance on traffic control devices such as signs, signals, and markings.

To compile the guidance from these and other existing resources into one document and supplement that guidance with observations of existing pedestrian rail treatments, *TCRP Report 175: Guidebook on Pedestrian Crossings of Public Transit Rail Services* (*Guidebook*) was developed under TCRP Project A-38. The *Guidebook* discusses issues associated with pedestrian crossing of public transit rail services and provides examples of treatments in use. The information contained in this *Guidebook* can be used by transit agencies to develop a decision process for establishing a consistent means of implementing pedestrian safety treatments. Having a national guide can also mean that consistency will extend further than one system or one region and could encompass multistate regions and the nation, thus providing pedestrians using a variety of systems with a consistent approach.

Included within the *Guidebook* are summaries of rail transit service options, safety, and accessibility issues related to pedestrians and rail crossings, and methods of selecting appropriate treatments for a given crossing. A collection of existing treatments are described, and case studies provide additional insight into the process for identifying and implementing pedestrian crossing treatments.

Scope of This Guidebook

This *Guidebook* applies to pedestrian crossings for three distinct types of public transit rail services: light rail, commuter rail, and streetcar. Other types of public transit rail services, most notably heavy-rail transit systems, are not within the scope of this research because such systems are typically designed such that the transit right-of-way (ROW) does not have publicly accessible crossings, and pedestrians are not required to cross the rails in order to access the service. This *Guidebook* focuses on engineering treatments installed at the site rather than educational or enforcement programs.

Organization of the Guidebook

The *Guidebook* is organized into the following chapters:

- **Chapter 1: Introduction** provides an overview of the document and describes its scope.
- **Chapter 2: Rail Transit Services** presents an overview of rail transit services.
- **Chapter 3: Pedestrian Safety** provides an overview of key pedestrian safety issues associated with public transit rail services along with an introduction to pedestrian characteristics.
- **Chapter 4: NEPA-Related Issues** discusses pedestrian crossing issues associated with the National Environmental Policy Act of 1969 (NEPA) after presenting an overview of NEPA.
- **Chapter 5: Accessibility/ADA Considerations** presents an overview of the key documents regarding the Americans with Disabilities Act (ADA).
- **Chapter 6: Treatment Selection** summarizes readily available decision flowcharts used to make decisions regarding pedestrian treatments at rail crossings.
- **Chapter 7: Treatment Considerations** introduces the sections in Chapter 8, provides an overview of the treatments, and discusses the experimental process for new traffic control devices.
- **Chapter 8: Pedestrian Treatments** presents information for 34 pedestrian treatments used at rail crossings. The treatments are grouped into the following categories:
  - Channelization
  - Barriers
  - Design
  - Signs
  - Signals
  - Pavement markings
  - Infrastructure
  - Operations
- **Chapter 9: Case Studies** includes four case studies that examine specific decisions with respect to pedestrian-rail crossings. These case studies are
  - Case Study A: Review of Sound Wall
  - Case Study B: Location of Station Entrance
  - Case Study C: Consideration of Visually Impaired Pedestrians When Designing a Station Entrance to a Platform Located Between Tracks
  - Case Study D: Control of Pedestrian Path

CHAPTER 2

Rail Transit Services

This chapter provides an overview of the types of rail transit services to which this *Guidebook* applies: light rail, commuter rail, and streetcar. The overview includes a description of each type of rail transit service as well as identification of the different types of grade crossings, ROW alignments, and station contexts for each type of rail transit service. The chapter concludes with a discussion of how the unique characteristics of these three types of rail transit services impact the design and implementation of treatments at pedestrian crossings.

Description of Rail Transit Services

Definitions

The *Guidebook* focuses on pedestrian crossings for light-rail, commuter-rail, and streetcar public transit rail services. The *Guidebook* does not consider other types of public transit rail services—notably heavy-rail transit systems—because such systems are typically designed so that pedestrians are not required to cross the rails in order to access the service.

A summary definition of each type of public transit rail service within the scope of the *Guidebook* follows (*9, 10*):

- **Light rail.** Light rail is a type of rail service provided by single vehicles or short trains on either dedicated ROW or on roads and streets (i.e., mixed with vehicle and pedestrian traffic). Light-rail vehicles (LRVs) are typically driven electrically with power being drawn from an overhead electric line via a trolley or pantograph. Passengers typically board LRVs in stations or from trackside stops in streets using either high-platform loading or low-level boarding steps to access the vehicle. In some cases, the LRV is boarded from the curb side, as shown in Figure 1. For this kind of boarding, there may be a bridge plate to eliminate the need to cross the platform-vehicle gap. Other examples of light rail are shown in Figures 2 and 3.
- **Commuter rail.** Commuter-rail service is defined as rail service that is provided on regular railroads or former railroad ROW, with trains made up of either self-propelled cars or locomotive-hauled cars. Commuter-rail passengers board in stations, with greater spacing between stations than other public transit rail services. Commuter-rail service is characterized by higher speed, infrequent-stop service over longer distances from outlying areas into the commercial centers of metropolitan areas. Examples of commuter rail are shown in Figures 4 and 5.
- **Streetcar.** Streetcar service is a specific type of light-rail service with frequent stops, in which almost the entire route is operated on roads or streets in mixed traffic with automobiles. Streetcars are typically used in denser, high-traffic areas and are designed for lower speeds and to allow for quick boarding and alighting by passengers. Examples of streetcars are shown in Figures 6 and 7.

Source: Fitzpatrick

Figure 1. Example of light rail in Portland.

Source: Gilleran. Permission granted by the owner for a one-time use of this photograph in the *Guidebook*. No right to otherwise reproduce this photograph is granted, and no rights of ownership of these photographs are transferred to TCRP.

Figure 2. Example of median-running light rail in Boston.

Source: Fitzpatrick

Figure 3. Example of light rail in Dallas.

Source: Warner

Figure 4. Example of commuter rail in Boston.

Inventory of U.S. Rail Transit Systems

The types of public transit rail services within the scope of this *Guidebook* include LRT systems, commuter-rail transit systems, and streetcar transit systems. Table 1 lists light-rail, commuter-rail, and streetcar transit systems in U.S. operation. As of August 2013, there are 27 LRT systems, 24 commuter-rail transit systems, and 9 streetcar transit systems in operation.

Source: Warner

Figure 5. Example of commuter rail in Los Angeles.

Source: Fitzpatrick

Figure 6. Example of vintage streetcar in Dallas.

Characteristics of U.S. Rail Transit Systems

Table 2 displays selected characteristics of a majority of the light-rail, commuter-rail, and streetcar transit systems listed in Table 1. The system asset and operational data shown in Table 2 were obtained from analysis of the FTA National Transit Database (NTD) (*12*). The most recent full year of data available from NTD is 2012. As a result, data for some rail transit systems listed in Table 1 are not included in Table 2, either because they opened for service in 2012 or later, or because they were not subject to NTD reporting requirements for the 2012 annual data.

The data reported in Table 2 summarize the operating characteristics of 59 unique rail transit systems operating a total of 4,539 route-miles of service in 41 different urban areas of the United States. In 2012, more than 978.5 million unlinked passenger trips were made on these 59 systems, with trips covering more than 13.5 billion passenger-miles. The magnitude of these figures suggests that the rail transit systems included in this research are important parts of the multimodal transportation system in the communities in which they operate.

Source: Fitzpatrick

Figure 7. Example of modern streetcar in Portland.

Table 1. U.S. light-rail, commuter-rail, and streetcar transit systems.

LRT Systems	
Baltimore, MD (Baltimore Light Rail)	Philadelphia, PA (SEPTA Light Rail)
Boston, MA (MBTA Green Line)	Phoenix, AZ (Metro Light Rail)
Buffalo, NY (NFTA Buffalo Metro Rail)	Pittsburgh, PA (Pittsburgh Light Rail)
Charlotte, NC (LYNX Rapid Transit Services)	Portland, OR (MAX Light Rail)
Cleveland, OH (RTA Rapid Transit Light Rail)	Sacramento, CA (Sacramento RT Light Rail)
Dallas, TX (DART Light Rail)	St. Louis, MO (St. Louis MetroLink)
Denver, CO (RTD Light Rail)	Salt Lake City, UT (UTA TRAX)
Houston, TX (Houston MetroRail)	San Diego, CA (San Diego Trolley)
Jersey City, NJ (Hudson-Bergen Light Rail)	San Francisco, CA (San Francisco MUNI)
Los Angeles, CA (Los Angeles Metro Rail)	San Jose, CA (VTA Light Rail)
Minneapolis, MN (Hiawatha Line)	Seattle, WA (Central Link Light Rail)
Newark, NJ (Newark Light Rail)	Tacoma, WA (Tacoma Link Light Rail)
Norfolk, VA (The Tide Light Rail)	Trenton, NJ (River Line)
Oceanside, CA (NCTD Sprinter)	
Commuter-Rail Transit Systems	
Albuquerque, NM (New Mexico Rail Runner)	New Haven, CT (CDOT Shore Line East)
Austin, TX (Capital MetroRail)	New York, NY (MTA Long Island Rail Road)
Baltimore, MD (MARC Commuter Rail)	New York, NY (MTA Metro-North Railroad)
Boston, MA (MBTA Commuter Rail)	New York, NY (NJ Transit Commuter Rail)
Chicago, IL (METRA Commuter Rail)	Oceanside, CA (NCTD Coaster)
Chicago, IL (NICTD South Shore Line)	Philadelphia, PA (SEPTA Regional Rail)
Dallas, TX (Trinity Railway Express)	Portland, OR (Westside Express Service)
Denton County, TX (A-Train)	Salt Lake City, UT (FrontRunner)
Los Angeles, CA (Metrolink)	San Francisco, CA (CalTrain)
Miami, FL (Tri-Rail)	Seattle, WA (Sounder)
Minneapolis, MN (Northstar Commuter Rail)	Stockton, CA (Altamont Commuter Express)
Nashville, TN (Music City Star)	Washington, DC (Virginia Railway Express)
Streetcar Transit Systems	
Dallas, TX (M-Line Streetcar)[a]	Portland, OR (Portland Streetcar)
Kenosha, WI (Kenosha Streetcar)	Salt Lake City, UT (UTA S-Line Streetcar)[a,b]
Little Rock, AR (River Rail Streetcar)	San Francisco, CA (San Francisco MUNI)
Memphis, TN (MATA Trolley)	Seattle, WA (South Lake Union Streetcar)
New Orleans, LA (NORTA New Orleans Streetcars)	Tampa, FL (TECO Line Streetcar System)

[a]Denotes transit system for which data are not reported in Tables 2 and 3.
[b]System opened after source table published
Source: *2013 Public Transportation Fact Book*, Appendix A (*11*)

Table 2. Selected characteristics of light-rail, commuter-rail, and streetcar systems based on 2012 annual data.

Characteristics	Light Rail	Commuter Rail	Streetcar
Number of U.S. Systems*	27	24	8
Total Route-Miles	783	3,720	36
Average System Length (Miles)	29.0	155.0	4.5
Range of System Length (Miles)	1.8–77.6	14.6–500.9	1.0–12.6
Average Operating Speed (mph)	14.3	32.1	4.9
Range of Operating Speed (mph)	7.7–23.8	21.8–49.6	2.2–7.7
Unlinked Passenger Trips	488,898,260	468,907,586	20,748,788
Total Passenger-Miles	2,456,381,722	11,046,803,916	29,550,430
Average Passenger Trip Length (Miles)	5.02	23.56	1.42

* Number of systems for which 2012 NTD data are available. The Dallas streetcar system listed in Table 1 is not included in the 2012 NTD data.

Source: Data from FTA NTD (*12*)

The data presented in Table 2 also reflect the diversity exhibited by the three rail transit modes included in this research in terms of physical and operational aspects. Average system length, average operating speed, and average trip length vary widely across the three modes. Streetcar systems are shortest in terms of system distance, with slower operating speeds and relatively short average trip lengths. The average LRT system is 29.0 miles in length, with average speeds approximately 14.3 mph and an average trip length of 5.02 miles. Commuter-rail transit systems are the longest of the three types of rail transit services examined here and also have the highest average operating speed (32.1 mph) and longest average trip length (23.56 miles).

Table 3 reports additional details on the physical infrastructure of the three types of rail transit services included in this research. The data reported in Table 3 include the total track-miles and the number of crossings for each type of service as reported by transit agencies in the 2012 NTD data (*12*). For track mileage, the NTD data are reported according to the type of ROW (at grade, elevated, open cut, or subway) and further classified for at-grade (exclusive ROW, with cross traffic, or mixed and cross traffic) and elevated structures (on structure or on fill). Track mileage at grade is classified as exclusive ROW (or exclusive alignment), with cross traffic (or semi-exclusive alignment), or mixed and cross traffic (or non-exclusive alignment). For the purposes of NTD data, cross-traffic track mileage includes any track segment where the transit ROW is closed to other vehicles (motor vehicles or nonmotorized traffic), and other vehicles can cross the transit ROW at designated locations. Mixed traffic segments, on the other hand, are locations where the transit vehicle and other vehicles travel in the same lane, and pedestrians may cross the tracks at any point. The number of crossings are also reported as either with cross traffic or mixed and cross traffic.

The infrastructure data summarized in Table 3 demonstrate the potential for operating conflicts between transit vehicles and pedestrians and reinforce the importance of considering

Table 3. Infrastructure of light-rail, commuter-rail, and streetcar systems.

	Light Rail	Commuter Rail	Streetcar
Track Mileage			
Total Track-Miles	1,746.5	7,563.8	55.7
• At Grade—Exclusive ROW	337.6	2,876.7	0.1
• At Grade—with Cross Traffic	719.9	3,943.4	24.0
• At Grade—Mixed and Cross Traffic	325.2	103.0	30.8
• Elevated—on Structure	146.1	76.0	0.6
• Elevated—on Fill	76.5	460.1	0.2
• Open Cut	53.0	68.3	0.0
• Subway	88.2	36.3	0.0
Subtotal of At-Grade Track-Miles	1,382.7	6,923.1	54.9
• % At-Grade Track-Miles to Total Track-Miles	79.2%	91.5%	98.6%
• % At Grade—Mixed and Cross-Traffic Track-Miles to At-Grade Track-Miles	23.5%	1.5%	56.1%
• % At Grade—Mixed and Cross-Traffic to Total Track-Miles	18.6%	1.4%	55.3%
Number of Crossings			
Total Number of Crossings	2,906	3,296	469
• With Cross Traffic	1,614	3,221	287
• Mixed and Cross Traffic	1,292	75	182
% of Mixed and Cross-Traffic to Total Number of Crossings	44.5%	2.3%	38.8%

Source: Data from FTA NTD (*12*)

pedestrians in the planning, design, and operation of rail transit systems. A majority of the track-miles for all three types of rail transit service included in this research are at grade level. Track-miles at grade account for 1,382.7 light-rail track-miles (79.2 percent), 6,923.1 commuter-rail track-miles (91.5 percent), and 54.9 streetcar track-miles (98.6 percent). Furthermore, the share of light-rail, commuter-rail, and streetcar at-grade track mileage characterized as mixed and cross traffic is 23.5 percent, 1.5 percent, and 56.1 percent, respectively. A similar pattern is noted among crossings for light rail, commuter rail, and streetcar, with mixed and cross-traffic crossings accounting for 44.5 percent, 2.3 percent, and 38.8 percent.

Rail Transit Crossings

Pedestrian-Rail Crossing Types

The highway-railroad crossing design guide published by the Southern California Regional Rail Authority (SCRRA) notes that pedestrian-railroad grade crossings can be characterized as one of four types (*13*):

- Pedestrian-rail grade crossings adjacent to a motor vehicle crossing.
- Pedestrian-rail grade crossings at stations adjacent to a motor vehicle crossing.
- Pedestrian-rail grade crossings at stations.
- Pedestrian-rail grade crossings not adjacent to motor vehicle crossing or in a station.

Pedestrian-Rail Crossings Adjacent to a Motor Vehicle Crossing

Pedestrian-rail grade crossings adjacent to a motor vehicle travel lane involve a crossing that is parallel to a roadway crossing the tracks. These crossings include cases where the road and adjacent pedestrian route cross the train tracks. Figure 8 shows an example from Dallas, while Figure 4 shows an example in Boston. Another case of pedestrian-rail grade crossings adjacent to a motor vehicle crossing is where the street and pedestrian crosswalk cross both the train tracks and vehicle lanes, such as where light-rail or streetcar transit services operate in mixed traffic along a roadway.

Source: Fitzpatrick

Figure 8. Example of pedestrian-rail crossing adjacent to a motor vehicle crossing in Dallas.

Source: Fitzpatrick

Figure 9. Example of pedestrian-rail crossing at a station adjacent to a motor vehicle crossing for median-running light rail in Boston.

Pedestrian-Rail Grade Crossings at Stations Adjacent to a Motor Vehicle Crossing

The second type of pedestrian-rail grade crossing is a pedestrian-rail grade crossing at a station adjacent to a motor vehicle crossing. Pedestrian-rail grade crossings at stations adjacent to a motor vehicle crossing are a special case of pedestrian-rail grade crossings. These crossings, along with pedestrian-rail grade crossings at stations (but not near a motor vehicle crossing), are used to provide access to rail transit station platforms for pedestrians from parking lots, intermodal transfers, or land uses adjacent to the rail transit line. Figure 9 shows an example from Boston.

Pedestrian-Rail Grade Crossings at Stations

The third type of pedestrian-rail grade crossing is a pedestrian-rail grade crossing at a station. Figures 10 and 11 show examples of in-station pedestrian crossing. Stations may also be located in the median of a street, requiring the passenger to cross one or more tracks as well as one or more highway lanes to access adjacent land uses. A more detailed discussion of issues related to the level and nature of pedestrian activity in station areas is provided below.

Source: Fitzpatrick

Figure 10. Example of pedestrian-rail crossing within a station in Portland.

Source: Gilleran. Permission granted by the owner for a one-time use of this photograph in the *Guidebook*. No right to otherwise reproduce this photograph is granted, and no rights of ownership of these photographs are transferred to TCRP.

Figure 11. Example of pedestrian-rail crossing within a station in Boston.

Pedestrian-Rail Grade Crossings Not Adjacent to Motor Vehicle Crossing or in a Station

The fourth type of pedestrian-rail grade crossing is when the crossing is not adjacent to a motor vehicle crossing or in a station. Such crossings are typically used on multi-use (i.e., walk or bicycle) paths adjacent to rail transit lines or to maintain established pedestrian traffic paths that are interrupted by the construction of a new rail transit line. The latter case may be the result of a cross-street closure; vehicle crossings of the rail line are eliminated, but pedestrian access is maintained. Figure 12 shows an example of a pedestrian-rail grade crossing in Baltimore.

Source: Fitzpatrick

Figure 12. Example of pedestrian-rail grade crossing in Baltimore not adjacent to motor vehicle crossing or in a station.

Station-Area Pedestrian Activity

Rail transit passengers connect to rail transit services via stations located along the lines. In order for rail transit services to effectively function as a viable transportation option, rail transit stations are typically located near areas where travelers live or work or near other major activity centers within the urban region. The success of a rail transit system in attracting ridership is highly dependent upon the ability of passengers to safely and conveniently access stations. Therefore, the design and implementation of treatments for pedestrian-rail grade crossings in the vicinity of station areas are of great importance to the success of rail transit.

TCRP Report 153: Guidelines for Providing Access to Public Transportation Stations identifies several factors influencing the amount of pedestrian activity in rail transit station areas (*14*). Major factors include the following:

- Station context (central business district, urban neighborhood, suburban park-and-ride, or special district).
- Adjacent development density.
- Supporting transit network at the station.
- Amount of on-site and off-site parking at the station.
- Adjacent pedestrian/bicycle networks.
- Types of trips served (rail trip access, egress, or both).

As part of the research for *TCRP Report 153*, access mode data for over 450 rail transit stations at eight transit systems were collected and summarized. Table 4 shows the average station pedestrian access mode share for different station types as identified by *TCRP Report 153*.

It is evident from the data presented in Table 4 how station context can influence the pedestrian access mode share at a rail transit station. The highest pedestrian mode shares are found in higher density commercial centers and neighborhoods. Special event or campus stations also tend to have a higher amount of pedestrian access. Suburban areas have lower levels of pedestrian activity depending upon specific contexts with the suburban area.

Even though some station contexts do not experience a high level of pedestrian access mode share, there are still pedestrian issues associated with station access via non-walking modes. Indeed, any station that is designed so that pedestrians are required to cross one or more tracks

Table 4. Average station pedestrian access mode share by station type.

Station Type	Average Pedestrian Access Mode Share (%)
Urban Commercial	82
High-Density Urban Neighborhood	72
Medium-Density Urban Neighborhood	80
Urban Neighborhood with Parking	35
Historic Transit Village	25
Suburban Transit-Oriented Development	32
Suburban Village Center	30
Suburban Neighborhood	29
Suburban Freeway	10
Suburban Employment Center	29
Suburban Retail Center	30
Intermodal Transit Center	27
Special Event/Campus	55
Satellite City	7

Source: *TCRP Report 153* (*14*)

to access the rail transit service will likely encounter pedestrian crossing issues. In the case of special-event-oriented stations or stations in major tourist areas, rail transit passengers may be unfamiliar with the setting and layout of the rail line. In the two example cases given in the bulleted list below, passengers may be in a hurry to catch the next train or connecting bus and, therefore, may ignore the warning devices and other treatments at pedestrian crossings:

- Park-and-ride–oriented stations with parking facilities on one or both sides of the tracks, requiring passengers to cross the tracks to access the rail service.
- Stations where rail-bus intermodal transfers take place, which also require pedestrians to cross the tracks.

These considerations are relevant in the planning and design of rail transit station areas that are expected to include pedestrian crossings.

A recent trend in land development is the construction of new housing or other types of development adjacent to rail transit stations. Such development, known as transit-oriented development (TOD), seeks to capitalize on the level of activity associated with transit stations. Among the characteristics of TOD are higher development densities, compact building design, mixed land uses, and high-quality walking environments (*15*). As of 2002, more than 100 TOD projects had been identified in the United States. Among these, 31 percent were developed near a light-rail line, while 22 percent were developed near commuter rail (*15*). The number of TODs near light rail and commuter rail has undoubtedly increased in the past decade; however, no reliable inventories of TOD construction have been undertaken since the publication of *TCRP Report 102.* TOD is a stated development goal for many transit agencies constructing rail transit projects (*16, 17, 18, 19, 20*). TOD also represents joint development opportunities for transit agencies to partner with private-sector developments to support financing for capital projects (*21, 22, 23*). The growth and popularity of TOD around rail transit stations generate additional pedestrian activity (transit passengers and non-passengers) and create additional challenges for the design and operation of pedestrian-rail crossings.

Pedestrian Walking Distances

Another important issue with respect to the characteristics of pedestrians is the distance that pedestrians are willing to travel to reach a rail transit station. This distance is relevant because it helps those who are planning and designing rail transit stations to understand the possible demand for pedestrian travel to/from a station by locating major pedestrian generators (e.g., employment centers, educational campuses, and sports/entertainment facilities) within a particular radius of a station. In turn, this information allows for a judgment on the expected level of pedestrian activity at a rail transit station.

Research on the topic of catchment areas around rail transit stations has yielded a range of distances that passengers are willing to travel to access rail transit stations. The general consensus of these studies is that passengers are willing to walk up to one-half mile to access a rail transit station (*7, 15, 24, 25, 26, 27*). The FHWA advises that transit agencies provide “safe and convenient pedestrian facilities within one-quarter to one-half mile of transit stops and stations” in order to encourage transit usage (*7*). The concept of the “half-mile circle” has emerged as a commonly accepted metric for measuring catchment area (*26*) although other factors, such as station context, the nature of the generators, and the quality of connectivity, can influence this distance. Areas within one-quarter mile of transit are considered to be well served, while areas within one-half mile of transit are considered to be served by transit (*27*). Assuming an average walking speed of 3 mph, the one-half-mile circle concept approximates the 10-minute walk rule noted by SCRRA in its crossing guidance document in terms of determining the potential for pedestrian activity at a commuter-rail grade crossing (*13*).

Rail Transit Alignments

Another important factor in the design and implementation of pedestrian crossings of public transit rail services is the type of alignment over which the rail service operates. Understanding the type of alignment (i.e., the characteristics of the rail transit ROW and its surroundings) is important because some types of alignments provide greater opportunities for operating conflicts between the rail transit service and pedestrians. Previous research from TCRP (*1*) identified a classification structure for rail transit alignments. *TCRP Report 69* (*2*) expanded on the three basic classes by adding more detailed categories of alignment types within each class. Table 5 shows the alignment classification structure for rail transit services as set forth in *TCRP Report 69.* The three basic classes of rail transit alignments can be described as follows:

- **Exclusive alignments.** These use full grade separation of both motor vehicle and pedestrian crossing facilities. Exclusive alignments eliminate grade crossings and operating conflicts and maximize safety and operating speeds.
- **Semi-exclusive alignments.** These separate the rail transit alignment from road vehicles and pedestrians, except at locations where road vehicles and pedestrians intersect at an at-grade crossing.
- **Non-exclusive alignments.** These allow for mixed-flow operation with motor vehicles or pedestrians, resulting in higher levels of operating conflicts and lower speed operations.

The alignment classification structure defined in *TCRP Report 17* (*1*) and *TCRP Report 69* (*2*) was developed considering the operational characteristics and needs of LRT services, which include both conventional light rail as well as streetcar transit services. Such services typically operate over alignments of Type b (semi-exclusive) or Type c (non-exclusive) as identified in Table 5.

The research for the *Guidebook* also includes commuter-rail transit services within its scope. While the original purpose of the classification structure described in Table 5 was to characterize alignments for LRT and streetcar transit services, the classification structure can also be applied to commuter-rail transit services. Most commuter-rail transit alignments can be characterized as Type b.1 (semi-exclusive and separate ROW), where the commuter-rail line operates over the existing railroad system. However, there are some instances of commuter-rail transit systems in the United States that include alignments that operate in very close proximity to the alignment of other modes, resembling alignments of Types b.2 and b.3. There are also examples of commuter rails that operate in non-exclusive ROWs.

Table 5. Rail transit alignment classification structure.

Class	Category	Description of Access Control
Exclusive	Type a	Fully grade separated or at grade without crossings
Semi-exclusive	Type b.1	Separate ROW
Semi-exclusive	Type b.2	Shared ROW, protected by barrier curbs and fences (or other substantial barriers)
Semi-exclusive	Type b.3	Shared ROW, protected by barrier curbs
Semi-exclusive	Type b.4	Shared ROW, protected by mountable curbs, striping, and/or lane designation
Semi-exclusive	Type b.5	LRT/pedestrian mall adjacent to parallel roadway
Non-exclusive	Type c.1	Mixed traffic operation
Non-exclusive	Type c.2	Transit-only mall
Non-exclusive	Type c.3	LRT/pedestrian mall

Source: *TCRP Report 69* (*2*)

Discussion

Every rail system operates in its own context, usually containing a variety of alignments throughout the system and sometimes even within a particular corridor. Pedestrian interaction with the rail system varies by the type of alignment, creating an assortment of safety issues. Segments with lower operating speeds often occur at locations with more interaction with pedestrians but with the potential severity dampened by the slower speeds. Segments with higher operating speeds often occur at locations with less interaction with pedestrians, but severity can be higher because of faster train operations. Protective treatments will vary between these two kinds of segments and by the type of alignment in which the train is operating.

CHAPTER 3

Pedestrian Safety

This chapter provides an overview of key pedestrian safety issues associated with public transit rail services.

Pedestrian Characteristics

In order to effectively plan and design pedestrian crossings for public rail transit services, an understanding of the characteristics of pedestrians can be beneficial. This section discusses the general characteristics of pedestrians, considerations for special pedestrian groups, and impacts of mobile device use on pedestrian risk.

General Characteristics

Pedestrians possess certain unique characteristics and behaviors that must be considered in the planning, design, and operation of pedestrian crossings for public rail transit services. Some of these characteristics include the following:

- **Pedestrians are slow.** Typical design speeds for pedestrians range from 3.0 to 5.0 ft/second (approximately 2.0 to 3.4 mph) (*28*). At such speeds, it is difficult for pedestrians to travel long distances in a short time period and move relatively quickly in response to emergency or urgent situations.
- **Pedestrians are flexible.** For what they lack in speed, pedestrians compensate by being the most flexible (i.e., maneuverable) of all transport modes. Pedestrians typically seek the shortest route between an origin and a destination and are not physically limited to designated rails, travel lanes, or pathways (*7*). Only larger objects such as buildings or natural features (i.e., water bodies or topography) or physical barriers prevent pedestrians from taking direct routes. The high maneuverability of pedestrians also means that they are able to jump out of the way or otherwise narrowly avoid crashes with transit vehicles or motor vehicles.
- **Pedestrians are fragile.** Unlike transit passengers inside transit vehicles or in motor vehicles, pedestrians have very little or no protection against injury from a crash with a transit vehicle, motor vehicle, bicycle, or even another pedestrian. The extent to which pedestrians are injured in such crashes is dependent on the speed and forces involved with the crash, as well as the strength and fragility of the pedestrian(s) involved (*3*).
- **Pedestrians are sensitive to their surroundings.** Pedestrians are exposed to a variety of natural and artificial sources of discomfort, such as weather (i.e., temperature, sunlight, and precipitation), noises, smells, and visual distractions. Pedestrians also have greater exposure to safety and security issues. Exposure to these elements among passengers in transit vehicles or motor vehicles is not as great. Because of the exposure to environmental conditions (e.g., rain, fog, and snow), pedestrians may be more willing to accept personal risk to shorten the travel distance (*3*).

- **Pedestrians may be inattentive.** Pedestrian inattentiveness to the surrounding environment has increased with the rapid emergence of mobile device use. In the United States, mobile device use has increased steadily over the past two decades, with a doubling in the number of wireless subscriber connections between 2002 and 2012 (*29*). The use of mobile devices among pedestrians introduces the possibility of multitasking by the pedestrian, specifically walking and using the mobile device. Doing one or more activities simultaneously causes attention to and performance of one or both tasks to decrease. There exists a small but growing body of literature (*30*, *31 32*, *33*, *34*, *35*, *36*) suggesting that the risk of distraction (i.e., compromising attention to and/or performance of the walking task) among pedestrians is higher when using a mobile device. For example, one study found that pedestrians using a mobile device tended to pay less attention to traffic before and during crossing and that mobile device use also resulted in slower crossing speeds (*30*). Pedestrians who were text-messaging displayed the highest risk of all distracted walkers, with slower crossing times and failure to display cautionary crossing behaviors (*34*).
- **Pedestrians prefer direct paths.** Due to their flexibility, pedestrians can take the most direct path to reach their destination. They will follow other pedestrians who have discovered a quicker route between two points.
- **Pedestrians may ignore warning signs.** In considering common safety problems experienced by transit operators, one cited concern is pedestrians ignoring warning signs (*2*). This could be due to inattentiveness, lack of situational awareness, or direct disobedience, maybe in order to reduce delay or catch a train.

Special Pedestrian Groups

In addition to the general pedestrian characteristics discussed above, there are special pedestrian groups that possess unique characteristics that should be considered in the planning, design, and operation of pedestrian crossings for public rail transit services. The special pedestrian groups include child pedestrians, older pedestrians, recent immigrants, and people with disabilities. The FHWA publication *Pedestrian Safety Guide for Transit Agencies* outlines the characteristics and behaviors of these pedestrian groups (*7*). Table 6 describes these characteristics and behaviors.

The pedestrian groups listed in Table 6 may also be among the greatest beneficiaries of improved rail transit services because they may be limited in their ability to use or access other travel options (such as a personal vehicle). Consequently, the characteristics and behaviors outlined in Table 6 should be carefully considered in the planning and design process, particularly if higher volumes of pedestrians from any of the four groups are expected to use a particular pedestrian crossing—for example, crossings located near schools, senior centers, or medical facilities.

Pedestrian Crash Characteristics

Previous Research

A series of previous TCRP reports addressed the safety concerns between light-rail operations and roadway users, including vehicles, pedestrians, and bicyclists. *TCRP Report 137* (*4*) summarizes the findings of *TCRP Report 17* (*1*) and *TCRP Report 69* (*2*), including major lists of common safety problems. Focusing on pedestrian-focused issues, the combined major pedestrian safety issues include the following:

- Trespassing on the tracks.
- Jaywalking.
- Station and/or cross-street access.

Table 6. Characteristics and behaviors of special pedestrian groups.

Pedestrian Group	Characteristics and Behaviors
Child Pedestrians	• May have difficulty choosing where and deciding when it is safe to cross the street. • May have difficulty seeing (and being seen by) drivers of all types of vehicles, including buses, because of less peripheral vision and shorter stature than adults. • May have difficulty judging the speed of approaching vehicles. • May need more time to cross a street than adults. • May be less likely to look both ways before crossing. • May be less likely to understand signs, including second train warnings. • May be drawn toward rail out of curiosity.
Older Pedestrians	• May have reduced motor skills that limit their ability to walk at certain speeds, turn their heads, or compensate for uneven crossing surfaces as compared to younger adults. • May need more time to cross a street or the rail than younger adults. • May have difficulty with orientation and understanding traffic signs, so they may need more information about how to access transit. • May need information provided in a larger font. • May have difficulty judging the speed of approaching vehicles. • May have trouble hearing rail vehicles, especially in quiet zones.
Recent Immigrants	• May have limited understanding of English, traffic laws, and typical roadway behaviors. • May not understand traffic signals that indicate when to walk. • May not have the experience to know how to interact safely with drivers.
People with Disabilities (e.g., people with impaired vision, hearing, cognition, or walking, including those using wheelchairs, scooters, walkers, crutches, or canes)	• May be more affected by surface irregularities in the pavement and changes in slope or grade. • May need more time to cross a street than people without disabilities. • May benefit from pedestrian signal information provided in multiple formats (i.e., audible, tactile, and visual). • May have trouble seeing (and being seen) by drivers of all types of vehicles due to seated position (people using wheelchairs). • Pedestrians who are blind or who have low vision may have trouble detecting yielding vehicles or communicating visually with drivers in crossing at unsignalized crosswalks. • Pedestrians who are blind or who have low vision may be unable to see or understand visual signs and signals. • Pedestrians who have impaired hearing may not hear oncoming trains or other vehicles, and may not hear audible warning devices. • May have wheels or the tips of mobility aids trapped by the flangeway gap. • Pedestrians with cognitive disabilities may have difficulty simultaneously using multiple sources of information for good decision-making.

Note: Efforts from this research project expanded on and/or modified material from an FHWA report, *Pedestrian Safety Guide for Transit Agencies* (*7*) to create the lists in this table.

- Limited sight distance at pedestrian crossings.
- Pedestrians darting across LRT tracks without looking.

Additionally, as part of the project, the *TCRP Report 137* project team consulted five transit agencies that noted these major pedestrian safety issues, among a longer overall list (*4*):

- Pedestrians jaywalking between marked crossing locations (e.g., midblock or at stations).
- Pedestrians trespassing at stadium stations after events.
- Pedestrians crossing against signals and/or against warning devices.
- Pedestrian crashes due to a "second train."
- Pedestrian inattention and/or distraction.
- Increased severity of pedestrian crashes.

Using all the safety issues, *TCRP Report 137* developed the following five areas of safety concern that must be addressed along LRT alignments (*4*):

- Inattention by motorists, cyclists, and pedestrians.
- Confusion of motorists, cyclists, and pedestrians.

- Lack of appropriate physical separation between motorists, cyclists, pedestrians, and the LRV.
- Risky behavior by motorists and pedestrians.
- Operator error or lack of information.

As stated above, a major concern is the severity of a crash between a train and a pedestrian. *TCRP Report 17* includes a statistical analysis that found pedestrian crashes account for approximately 10 percent of the crashes but approximately 50 percent of the fatalities (*1*). An additional statistical analysis, performed by the *TCRP Report 137* team, calculated that although crashes between pedestrians and LRVs in the systems they reviewed represented 22 percent of the total crashes, these crashes represented 80 percent of all fatalities (*4*).

These combined safety issues and concern for the severity of pedestrian crashes highlight the characteristics of pedestrians. Ogden (*37*) notes that pedestrians tend to look down, not up; may lack awareness or be distracted; create their own pathways; tend to take the shortest route; may be children; or may be persons with disabilities. The FRA report *Compilation of Pedestrian Safety Devices in Use at Grade Crossings* (*5*) cautions that pedestrians do not always think of themselves as part of the overall traffic stream, and therefore they think they are not subject to traffic control devices. Metaxatos and Sriraj (*38*) found through literature review and field observations that larger platoons of pedestrians are more likely to commit a violation, pedestrians near passenger rail facilities may interpret auditory warnings as an indication that the train is approaching and that they should hurry to get in boarding position, and pedestrian warning devices are commonly ignored and easy to circumvent. A December 2013 FRA report (*39*) highlights the latter point by finding that with the addition of gate skirts to already existing pedestrian gate arms, more pedestrians bypassed the pedestrian automatic gate assembly by using the adjacent roadway. The FTA *2009 Rail Safety Statistics Report* (*40*) found that pedestrian actions caused 61 percent of light-rail crash fatalities.

Safety Database Analysis

There are two primary sources of data related to crashes between rail transit vehicles and pedestrians. Light-rail and streetcar safety data are available through the FTA NTD (*12*), and commuter-rail safety data are available through FRA (*41*, *42*). This section highlights the major online crash databases available from both entities and presents summary analyses of these databases.

Light Rail and Streetcar

The FTA NTD reports pedestrian safety data for light-rail and streetcar systems. Pedestrian-specific data were not collected prior to 2008; however, beginning in 2008, fatality and injury numbers are presented for the following pedestrian categories (*12*):

- **Pedestrian in Crossing.** The number of pedestrians in crosswalks killed/injured.
- **Pedestrian Not in Crossing.** The number of pedestrians not in crosswalks killed/injured.
- **Pedestrian Crossing Tracks.** The number of pedestrians crossing tracks killed/injured.
- **Pedestrian Walking Along Tracks.** The number of pedestrians walking along tracks killed/injured.

Non-pedestrian categories include passengers, revenue facility occupants, employees, bicyclists, other vehicle occupants, trespassers, and suicides.

At the time of this research, pedestrian safety data in the FTA NTD was current through December 2012. Therefore, Table 7 presents the pedestrian-specific safety data included in the NTD for 2008 to 2012. Beginning in 2012, the data provide segregation of the light-rail

Table 7. Pedestrian fatalities and injuries reported by agencies operating light-rail and streetcar transit systems, 2008–2012.

Year	2008	2009	2010	2011	2012		Total
Mode	Light Rail (LR) and Streetcar (SR) Combined				LR	SR	
Fatalities							
• Pedestrian in Crossing	3	5	2	6	3	0	19
• Pedestrian Not in Crossing	2	4	1	1	1	0	9
• Pedestrian Crossing Tracks	1	4	4	4	7	0	20
• Pedestrian Walking Along Tracks	1	5	2	2	6	0	16
Total Pedestrian Fatalities	7	18	9	13	17	0	64
Total Non-Pedestrian Fatalities	10	16	15	23	28	0	92
Total All Fatalities	**17**	**34**	**24**	**36**	**45**	**0**	**156**
Injuries							
• Pedestrian in Crossing	15	9	12	12	10	0	58
• Pedestrian Not in Crossing	3	6	6	8	5	0	28
• Pedestrian Crossing Tracks	12	9	10	15	15	2	63
• Pedestrian Walking Along Tracks	6	8	7	4	6	0	31
Total Pedestrian Injuries	36	32	35	39	36	2	180
Total Non-Pedestrian Injuries	980	1,046	890	929	808	48	4,701
Total All Injuries	**1,016**	**1,078**	**925**	**968**	**844**	**50**	**4,881**

Source: FTA NTD (*12*)

designations into light rail and streetcar. Table 7 contains the total combined light-rail and streetcar fatalities and injuries for 2008 to 2011 and the separate light-rail and streetcar fatalities and injuries for 2012. The table only contains the pedestrian categories and excludes other categories, such as bicyclists, trespassers, or suicides.

Approximately 41 percent (64 out of 156) of the total fatalities involving light-rail or streetcar rail transit vehicles between 2008 and 2012 were pedestrians, according to Table 7. However, pedestrian injuries for that time period only accounted for about 4 percent (179 out of 4,880) of all injuries.

Commuter Rail

The FRA 2012 Operational Data Tables database (*43*) contains 810 different railroad reporting marks, with 185 railroad reporting marks containing passenger movements. These include the 24 U.S. commuter-rail systems, Amtrak, Alaska Railroad, and some light-rail systems. The remaining entities, not included in this analysis, are tourism trains or railroads that move some sort of passenger excursion train during the year. The FRA uses a classification system for affected persons, with two of the classifications related to pedestrian activity on railroad property. These two classifications are defined below, along with a listing of the remaining categories grouped as "Other Categories" for this analysis:

- **Non-trespassers on railroad property.** Persons lawfully on that part of railroad property that is used in railroad operation (other than those defined as workers, passengers, or trespassers) and persons adjacent to railroad premises when they are injured as the result of the operation of a railroad. This class also includes other persons on vessels or buses, whose use arises from the operation of a railroad.
- **Trespassers.** Persons who are on the part of railroad property used in railroad operation and whose presence is prohibited, forbidden, or unlawful. A person on a highway-rail grade crossing should not be classified as a trespasser unless one of the following occurs:
  - The crossing is protected by gates or other similar barriers, which were closed when the person went on the crossing.

– The person attempted to pass over, under, or between cars or locomotives occupying the crossing.

- **Other Categories.** The classifications combined in this category include Worker on Duty–Employee; Employee Not on Duty; Worker on Duty–Contractor; Contractor–Other; Passengers on Trains; and Non-Trespassers–Off Railroad Property.

A person or vehicle that enters the crossing without a physical barrier (e.g., gates in a lowered position) is not classified as a trespasser, even when the highway-rail grade crossing lights are activated or other warning systems are functioning. The person is classified as a non-trespasser.

Table 8 contains commuter-rail fatality- and injury-related data analyses for the latest 5-year period. The table shows a total of 414 fatalities and 10,233 injuries occurring between 2008 and 2012. Trespassers represented 86 percent of the fatalities but only 3 percent of the total injuries when compared to the other types of people involved.

Identifying Pedestrian Safety Issues

Several methods are used to identify and evaluate pedestrian safety issues at public transit rail services, including the following:

- Risk-based analysis
- Safety audit
- Diagnostic safety teams

Risk-Based Analysis

Risk-based analysis methods evaluate the risk of crashes between pedestrians and rail transit vehicles. The concept of safety assessments is familiar for roadways, with publications such as the *FHWA Road Safety Audit Guidelines* (*44*) and the AASHTO *Highway Safety Manual* (*45*) providing tools to evaluate roadway safety. The FRA publication *Guidance on Pedestrian Crossing Safety at or near Passenger Stations* (*6*) recommends that passenger rail operators use risk-based, proactive, hazard analysis methods to evaluate the risk associated with the movement of pedestrians at or near passenger stations.

Table 8. Commuter-rail fatalities and injuries by type of person, 2008–2012.

Type of Person	2008	2009	2010	2011	2012	Total	Percent of Total
Fatalities							
Non-Trespasser on Railroad Property	4	0	3	5	7	19	5%
Trespasser	75	63	70	64	84	356	86%
Other Categories	29	3	2	3	2	39	9%
Total	**108**	**66**	**75**	**72**	**93**	**414**	**100%**
Injuries							
Non-Trespasser on Railroad Property	466	476	515	506	404	2,367	23%
Trespasser	48	51	67	50	67	283	3%
Other Categories	1,583	1,514	1,531	1,546	1,409	7,583	74%
Total	**2,097**	**2,041**	**2,113**	**2,102**	**1,880**	**10,233**	**100%**

Source: FRA, Office of Safety Analysis (*42*)

Safety Audit

TCRP Report 137 presents a light-rail risk analysis methodology and defines a safety audit as using "a multi-disciplinary approach to identify potential crash risks through a detailed examination of all relevant design and environmental factors" (*4*). This risk analysis methodology is based on many of the existing roadway safety audit standards and includes the following steps (*4*):

1. Select the safety audit team.
2. Provide background information to the safety audit team.
3. Conduct a pre-audit meeting to review project information.
4. Assess/analyze background information.
5. Perform site inspections under various conditions.
6. Prepare and submit a safety audit report.
7. Conduct a safety audit completion meeting.
8. Prepare a formal response.
9. Incorporate safety audit findings into the project (where appropriate).

The *TCRP Report 137* research team discusses using safety audits for the different stages (*4*):

- **Preliminary design stage.** Safety audits during this stage should be conducted once critical decisions regarding route choice and project design/layout have been determined. The audit should use preliminary design drawings and site visits.
- **Detailed design stage.** Safety audits during this stage should be conducted when detailed design drawings and sufficiently detailed base maps are available and should include field investigations in order to gain enhanced understanding of the project layout. By this stage, significant changes to the design require greater expenditure to implement.
- **In-use stage.** After operations begin, the safety audit seeks to identify where crashes will occur and their potential severity. For an established system, it is important to examine the potential changes to the conditions since construction, including increased operational levels, adjoining land use, and magnitude of pedestrian volumes. *TCRP Report 137* emphasizes that elements of the facility that were reasonable and effective in design may no longer serve their purpose if significant changes have occurred in the surrounding area.

The *TCRP Report 137* research team states that in general the earlier in the project the safety audit is conducted, the greater the potential to improve safety while minimizing costs. Therefore, safety audits performed during the design stage have the greatest opportunity to improve safety with minimal costs (*4*).

The framework contained in *TCRP Report 137* in which to perform a risk-based analysis for safety measures along light-rail alignments is a checklist. In developing the checklist, the team determined that a rigid framework was not the best tool since it would not be adaptable to the wide range of situations found in practice. Therefore, the checklist is not intended to cover an exhaustive list of all possible issues to be addressed but is intended to serve as a guide to help identify safety issues. The LRT alignment risk assessment checklist is provided in Table 9.

Diagnostic Safety Teams

APTA also provides risk-based analysis guidance with APTA standard RT-RGC-RP-003-03, *Recommended Practice for Rail Transit System Highway Rail Grade Crossing Safety Assessment*, which applies to new start and existing rail transit, light rail, and rapid rail lines on an exclusive ROW. The safety assessment process (*46*) involves

1. Diagnostic review team
2. Site visit and data collection
3. Evaluation/engineering analysis

Table 9. LRT alignment risk assessment checklist.

LRT Alignment Risk Assessment Checklist This checklist is intended to provide a framework for a comprehensive risk assessment of a location along an LRT alignment. The risk assessment report would be prepared as a separate document or as an attachment to this form, using the form as a table of contents.	
	Completed
Reason for assessment: Note the reason for assessment. Possible reasons include crash(es), crash precursors (near misses or violations), operator or public complaints, and routine assessment of sites on a rotational basis.	□
Area type: Describe the surrounding area (industrial, school, urban core, suburban, proximity to parks and senior homes/centers, etc.)	□
Crash history: List past crashes (LRT, vehicle, pedestrian, or bicycle) and possible causes. If available, list crash precursors.	□
Exposure: If available, record the a.m. peak, p.m. peak, and daily volumes for the location for all traffic types involved:	□
Pedestrian volume	□
Road volume	□
LRV frequency	□
Roadway design elements: Describe the roadway (if applicable). Include sketches or photos as necessary.	□
Speed and classification	□
Cross-section type (lanes, channelization, islands, barriers, etc.)	□
Sight distance	□
Warning devices	□
Traffic control and barrier devices	□
Pedestrian environment design: Describe the pedestrian environment (if applicable). Include sketches or photos as necessary.	□
Surface type, grade cross slope, accessibility	□
Horizontal and vertical clearance	□
Obstacles to movement (e.g., crossing padding)	□
Positive guidance and handrails	□
Warning devices	□
Barrier devices	□
Conflict definition: Define the nature of the conflict (e.g., grade crossing or parallel alignment at grade), with a sketch as necessary to show possible impact types.	□
Lighting: Investigate the impacts of lighting at different times of day. Describe from the pedestrian, vehicle, and LRV operator perspectives.	□
Driver sight lines: Determine if conflict points and the approaches to conflict points are visible to the LRV operator and other users for the expected speed(s).	□
Obstructions (trees, poles, etc.)	□
Horizontal and vertical alignment	□
Potential problems with glare, haze, fog, foliage, snow storage, etc., for different times of day and seasons of the year	□
Clearance time: If applicable, determine whether the clearance time provided by vehicle, pedestrian, and train signals is sufficient to safely clear the intersection.	□
Design consistency: Are any aspects of the site features sufficiently unusual to be surprising or contrary to the reasonable expectations of the users? (describe)	□
Operator/public complaints: Comment on any complaints that may have been received in the context of the site review—are they reasonable and/or explainable?	□
Propose possible solutions/mitigations to address reason(s) for assessment.	□

Source: *TCRP Report 137* (*4*)

4. Development of recommendations
5. Implementation of recommendations
6. Grade crossing inventory
7. Follow-up
8. Periodic review

APTA states that the diagnostic review team should be interdisciplinary in nature and represent all groups that share responsibility for safety at grade crossings such as rail and highway systems, law enforcement agencies, and local municipalities. The document includes a lengthy list of factors that should be considered during the evaluation of each crossing including the following (*46*):

- Maximum speed of rail vehicles.
- Number of tracks, mainline or other.

- Number and types of rail vehicles daily during peak periods.
- Multiple trains approaching a crossing simultaneously.
- Types of existing warning and traffic control devices if any.
- Sight distances, motor vehicle to rail.
- Number of traffic lanes.
- Condition of highway-rail grade crossing surface.
- Speed of motor vehicles over tracks.
- Queuing potential across tracks.
- Accident information/history.
- Multiple adjacent or parallel grade crossings in close proximity.
- Nearby vehicle and pedestrian traffic generators.
- Geometry of the highway-rail grade crossing, both horizontal and vertical.
- Impact on adjacent highway/street operations.
- Rail operating characteristics (e.g., braking distances).
- Rail operating rules (e.g., horn blowing and near-side station stops).
- Signal interconnection with highway traffic devices including preemption and priority.
- Visibility of warning devices.
- Switching operations in the area that may trigger nuisance operation of the grade crossing.

Additional risk-assessment tools in the form of checklists are provided by Utah and California. The *UDOT Pedestrian Grade Crossing Manual* (*47*) from the Utah Department of Transportation (UDOT) emphasizes that each grade crossing is unique and should be evaluated on a case-by-case basis by a diagnostic team. The manual includes a checklist from the *UDOT Railroad Coordination Manual of Instruction* (*48*) for evaluating pedestrian grade crossing hazard analysis, which is divided into three parts: general information, potential hazards, and proposed mitigations.

The California Public Utilities Commission's (CPUC's) *Pedestrian-Rail Crossings in California* (*49*) includes in an appendix a copy of a UK assessment sheet for evaluating crossings located at stations. When the crossing score is more than 55, "then the risk must be reduced." A crossing score between 35 and 55 is when "measures to reduce the risk must be considered." Factors being considered include crossing abuse; the number of people using the crossing; the number of trains passing over the crossing; the percent of non-stop trains over the crossing; the maximum speed of non-stop trains; lines crossed without a pedestrian refuge; warning time at the crossing; the chance of stepping out behind another train or obstruction and being hit by a train; loud external noise sources; use by significant numbers of vulnerable, distracted, or encumbered users; potential for slippery conditions; potential for fog/smoke; whether the crossing is on canted tracks; and other local factors. Suggested countermeasures to use when a crossing score is high were not provided with the assessment sheet.

CHAPTER 4

NEPA-Related Issues

In the United States, any rail transit project that receives capital funding assistance from FTA or FRA is subject to an environmental review process as required by the National Environmental Policy Act of 1969, subsequent amendments, and Executive Orders. Collectively, the environmental review process is known as the NEPA process, reflecting the original law requiring transit agencies to conduct these activities. This chapter provides an overview of the NEPA process and a specific discussion of several aspects of the NEPA process that pertain to the planning, design, and operation of safe and effective pedestrian crossings of public rail transit services.

Overview of the NEPA Process

Regulations pertaining to the environmental review process for rail transit are published by FTA (*50*) and FRA (*51*) for projects within the scope of the respective agencies. These regulations provide details on the purpose of the NEPA process, the classes of actions to be taken by FTA or FRA resulting from an environmental review, and the types of impacts that are evaluated as part of the environmental review process. The environmental review process is not a fixed set of activities required by transit agencies pursuing compliance with NEPA regulations; rather, environmental review guidelines provide transit agencies (applicants) and the FTA or FRA (lead federal review agency) with sufficient flexibility to allow for project-specific impacts to be identified and resolved in a manner consistent with the collaborative spirit of NEPA and related requirements.

Purpose of the NEPA Process

In general, the purpose of the NEPA process is to identify and evaluate the environmental impacts of a proposed action (i.e., a rail transit project) against a spectrum of feasible alternative actions (i.e., alternative investment) as well as a no-build or no-action alternative. Identification of environmental impacts and potential measures necessary to mitigate any adverse impacts is also required. The NEPA process also allows for public agencies and other affected entities to provide comments on proposed action(s). Finally, public involvement in the NEPA process, providing input on proposed alternatives and ensuring all affected populations have an opportunity to participate, is an essential element of every stage of the process.

Classes of NEPA Actions

Environmental review regulations outline three types of actions that could result from the NEPA process: Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement. These types of actions are generally associated with the types of documentation that are required to be prepared by the transit agency and the type of approval provided by FTA or

FRA. FTA and FRA environmental review regulations differ slightly in formal structure for the types of actions, but the general process is similar for the two agencies.

The first type of action, known as a **Categorical Exclusion (CE)**, is a specific type of action that does not involve significant environmental impacts. FTA and FRA regulations provide a list of actions that qualify as CEs. These lists are based on past agency experience with similar actions or are activities associated with the routine operations of a rail transit service such as schedule adjustments, maintenance activities, or technology improvements. For actions classified as CEs, no Environmental Assessment documentation is required.

For a project not classified as a CE, the applicant (i.e., a transit agency) is required to prepare an **Environmental Assessment (EA)**. An EA is a preliminary evaluation of the environmental impacts of a proposed project and identification of any adverse effects. Upon preparation, the EA is submitted to the appropriate agency (FTA or FRA) for review. If the agency determines that a proposed project has no significant environmental impacts or if appropriate mitigation measures are incorporated into the project to adequately deal with any adverse impacts, the EA will serve as the basis for a **Finding of No Significant Impact (FONSI)** to be issued by the agency, allowing for the project to be executed.

If an EA shows that a proposed project will result in significant or adverse environmental impacts, the transit agency will be required to prepare an **Environmental Impact Statement (EIS)** for the proposed project. An EIS is a comprehensive document that identifies all foreseeable environmental impacts and proposed mitigation strategies for adverse impacts and documents all public involvement activities. The FTA regulations note that the new construction or extension of fixed-rail transit facilities (e.g., light rail, commuter rail, or streetcar) normally requires preparation of an EIS. The FRA regulations note that any construction of new major railroad lines or new major facilities or any change that will result in a significant increase in traffic normally requires preparation of an EIS. Upon completion of an EIS, FTA or FRA will issue a **Record of Decision (ROD)** approving the content of the EIS and the proposed plan to mitigate the adverse effects. Similar to a FONSI, the ROD provides the authority for a transit agency to execute a proposed project.

To initiate the NEPA process, FTA encourages transit agencies intending to apply for FTA funds to notify the FTA at the time the project concept is identified. If requested, the FTA will attempt to determine the probable class of action (CE, EA, or EIS) and related environmental laws and requirements that would be applicable to the proposed project. This process, known as early coordination, allows the FTA to communicate proposed projects to other affected public agencies and allows for involvement with affected agencies as early as possible in the NEPA process. The FTA Environmental Impact and Related Procedures (23 CFR 771.111(j)) provides details on how transit agencies can obtain more information on the FTA environmental process.

Impacts Evaluated

The types of environmental impacts evaluated in the NEPA process are aligned with the goals of NEPA and related statutes as outlined in the agency-level regulations. The FTA guidance on environmental impacts and related procedures states that the "social, economic, and environmental impacts of the proposed transportation improvement" should be evaluated as part of the NEPA process. The FRA guidance provides a more exhaustive list of potential environmental impacts to be evaluated. These impacts include the following:

- Air quality.
- Water quality.
- Noise and vibration.
- Solid waste disposal.

- Ecological systems.
- Impacts on wetland areas.
- Impacts on endangered species.
- Flood hazards and floodplain management.
- Coastal zone management.
- Use of energy resources.
- Use of other natural resources, such as water, minerals, or timber.
- Aesthetic and design quality impacts.
- Impacts on transportation.
- Possible barriers to the elderly and handicapped.
- Land use, existing and planned.
- Impacts on the socioeconomic environment.
- Environmental justice.
- Public health.
- Public safety, including any impacts due to hazardous materials.
- Recreational opportunities.
- Locations of historic, archeological, architectural, or cultural significance.
- Use of 4(f)-protected properties.
- Construction period impacts.

A review of several EISs for rail transit projects under the purview of FTA indicates that the impacts listed above are also examined for FTA-related projects. Analysis of environmental impacts typically includes an identification of the affected environment (i.e., the location of the impacts), the environmental consequences (i.e., the impacts), and proposed mitigation.

Pedestrian Crossing Issues

With respect to the planning, design, and operation of pedestrian crossings for public transit rail services, a potential safety implication related to the requirements of the NEPA process for rail transit services is the result of the NEPA requirements related to the noise and vibration impacts of proposed rail transit projects.

Transit Noise Sources

Noise and vibration assessments are important elements of the environmental impact assessment process for public transit rail services projects. Noise generated by public transit rail services can result in significant adverse impacts on residences, businesses, and other adjacent properties. FTA (*52*) and FRA (*53*) have each issued handbooks providing guidance on how to conduct noise impact assessments for rail transit projects. These handbooks provide insight into the noises generated by public transit rail services and potential mitigation for these noises. The material provided in the following sections is drawn from the guidance supplied in these handbooks.

The types of noises generated by public transit rail services include noise generated by vehicle propulsion units, noise from the interaction of wheels on rails, and noise from warning devices.

Vehicle propulsion units generate the following noises:

- Whine from electric control systems and traction motors that propel rapid transit vehicles.
- Diesel-engine exhaust noise, from diesel-electric locomotives.
- Air-turbulence noise generated by cooling fans.
- Gear noise.

The interaction of steel wheels on steel rails generates three types of noise:

- Rolling noise due to continuous rolling contact.
- Impact noise when a wheel encounters discontinuity in the running surface, such as a rail joint, turnout, or crossover.
- Squeal generated by friction on tight curves.

Finally, transit vehicles are equipped with horns and bells for use in emergency situations and as a general audible warning to track workers and trespassers within the ROW as well as pedestrians and motor vehicles at grade crossings. Several different types of grade crossing warning treatments emit audible warning signals, including bell-like sounds or audible statement warnings.

Collectively, these three sources of rail transit noise can have significant adverse impacts on the environment surrounding a rail transit project.

Mitigation of Noise Impacts

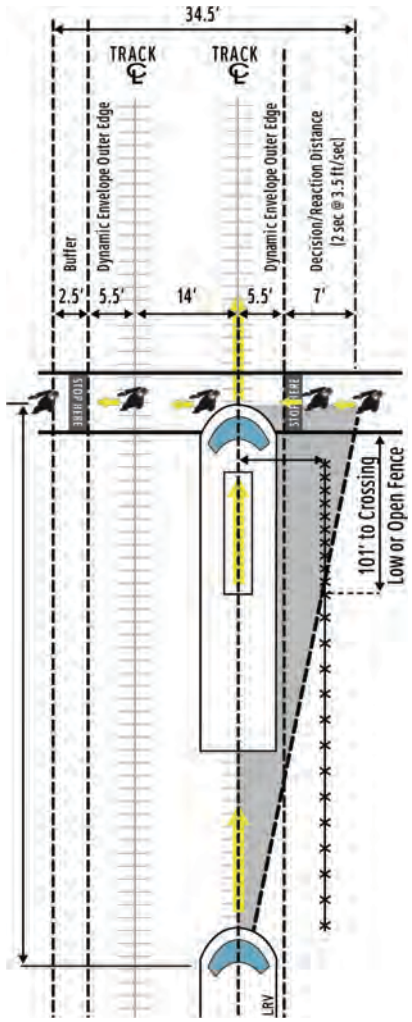
NEPA requirements necessitate that transit agencies mitigate any significant adverse impacts associated with a rail transit project, including noise impacts. Several options are available to transit agencies for mitigating rail transit noise impacts. Noise mitigation can be achieved by reducing noise:

- **At the source (i.e., the transit vehicle).** Noise impact mitigation treatments at the source include stringent vehicle noise specifications, operational restrictions, rail grinding, rail lubrication, and other treatments.
- **Along the source-to-receiver propagation path.** One of the most effective noise mitigation options is the construction of a sound barrier. A sound barrier can consist of a sound wall or artificial earthen berm or can be the result of locating a transit alignment in a cut section. Sound barrier walls located very close to the rail line may only need to be as tall as 3 to 4 ft above the top of the rail to be effective (*52*). If barriers are placed further away from the tracks, such as near the edge of the ROW, the walls should be higher to maintain effectiveness. Sound walls can also effectively function as a means of reducing the visual impacts of a rail transit project.
- **At the receiver.** Mitigation options for the receiver include building insulation and the acquisition of property rights to be used for the construction of sound barriers.

Sound Barriers

With respect to safety issues at pedestrian-rail crossings of public rail transit services, the use of a sound barrier wall to mitigate adverse impacts from rail transit noise (as required by NEPA) may be in direct conflict with the need to provide adequate sight distance at pedestrian crossings. Specifically, the height of sound barrier walls near pedestrian crossings may not provide sufficiently clear sight lines to allow a pedestrian to determine whether it is safe to cross the tracks and to safely complete the crossing. The pedestrian sight triangle concept (*54*), shown in Figure 13, illustrates the line-of-sight conflict with an example from Tri-Met, the Portland, Oregon, area transit agency. The example shown in Figure 13 indicates that, for an LRV traveling at 35 mph, the line-of-sight requirement under an emergency or unanticipated stop situation is 101 ft. Therefore, any fencing, sound wall, building, or other obstruction must be more than 101 ft away from the crossing or sufficiently low enough to allow a pedestrian to look over the obstruction.

The conflict between NEPA-required sound barrier walls for noise mitigation and the requirement to provide adequate sight distance has profound implications for the planning, design, and operation of pedestrian crossings at public transit rail services. In the planning process, if sound barrier walls are expected to be part of the NEPA-required noise mitigation plan, the placement



Case: LRV Approaching Crossing at 35 mph
Figure illustrates sight distance required for pedestrian to safely cross two tracks, covering a distance of 34.5 ft.

Assumptions:

- Two-track configuration.
- LRV approaching from left to right on first track.
- Time required by pedestrian to travel 34.5 ft, based on 3.5 ft/second walking speed = 9.86 seconds.
- Fence 10 ft from centerline of near track.

Minimum Crossing Distance, 34.5 ft, where:

- 7.0 ft is the distance traveled at 3.5 ft/second during decision/reaction period of 2 seconds.
- 5.5 ft is the distance from the centerline of the near track to the outer edge of the dynamic envelope of the near track.
- 14.0 ft is the distance between the centerlines of the two tracks.
- 5.5 ft is the distance from the centerline of the far track to the outer edge of the dynamic envelope of the far track.
- 2.5 ft is the width of the buffer/clearance zone beyond the track and dynamic envelope.

LRV Speed (mph)	LRV Traveled Distance (ft) in 9.86 Seconds	Full Service Braking Distance (ft)	Emergency Braking Distance (ft)	Distance of Low or Open Fence (ft)
15	217	110	81	43
25	352	244	175	72
35	*506*	*428*	*302*	*101*
45	651	660	462	130
55	795	942	654	159

Fence Height

- Based on distance of 506 ft covered in 9.86 seconds and 7-second reaction time, fence height should not obstruct view 101 ft from crossing

Figure NOT TO SCALE

Source: Adapted from "Safety Criteria for Light Rail Pedestrian Crossings," *Transportation Research Circular E-C058*, Figure 12, p. 287 (*54*)

Figure 13. Example pedestrian sight triangle.

of pedestrian crossings in locations where the sound walls can be reduced in height or eliminated should be considered.

Horns and/or Bells

Another type of rail transit noise impact that affects the design of pedestrian crossings, as well as motor vehicle crossings, is the noise generated by horns and/or bells that are sounded as warnings to motorists and pedestrians when a transit vehicle approaches and passes a grade crossing. Transit vehicles are equipped with these devices for use in emergency situations as well as to provide a general audible warning in the grade crossing environment. Horns and bells on the moving transit vehicle, combined with stationary bells at grade crossings, can generate noise levels considered to be extremely annoying to nearby residents and, as a result, can be a significant contributor to adverse noise impacts from a rail transit project (*52*).

The requirement for transit agencies to mitigate adverse noise impacts, including impacts caused by the use of transit vehicle horns or bells, is in conflict with the requirement for rail transit

Table 10. Techniques for reducing community impacts of audible crossing devices.

Technique	Operational Context	Recommended Action
Reduce Sound Level of Device	All crossings except those in a high-noise environment	Adjust sound level of bell, replace non-adjustable bell with adjustable bell, and replace electromechanical bell with electronic device
Vary Sound Level of Device	Crossings where background sound level fluctuates	Set warning level 10 dB above ambient noise level, either by measuring ambient levels or with a time clock
Improve Directionality of Device	Crossings where noise-sensitive receptors are not in line with pedestrian approaches	Install shrouds on existing bells or replace bells with wayside horns
Lower Mounting Height of Device	Crossings where nearby walls or structures would block sound from a lowered device	Move crossing bell from top of post to location within pedestrians' field of perception
Reduce Number of Devices	Crossings with multiple gates and flashing-light devices	Remove one or more crossing bells while maintaining sufficient coverage for pedestrians on all approaches
Reduce Time Device Is Activated	Crossings with gates on all pedestrian approaches	Adjust bells to sound only until gates reach horizontal (closed) position

Source: *TCRP Research Results Digest 84* (*3*)

vehicles to sound their horns or bells at a grade crossing. By their very nature, the horns and bells found on transit vehicles and grade crossings are designed to be loud enough to command the attention of motorists and pedestrians. Because sound barrier walls are not feasible at grade crossings, other mitigation techniques are required if adverse effects are identified. *TCRP Research Results Digest 84* (*3*) outlines several techniques for reducing the community impacts of audible crossing devices such as horns or bells. Table 10 describes these techniques.

In addition to the options reported in Table 10, the establishment of a quiet zone where no horns or bells are sounded is also an option for some rail transit services. Quiet zones require FRA approval if FRA has regulatory authority, and crossings located in a quiet zone are subject to supplemental safety measures designed to provide an equivalent level of safety at a crossing. Supplemental safety measures include four-quadrant gates, medians or other channelization devices, one-way streets, or crossing closure. Nothing regulates onboard audible devices where FRA has no authority; therefore, industry conventions are utilized when considering quiet zones. Crossings in quiet zones—specifically when the rail vehicles are especially quiet due to the nature of propulsion, the nature of the vehicle, or the nature and condition of the rails—place pedestrians who are visually impaired at considerable risk.

Crossing Treatments

Sound walls and the techniques discussed above can reduce the community impacts of audible crossing devices, but if inadequate sight lines remain at a crossing, enhanced pedestrian crossing treatments are required. Three different publications (*2, 13, 47*) provide decision trees to assist in determining the necessity of treatment, all of which use sight obstructions as decision points for warrants. At those locations where sight distance is an issue, the most robust safety treatments should be used. These generally include active warning, channelization, and positive control (swing gates or automatic pedestrian gate arms).

CHAPTER 5

Accessibility/ADA Considerations

An important factor in the design of pedestrian crossings for public rail transit services is the need to provide safe pedestrian crossings for all users, including users with disabilities. This includes pedestrian-rail crossings adjacent to roadway crossings, on dedicated pedestrian paths, or within station areas. The Americans with Disabilities Act (ADA) (*55*) prohibits discrimination based on disability in public accommodations and services, including public transit rail services. Section 504 of the Rehabilitation Act of 1973 (*56*) also prohibits discrimination on the basis of disability by recipients of federal funds. Public entities that operate rail transit services—including transit agencies, state and local governments, and Amtrak—are required to comply with ADA guidelines and standards in new construction and additions or alterations for stations, vehicles, and other facilities. Requirements in the following documents are intended to make rail crossings accessible:

- *ADA Standards for Transportation Facilities* (*57*)
- *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (Proposed PROWAG)* (*58*)
- 2009 *Manual on Uniform Traffic Control Devices* (*8*)

These documents and standards are regularly updated, so revisions may have been made to the information provided in this chapter. The *Proposed PROWAG* is expected to be adopted as a standard by 2015. In addition, the National Committee on Uniform Traffic Control Devices (NCUTCD) approved recommended revisions to the MUTCD for Section 8D on sidewalk and pathway rail grade crossings in June 2013 (*59*). These revisions were created by the Railroad/Light Rail Transit Technical Committee.

Current and Proposed ADA Technical Specifications

The ADA requirements are **minimum** technical standards to provide access for pedestrians with disabilities; they are not preferred widths or designs. Currently, as noted above, two documents provide technical specifications to comply with the ADA for accessible routes and facilities: the *ADA Standards for Transportation Facilities* (*57*), adopted by the U.S. Department of Transportation in 2006, and the *Proposed PROWAG* (*58*), published by the United States Access Board in 2011. The 2006 document is a finalized standard explicitly covering transportation facilities, such as stations and station areas. The *Proposed PROWAG* is intended to cover pedestrian facilities in the public ROW. While not finalized at this time, the *Proposed PROWAG* provides technical specifications especially developed to address sidewalks and street crossings, including rail crossings. In the two documents, there are some differences in the requirements, which are noted in the sections below. A difference in notation is that the *ADA Standards for Transportation Facilities* describes slope in proportions and the *Proposed PROWAG* describes slopes in percentages. For example, in the *ADA Standards for Transportation Facilities*, a sidewalk slope requirement is stated as 1:20, while the same slope requirement in the *Proposed PROWAG* is stated as 5 percent.

ADA Standards for Transportation Facilities

The *ADA Standards for Transportation Facilities* (*57*), effective November 29, 2006, contains some accessibility standards of particular relevance for rail transit crossings. These 2006 standards predominantly adopt—with some changes especially relevant to transportation facilities, including rail crossings—the United States Access Board's 2004 revisions to the technical specifications of the ADA, which have now been now adopted by the U.S. Department of Justice as the *ADA Standards for Accessible Design* (*60*). The *ADA Standards for Transportation Facilities* includes requirements for accessible routes and pedestrian circulation paths, walking surfaces, turning spaces, protruding objects, doorways, access gates, slopes, ramps, curb ramps, detectable warnings, and openings for wheel flanges.

Walking Surfaces

Walking surfaces must have a running slope not steeper than 1:20 and a cross slope of 1:48 or less, and be stable, firm, and slip resistant. A surface with a slope of more than 1:20 is considered a ramp, and the ramp or curb ramp requirements described for slope, landings, and handrails apply. Openings or grates in walking surfaces must not allow passage of a sphere more than 0.50 inch in diameter, and elongated openings must be placed so that the long dimension is perpendicular to the dominant direction of travel. An exception to this is flangeway gaps, which are permitted to be a maximum of 2.5 inches wide. Changes in level greater than 0.50 inch are not allowed. Changes up to 0.25 inch are permitted to be vertical, while changes in level between 0.25 inch and 0.50 inch are required to be beveled, with a slope not steeper than 1:2.

Accessible Route Width

The width of accessible routes is critical at rail crossings, especially for pedestrians who use wheelchairs. The requirements are quite specific as applied to crossings approached by way of pedestrian fencing to allow appropriate turning space. The width requirements differ somewhat between the *ADA Standards for Transportation Facilities* and *Proposed PROWAG*. When the *Proposed PROWAG* is adopted, the PROWAG standard will apply because it is specifically designed for public ROW, including street crossings.

Ramps

Ramps, including curb ramps, are permitted at rail transit crossings, but they must comply with ADA requirements for ramps. Ramps must have a running slope no steeper than 1:12, and the cross slope must not exceed 1:48. Handrails are required on ramps with more than 6 inches of rise.

Protruding Objects

Protruding objects can be hazardous for pedestrians, especially pedestrians who are blind or have low vision. Vertical clearance of at least 80 inches is required for the entire pedestrian circulation path. ADA standards require that objects that have their lowest surface between 27 and 80 inches protrude into accessible routes by a maximum of 4 inches, providing that they do not encroach on the required clear width of the accessible route. Therefore, only 4 inches of the counter-weight of a gate arm would be permitted to protrude into the sidewalk (see Figure 14 as an illustration of conflict). Pole or post-mounted objects, such as signs, are permitted by ADA

Source: Fitzpatrick

Figure 14. Example of conflict between a pedestrian and a counterweight. The pedestrian's finger is resting on a bolt that protrudes 1 inch, at her eye height.

standards to protrude into accessible routes by a maximum of 12 inches from the base of the pole or post.

Gates

Gates across accessible routes, such as where the approach to a crossing is constrained within railings, must provide a clear width of 32 inches, although a greater width is preferred. There must also be sufficient maneuvering space upon approaching such gates to enable people using wheelchairs to reach the gates and any operating mechanism. The requirements for maneuvering space are specific to the direction of approach, the depth of the opening, and whether the gate requires manual opening. Changes in level are not permitted within the required maneuvering distances. There are also requirements for gate latches and opening and closing force of gates. Gate latches must be operable with one hand and not require tight grasping, pinching, or turning of the wrist. Latches must be between 34 inches and 48 inches above the walking surface.

Curb Ramps

The *ADA Standards for Transportation Facilities* (*57*) requires truncated dome detectable warnings on curb ramps, as does the *Proposed PROWAG* (*58*). Detectable warnings must comply with surface specifications in the ADA and are to be installed on curb ramps 24 inches deep measured from the back of the curb on the ramp surface, excluding the ramp flare. Detectable warnings are required at platform boarding edges, where they must be 24 inches deep and extend the full length of the public use areas of the platform.

Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way

The *Proposed PROWAG* (*58*) is a newer document than the *ADA Standards for Transportation Facilities* (*57*) and because it is specific to the public ROW, it is especially relevant to pedestrian-rail crossings. Some issues are explained more clearly in advisory text, and requirements specifically address sidewalks along roadways, street crossings, and pedestrian signals.

Continuous Clear Width

The *Proposed PROWAG* (*58*) contains additional requirements that are intended to make at-grade rail crossings more accessible to people with mobility impairments. The continuous clear width of pedestrian access routes, including sidewalks and at-grade crossings, must be a minimum of 4 ft (rather than 3 ft as required by the *ADA Standards for Transportation Facilities* [*57*]). This width cannot be reduced by street furniture or other objects. Where the pedestrian route is wider than 4 ft, however, only 4 ft of the width is required to meet the additional requirements. At turns or changes in direction, or where the grade exceeds 5 percent, a width greater than 4 ft is recommended. Where the pedestrian route is less than 5 ft wide, passing spaces that are a minimum of 5 ft by 5 ft are required at intervals of 200 ft.

Grade

The grade of pedestrian-rail crossings, whether or not they are contained within pedestrian street crossings, cannot exceed 5 percent, and cross slope is limited to 2 percent. In addition to the requirements in the *ADA Standards for Transportation Facilities* (*57*) prohibiting vertical alignment changes of more than 0.5 inch on accessible routes, the *Proposed PROWAG* (*58*) requires that at-grade pedestrian-rail crossings have a surface that is level and flush with the top of the rail at the outer edges of the rails and that the surface between the rails be aligned with the top of the rail. An advisory note discusses the choice of smooth surfaces that facilitate mobility, and guidance is provided.

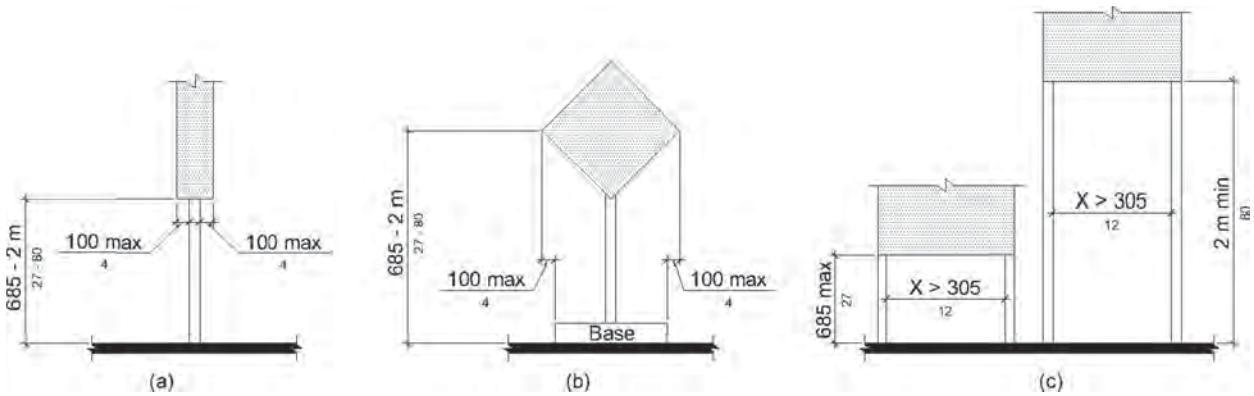
Flangeway Gaps

Flangeway gaps can trap the front wheel of wheelchairs. While the *Proposed PROWAG* (*58*) requires that flangeway gaps be a maximum of 2.5 inches on non-freight rail track (same as the *ADA Standards for Transportation Facilities* [*57*]), it permits flangeway gaps of 3 inches on freight rail track. Because commuter rail often operates over freight rail track, the flangeway gaps on commuter-rail systems may also be 3 inches.

Installation of Detectable Warnings

Proposed PROWAG R208 and R305 (*58*) provide much greater detail regarding the installation of detectable warnings, although the surface specifications are the same as those in the *ADA Standards for Transportation Facilities* (*57*). The *Proposed PROWAG* also includes advisory text to clarify that detectable warnings should indicate the boundary between the pedestrian and the vehicular way in locations where a flush rather than a curbed connection exists. The detectable warning surface is not intended to provide wayfinding information. Wherever detectable warnings are used, they must be a minimum of 24 inches deep in the direction of pedestrian travel and must extend the full width of any area in the pedestrian way where a level transition between the pedestrian and vehicular way exists. This also applies to at-grade pedestrian-rail crossings. Where at-grade pedestrian-rail crossings are within a street or highway crossing, curbs or the detectable warnings on curb ramps make additional detectable warnings at the rail crossing unnecessary unless there is a pedestrian median or refuge.

As applied to at-grade pedestrian-rail crossings not within a street or highway, detectable warnings must extend the full width of the crossing. This means that the warning is not limited to a small area deemed to be the accessible route, but is required across the entire width of the pedestrian way or pedestrian circulation path. Detectable warning surfaces are required on each end of the rail crossing and must be between 6 ft and 15 ft from the centerline of the closest rail. Where there are pedestrian gates, the detectable warning surfaces must be on the side of the gates that is farthest from the rail.



Source: adapted from *Proposed PROWAG*, R4 (*58*)

Figure 15. Post-mounted objects from the* Proposed PROWAG, R4: *"Supplementary Technical Requirements."

Accessible Pedestrian Signals

The *Proposed PROWAG* (*58*) also contains requirements for accessible pedestrian signals (APSs) where pedestrian signals are provided and refers to the MUTCD (*8*) for technical specifications. Pedestrian-rail crossings having pedestrian signals require APSs.

While the *ADA Standards for Transportation Facilities* (*57*) allows signs to protrude 12 inches from their base, Section R402.3 of the *Proposed PROWAG* (*58*) limits protrusion of post-mounted objects to 4 inches (see Figure 15), and makes it clear that the requirements for protruding objects apply across the entire width of the pedestrian circulation path, not just the accessible route. As noted earlier, counterweights within the pedestrian circulation path are protruding objects.

More details about these requirements are included with the specific treatment sections in Chapter 8.

Additional Accessibility Design Guidance

Manual on Uniform Traffic Control Devices

The MUTCD (*8*) is published by FHWA to provide uniformity of traffic control devices, which include signs, signals, and pavement markings.

Information relevant to various treatments used at pedestrian-rail crossings is discussed in Chapter 8 of the MUTCD (8). NCUTCD has recommended extensive revision to Chapter 8 to FHWA, so it is possible that the next edition of the MUTCD (*8*) may differ considerably from the 2009 edition.

When there is construction that affects a pedestrian crossing or a pedestrian circulation path, the requirements in the MUTCD (*8*) and ADA should be considered to provide temporary routes accessible to pedestrians with disabilities. Part 6 of the 2009 MUTCD, "Temporary Traffic Control," specifically notes that "needs of all road users (motorists, bicyclists, and pedestrians within the highway, or on private roads open to public travel [see definition in Section1A.13], including persons with disabilities in accordance with the ADA of 1990, Title II, Paragraph 35.130) through a Temporary Traffic Control zone is an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents."

FRA Guidance

The FRA *Guidance on Pedestrian Crossing Safety at or near Passenger Stations* (*6*) provides a list of ADA requirements to be incorporated into the design of stations to provide safe access to all users. These items were grouped and are summarized below (see the FRA document or the relevant ADA document for additional details):

- Accessible routes should coincide with, or be located in, the same area as general circulation paths. Elements such as ramps, elevators, or other circulation devices; fare vending or other ticketing areas; and fare collection areas should be placed to minimize the distance that wheelchair users and other persons who cannot negotiate steps may have to travel compared to the general public. See Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG) Section 206.3 (*61*).
- Where it is necessary to cross tracks to reach boarding platforms, the route surface should comply with the standards for accessible routes.
- Revolving doors, revolving gates, and turnstiles should not be part of an accessible route. See ADAAG Section 404.3.7 (*61*).
- Swing gates can be difficult to operate for some persons using wheelchairs. Care should be taken to avoid a situation in which a person using a wheelchair could become trapped between two gates if he or she were unable to open the gate on the opposite side of a crossing. Automatic openers complying with ADAAG Section 404.3 (*61*) can be used. If manual gates are used, maneuvering clearances, gate hardware, closing speed, and opening force should comply with ADAAG Sections 309.4 and 404 (*61*). Swinging door and gate surfaces within 10 inches (255 mm) of the floor or ground, measured vertically, should have a smooth surface on the push side extending the full width of the door or gate (i.e., a kick plate). Parts creating horizontal or vertical joints in these surfaces should be within $\frac{1}{16}$ of an inch (1.6 mm) of the same plane as the other.
- Detectable warnings consisting of raised, truncated domes that comply with ADAAG Section 705 (*61*) should be installed on either side of the tracks at pedestrian crossings.
- Where audible systems are used to communicate train arrival and track assignments to the public, a means of conveying the same or equivalent information to persons with hearing disabilities should also be provided.
- Supplemental warnings can be provided by crossing bells or flashing lights connected to a train detection system so that, upon train arrival, the bell sounds and flashing lights display to indicate when it is not safe to cross. A wayside bell or half-gates can be installed to help get the pedestrian's attention.

All signs should comply with the appropriate subsections of ADAAG Section 703 (*61*) including, as necessary, raised characters, lettering contrast and spacing, character size and proportion, Braille, appropriate international symbols, and pictogram text descriptors.

CHAPTER 6

Treatment Selection

Given the number of possible treatments that could be implemented, it is important to have a method by which practitioners can determine what treatment(s) may be most appropriate for a given crossing or set of conditions. A variety of methods can be used to guide a practitioner in selecting treatments; examples of methods and considerations are provided in this chapter.

Compilation of Pedestrian Safety Devices in Use at Grade Crossings

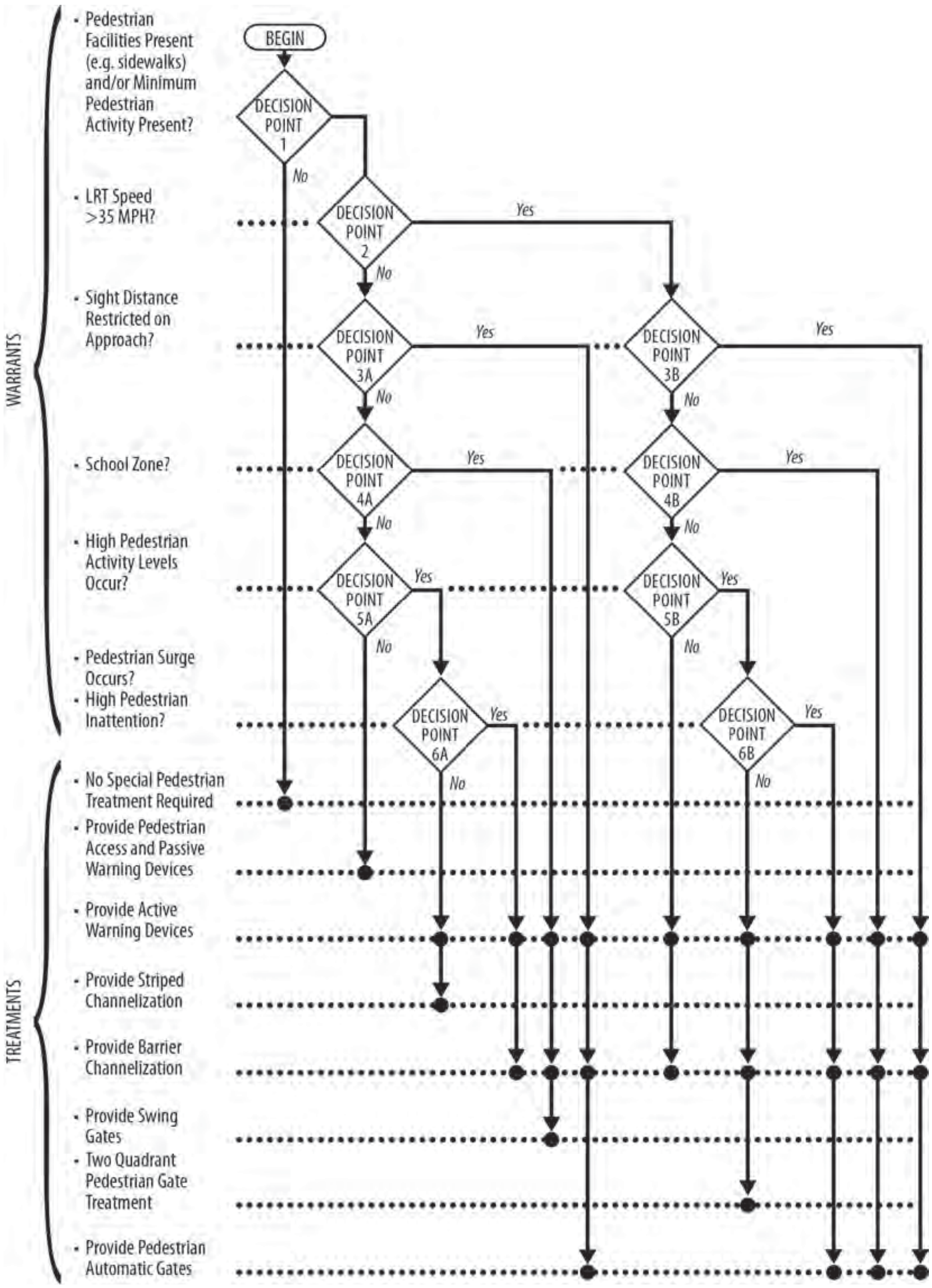
FRA, in *Compilation of Pedestrian Safety Devices in Use at Grade Crossings* (*5*), included the following general points to consider during device selection. The selection of a traffic control device for use where pedestrians are intended to cross railroad tracks at grade should be the result of an engineering study; the study's simplicity or complexity should be determined by conditions at the crossing in question. In general, the factors to be examined during device selection should include the following:

- Crash experience, if any, at the crossing, as it involves pedestrians.
- Pedestrian volumes and peak flows, if any.
- Train speeds, number of trains, and railroad traffic patterns, if any.
- Sight distance that is available to pedestrians approaching the crossing.
- Skew angle, if any, of the crossing relative to the railroad tracks (*5*).

TCRP Report 69

TCRP Report 69 (*2*) provides a pedestrian-controls decision tree (see Figure 16) for LRT alignments with LRVs traveling at speeds greater than 35 mph with at-grade crossings. The decision tree defines the type of pedestrian devices and controls using six decision points relative to the pedestrian crossing environment. Table 11 discusses Decision Points 1 through 3, and Table 12 discusses Decision Points 4 through 6.

The authors of *TCRP Report 69* emphasize, as indicated in Figure 16, that there are numerous possible outcomes based on responses to the six decision points. In the least restrictive condition with at least some minimal level of pedestrian activity—a crossing with relatively low activity levels, not located in a school zone, where LRT speed does not exceed 55 km/h (35 mph), where sight distance is good, and where no other factors warrant special consideration—the recommended practice is to provide a pedestrian route and passive warning devices at the crossing. In the most restrictive conditions—a crossing where LRT speeds exceed 55 km/h (35 mph), sight distance is inadequate, the crossing is located in a school zone, and pedestrian surges or high



Source: *TCRP Report 69*, Figure 3-38 (*2*)

Figure 16. **TCRP Report 69** ***pedestrian-controls decision tree (see Tables 11 and 12 for considerations for each decision point).***

Table 11. Criteria 1 to 3 of the decision tree from *TCRP Report 69* (see Figure 16 for illustration of the decision tree).

Decision Point	Condition	Considerations
1	Pedestrian facilities and/or minimum pedestrian activity present or anticipated	• This decision point describes locations where sidewalks or crosswalks exist on both approaches to the LRT crossing, and/or minimum pedestrian activity exists or is anticipated. • Passive pedestrian control (i.e., a LOOK BOTH WAYS sign) is necessary where pedestrian facilities have been installed. Pedestrian facilities include sidewalks, crosswalks, pedestrian-only or bicycle-only paths/trails, and station access routes. Where these facilities have been provided, it is assumed that some minimal level of pedestrian activity is present, and thus passive pedestrian control is required.
2	LRT speed exceeds 35 mph	• Active warning devices should be provided at all pedestrian crossing locations where the maximum operating speed for the LRV exceeds 55 km/h (35 mph).
3	Sight distance restricted on approach	• Pedestrian automatic gates should be installed at pedestrian crossings where an engineering study has determined that the sight distance at the crossing is not sufficient for pedestrians to see the LRV far enough down the tracks to complete the crossing before the train arrives at the crossing. • Positive control is required if sight distance is inadequate. Under ideal circumstances, there is adequate sight distance for both the LRT operator and the pedestrian. For the purpose of this assessment, adequate sight distance for the LRT operator means there is enough advance visibility of the crossing area so that pedestrian presence can be identified and, before the LRV enters the crossing, the operator can estimate the need to slow the LRV or bring it to a halt. Similarly, adequate sight distance for the pedestrian means the pedestrian can see an approaching LRV and estimate the closing speed and time available before the LRV arrives at the crossing to determine whether it is safe to cross the trackway. • For the purpose of Decision Point 3, positive control is logically required if, through analysis of sight distance, it can be determined that neither party has adequate sight distance and therefore that pedestrian access to the crossing should be blocked or impeded. For the more frequent condition in which the pedestrian has sight distance but the LRV operator does not, a positive control device should be considered. • In either case, there may be feasible actions that would increase sight distance, either widening the clear area on either side of the track or moving objects such as signal cabinets, communication rooms, and passenger ticket vending machines, which diminish visibility of portions of the crossing. Such actions should be considered in conjunction with the decision to provide positive control. • Barrier channelization is also required at locations where the sight distance is not adequate. The intent of barrier channelization is to direct a pedestrian to a location where sight distance is not restricted or to a crossing that is controlled by pedestrian automatic gates.

Source: *TCRP Report 69*, Figure 3-38 (*2*)

pedestrian inattention occurs—active warning devices, barrier channelization, and pedestrian automatic gates (positive control) are recommended.

SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual

SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual (*13*) provides information on highway-rail crossings. The publication states that

> in order to determine if a crossing has, or has the potential for, pedestrian activity, pedestrian-rail crossings shall be evaluated using the 10-minute walk rule. This rule is based upon research conclusions that pedestrians will walk 10 minutes to reach their destination. This equates to a one-third to one-half mile walk. Therefore, if the crossing is located within this radius of schools, hospitals, substantial pedestrian generators, or other facilities, then the lead Engineer should consider pedestrian traffic features over the crossing.

SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual (*13*) has a design process and consideration table that are similar to those in *TCRP Report 69*,

Table 12. Criteria 4 to 6 of the decision tree from *TCRP Report 69* (see Figure 16 for illustration of the decision tree).

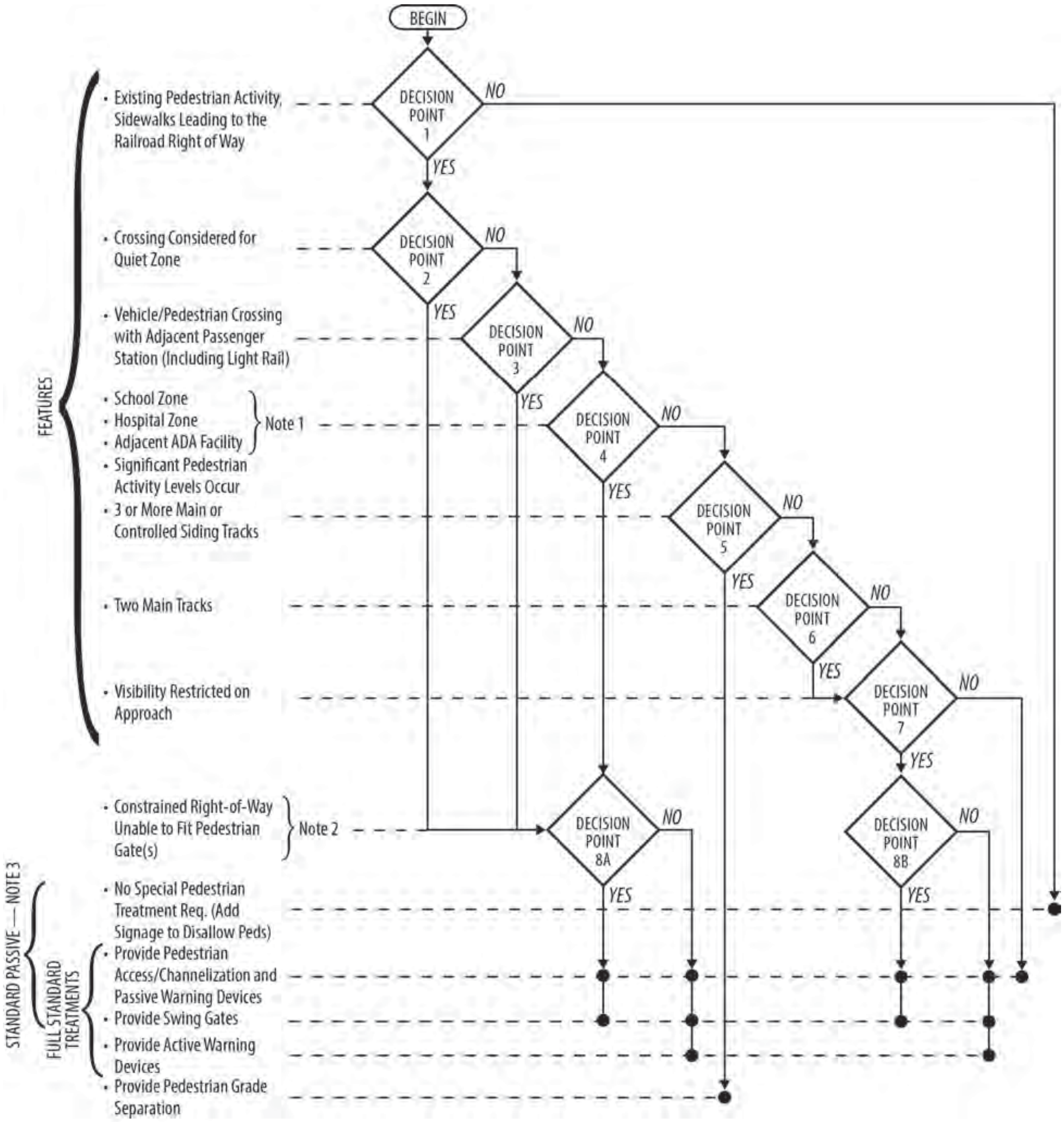
Decision Point	Condition	Considerations
4	Crossing located in a school zone	• For the basis of this decision point, a school zone is defined as the area within 182.8 m (600 ft) of a school boundary, and school routes with high levels of school pedestrian activity as defined in Decision Point 5. • Barrier channelization is required within a school zone. The intent of barrier channelization is to direct a pedestrian to a location protected by active warning devices and swing gates or pedestrian automatic gates. • At pedestrian crossings of LRT tracks within a school zone where LRT does exceed 55 km/h (35 mph), pedestrian automatic gates should be used. • At pedestrian crossings of LRT tracks within a school zone where LRT does not exceed 55 km/h (35 mph), active warning devices and swing gates may be used instead of automatic gates.
5	High pedestrian activity levels occur	• Pedestrian crossings of LRT tracks with high pedestrian activity levels are defined as locations where at least 60 pedestrians use the crossings during each of any two hours (not necessarily consecutive) of a normal day or locations where at least 40 school pedestrians use the crossing during each of any two hours (not necessarily consecutive) of a normal school day. • Active warning devices should be used at all pedestrian crossings of LRT tracks where high levels of pedestrian activity occur. • At pedestrian crossings where LRT maximum operating speed exceeds 55 km/h (35 mph) and high levels of pedestrian activity occur, pedestrian automatic gates should be installed on the two quadrants that are occupied by motorist gates by either moving the motorist gate behind the sidewalk or adding an additional pedestrian gate. • At pedestrian crossings where LRT maximum operating speed does not exceed 55 km/h (35 mph) and high levels of pedestrian activity occur, striped channelization should be used. Barrier channelization should be used if there are pedestrian surges or if locations with high pedestrian inattention are present (see Decision Point 6). • High activity levels in the vicinity of the crossing or dispersed pedestrian activity may require barrier channelization to reinforce crossing safety, to focus pedestrian movement at locations where warning and protection devices are installed, and to enhance compliance with installed devices.
6	Pedestrian surge or high pedestrian inattention occurs	• This decision point describes locations where pedestrian volume is extremely high during peak periods, such as at transfer station locations or near places of public assembly where pedestrian inattention is high, such as special event locations where pedestrian judgment is potentially compromised. • At pedestrian crossings where LRT maximum operating speed does not exceed 55 km/h (35 mph) and pedestrian surges or high pedestrian inattention may occur, barrier channelization should be installed to direct pedestrians to a crossing with active warning devices. • At pedestrian crossings where LRT maximum operating speed exceeds 55 km/h (35 mph) and pedestrian surges or high pedestrian inattention occurs, pedestrian automatic gates should be installed in addition to the barrier channelization. For example, crossings near special generators such as sports facilities, where crowds may encourage incursion onto the crossing, may warrant positive control regardless of sight distance. • For the purpose of Decision Points 5 and 6, existing or future (i.e., predicted for the design year) high levels of pedestrian activity can be identified by assessing the level of service of the crossing as defined in the Transportation Research Board's *Highway Capacity Manual* (*28*).

Source: *TCRP Report 69*, Figure 3-38 (*2*)

but which include changes to several of the decision points. Figure 17 shows the flowchart, and Table 13 provides additional discussion of the decision points.

United Kingdom

Pedestrian-Rail Crossings in California (*49*) includes in an appendix an assessment sheet (shown in Table 14) for evaluating crossings located at stations in the United Kingdom, based on a report from the Department for Transport's Rail Accident Investigation Branch (*62*). The assessment includes 14 factors, and each factor is assigned a numerical score; the factor scores are summed



NOTES:

1. Ten minute walk rule — crossing located within ten minutes walk ($\frac{1}{3}$ to $\frac{1}{2}$ mile walk).
2. SCRRA approval required.
3. For passive warning devices, the designer shall use the following order from least to the most:
   A. Signage (if no sidewalks are present or planned).
   B. Signage and detectable strip.
   C. Signage, detectable strips and swing gates.
   D. Signage, detectable strips, swing gates and channelization.

Source: *SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual*, Figure 4-2 (*13*)

Figure 17. Design process and consideration flowchart from* SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual *(see Table 13 for considerations for each decision point).

Table 13. Decision points for the design process and consideration flowchart from SCRRA (see Figure 17 for illustration of the decision process).

Decision Point	Description
1	The existence of pedestrian activity shall be determined. This includes sidewalks leading up to the ROW or evidence of pedestrians crossing at that location. The lead engineer shall determine from the highway agency the existing and desired future status of any pedestrian-related facilities in the highway and railroad ROWs, including easements, licenses, and construction and maintenance agreements. SCRRA-recommended design practices and standards call for the addition of pedestrian treatments if the highway agency and SCRRA are in agreement and the highway agency legally allows pedestrians to use the highway ROW for crossing the track(s). The lead engineer shall take the following actions when evidence of activity exists without pedestrian facilities: • Determine the level of pedestrian activity and whether the pedestrian activity is legal and supported by the local highway agency. • Work with the local highway agency to modify sidewalks and bring them into compliance with ADA requirements. • If warranted, provide sidewalks over the railroad ROW and tracks. • If warranted, take steps to prevent possible trespassing.
2	If the pedestrian-rail grade crossing is to be included in a quiet zone, then full pedestrian treatments for safety enhancements and quiet zone signage shall be applied.
3	The type of pedestrian-rail grade crossing is analyzed at this step. A station pedestrian-rail grade crossing or a pedestrian-rail grade crossing combined with a highway-rail grade crossing adjacent to the station (including any light-rail stations located within a common rail corridor) requires full pedestrian treatments.
4	Is the pedestrian-rail grade crossing located within a 10-minute walking distance of a school, hospital, or other facility that can be expected to support disabled people? If the answer is yes to any of the listed facilities, then full pedestrian treatment shall be applied. If the answer is no, then is there significant pedestrian activity? In order to answer no to whether there is significant pedestrian activity, the lead engineer shall conduct a study to determine the volume of pedestrian use during both on-peak and off-peak hours, the types of pedestrians (i.e., school children, elderly, disabled, bike riders, etc.), and pedestrians' behavior patterns (i.e., are pedestrians behaving in a safe manner when using the crossing, and are they cognizant of potential train activity?). The lead engineer will then discuss the results of this study with SCRRA and CPUC for clear consensus with the safety review team as to the presence or absence of significant pedestrian activity. Full pedestrian treatments shall be applied for a yes answer to any of these questions.
5	Does the crossing have three or more main tracks? If the answer is yes, the pedestrian-rail grade crossing shall be grade separated. The grade separation can be an overpass or an underpass.
6	Does the crossing have two main tracks? This decision point is arranged so that a yes answer for this question accounts for two tracks in rural areas that see few pedestrians. In this case, it may not be appropriate to install full pedestrian treatments, but a request for a deviation not to do so must be submitted to SCRRA. In an urban/metropolitan environment, full pedestrian treatments shall be applied when multiple tracks are in a location with limited visibility.
7	Does the crossing location have restricted visibility? Full pedestrian treatments shall be applied where there is limited visibility at crossings.
8	Is the ROW necessary to comply with the manual unobtainable? If not, then full pedestrian treatments are required. SCRRA standard drawings include variations to the standard configuration, depending on the available ROW. In cases where the ROW required for the use of one of these standard applications cannot be acquired due to existing property uses, or because of other conditions, the lead engineer shall request a deviation from the standard and design a nonstandard application.

Source: *SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual*, Figure 4-2 (*13*)

to produce a crossing score, between zero and 86. The assessor is instructed that "the risk must be reduced" when the crossing score is more than 55. A crossing score between 35 and 55 indicates that "measures to reduce the risk must be considered." Suggested countermeasures to use when a crossing score is high were not provided with the assessment sheet. Details of each factor are described in Tables 15 and 16.

UDOT Pedestrian Grade Crossing Manual

A standard evaluation and implementation procedure helps build a consistent use of safety treatments, thus protecting the safety of pedestrians at grade crossings throughout a jurisdiction. A chapter in the *UDOT Pedestrian Grade Crossing Manual* (*47*) defines the evaluation and

Table 14. Assessment sheet for crossings located at stations in the United Kingdom.

Question	Responses & Scores		Assessor's Notes	Score
1. Is there unauthorized use at the crossing?	None Irregular Regular (daily) Constant	0 4 8 12		
2. How many people use the crossing in the busiest hour? (See the guidance for the equivalent daily figures.)	< 5 5–15 16–50 > 50	0 4 8 12		
3. How many trains pass over the crossing in the busiest hour? (See the guidance for the equivalent daily figures.)	< 3 3–5 6–9 10–13 > 13	0 4 8 12 16		
4. Do any trains pass non-stop through the station?	None < 10% 10–50% > 50%	0 1 3 6		
5. What is the maximum likely speed of non-stop trains?	N/A Up to 30 mph 31–75 mph > 75 mph	0 1 2 4		
6. How many lines are crossed (without refuge)?	1 line 2 lines > 2 lines	0 1 3		
7. What is the warning time? (Timings are for crossings over one or two tracks. For more tracks see the guidance.)	> 30 s 20–30 s < 20 s	0 6 12		
8. What is the probability that customers could step out from behind a train and be hit by one traveling in the opposite direction? (See the guidance for details on this.)	Not possible Unlikely Possible Likely	0 1 4 6		
9. Is there any environmental reason why passengers might not be able to hear trains approaching this location?	No Yes	0 2		
10. Is there disproportionate use of the crossing by vulnerable, distracted, or encumbered users? (See guidance for details on this.)	No Yes (by/with staff) Yes (customers)	0 2 5		
11. Is the location susceptible to higher than average rain, snow, ice, or frost?	No Yes	0 1		
12. Is the location susceptible to any factors that might temporarily affect customers' ability to see trains (e.g., fog/smoke)?	No Yes	0 2		
13. Is the crossing on canted track?	No Yes	0 1		
14. Are there other local factors that could affect the risk?	None Small Significant	0 1 4		
CROSSING NAME:			**TOTAL**	
Standard of crossing lighting, signage, and maintenance				
Note here if any are inadequate				

Sources: *Pedestrian-Rail Crossings in California* (*49*) and *Rail Accident Report: Investigation into station pedestrian crossings (including pedestrian gates at highway level crossings); with reference to the fatal accident at Elsenham station on 3 December 2005* (*62*). Permission to reproduce this table granted through Crown copyright.

Table 15. Details considered for assessment of station crossings in the United Kingdom (Factors 1–7).

Factor No.	Factor	Description
1	Crossing abuse	If there is misuse of the crossing, then the risk of someone crossing being struck by a train is increased. Staffed crossings are likely to score lower than unstaffed ones for this factor.
2	Number of people using the crossing	The use of peak hour is intended to allow for those stations where the flow of people over a crossing (or the number of trains) changes during the day (e.g., due to passengers commuting). Where the level of use of the crossing does not change much during the day, and daily figures are available, use the following scores: • Score 0 for fewer than 25 people in a day. • Score 4 for at least 25 and not more than 100 people in a day. • Score 8 for more than 100 and not more than 250 people in a day. • Score 12 for more than 250 people in a day.
3	Number of trains passing over the crossing	Use the numbers in both directions for a peak hour (for the circumstances of Factor 1 where a station crossing is sometimes staffed and sometimes not). Where the number of trains passing over the crossing does not change significantly during the day and the number of trains per day is known, use the following scores: • Score 0 for up to 20 trains in a day. • Score 4 for between 21 and 60 trains inclusive in a day. • Score 8 for between 61 and 120 trains inclusive in a day. • Score 12 for between 121 and 180 trains inclusive in a day. • Score 16 for more than 180 trains in a day.
4	Percentage of non-stop trains over the crossing	The count includes all types of trains in the busiest hour.
5	Maximum speed of non-stop trains	This factor is concerned with sighting and hearing distance and chance to evade an approaching train.
6	Lines crossed without a pedestrian refuge	This is the number of tracks a pedestrian must cross between refuge areas at the crossing.
7	Warning time at the crossing	This is based on the warning time provided by warning systems or, if there are no warning systems, the sighting time. Where there are no warning systems, score for the sighting time. • Score 0 for warning time greater than 15 times crossing time. • Score 6 for warning time between crossing time and 15 times crossing time. • Score 12 for warning time less than crossing time.

Source: *Pedestrian-Rail Crossings in California* (*49*) and *Rail Accident Report: Investigation into station pedestrian crossings (including pedestrian gates at highway level crossings); with reference to the fatal accident at Elsenham station on 3 December 2005* (*62*). Permission to reproduce this table granted through Crown copyright.

Table 16. Details considered for assessment of station crossings in the United Kingdom (Factors 8–14).

Factor No.	Factor	Description
8	Chance of stepping out behind another train or obstruction and being hit by a train	The response for Factor 4 (proportion of non-stopping trains) needs to be considered when determining the score for this factor, as does the position of trains on the platform (i.e., are they near to the crossing or is there some visibility?). Warning systems such as white lights will minimize the risk of this happening and hence should score 0 unless there is a significant risk of user abuse, when the appropriate score in Table 14 should be used.
9	Loud external noise source	Is there a busy station, major road, or other loud noise source nearby?
10	Use by significant numbers of vulnerable, distracted, or encumbered users	This includes staff with catering trolleys, water bowsers, mail trolleys, etc., and public who are disabled or with cycles, pushchairs, etc. If there are such users from both staff and public users, score as for public.
11	Potential for slippery conditions	Is the crossing likely to be slippery due to high rain levels, snow, ice, or frost?
12	Potential for fog/smoke	Is the crossing susceptible to factors that might temporarily affect visibility?
13	Is the crossing on canted tracks?	Yes/no
14	Other local factors	Are there any other factors that may affect risk at the crossing? This may include: • Variable warning times (e.g., due to both stopping and non-stopping trains, especially where warning lights are provided). • Other train routes nearby that may cause confusion when heard. • Uneven passenger use (e.g., significant use at certain times of day or significant seasonal use).

Source: *Pedestrian-Rail Crossings in California* (*49*) and *Rail Accident Report: Investigation into station pedestrian crossings (including pedestrian gates at highway level crossings); with reference to the fatal accident at Elsenham station on 3 December 2005* (*62*). Permission to reproduce this table granted through Crown copyright.

implementation procedure to be used throughout Utah as new grade crossings are created and existing grade crossings are reviewed and improved. Each grade crossing is unique and therefore is evaluated on a case-by-case basis by a diagnostic team as defined in the current *UDOT Railroad Coordination Manual of Instruction* (*48*).

The *UDOT Pedestrian Grade Crossing Manual* (*47*) includes tools to aid diagnostic teams in the evaluation process. The checklist shown in Figures 18 and 19 is one of these tools. The checklist is divided into three parts: general information, potential hazards, and proposed mitigations (included as part of the flowcharts shown in Figures 20 and 21). When used for the design of a proposed crossing or the redesign of an existing one, the general information and potential hazards sections of the checklist should be completed in the early stages of the evaluation. Additional hazards may be defined and added to the checklist as deemed appropriate by the diagnostic team. The proposed mitigations section may be completed concurrently with the preliminary design. The preliminary design and checklist with proposed mitigations are presented to the diagnostic team during the initial review of existing or proposed crossings. The checklist with the mitigations may be updated during diagnostic team field reviews of the crossing.

The flowcharts shown in Figures 20 and 21 are another tool UDOT developed to guide designers and diagnostic teams through a consistent process of determining potential mitigations for the hazards identified in the potential hazards section of the checklist. The first flowchart shown in Figure 20 addresses issues related to pedestrian safety at grade crossings in an urban environment; the flowchart shown in Figure 21 addresses similar issues relevant to grade crossings in a rural environment.

DIAGNOSTIC TEAM CHECK LIST PEDESTRIAN GRADE CROSSING HAZARD ANALYSIS	Diagnostic Team Member: ____________________ Date: ________________
Grade Crossing Location (City/County): Street Name:	Diagnostic Team Initial Review Date:____________________ Final Review Date: ____________________
Crossing No.:	
General Information:	Train Speed: ________ mph Crossing Width: ________ft (stop bar to 6' past far rail) Max. Frequency of Trains: ______ /______ (trains per unit time) Number of Tracks: _________
Type of Alignment:	Semi-exclusive ☐ Yes ☐ No A railroad alignment that is in a separate right-of-way or along a roadway where motor vehicles, pedestrians, and bicycles have limited access and cross at designated locations only. The alignment is typically separated by fencing or barriers between crossings. Street Running ☐ Yes ☐ No A railroad alignment in which trains operate in mixed traffic with all types of road users. The alignment is typically separated from traffic by a curb or striping.
Type of Train Operation: (check all that apply)	Passenger ☐ Yes ☐ No Light Rail ☐ Yes ☐ No Freight ☐ Yes ☐ No Trolley ☐ Yes ☐ No Commuter Rail ☐ Yes ☐ No Other____________ ☐ Yes ☐ No
Crossing Gate Timing:	Warning Time ______ sec Preemption Time ______ sec Clearance Time ______ sec Total Time ______ sec
Area Information:	Area Type: ☐ Rural ☐ Urban Population within 1 sq. mi.: ☐ ≤1000 ☐ >1000
Proximity of Sidewalk to Highway-Rail Grade Crossing:	☐ Sidewalk ≤25 feet from Edge of Traveled Way (sidewalk may be treated as part of the grade crossing) ☐ Sidewalk >25 feet from Edge of Traveled Way (sidewalk must be treated separately)
Comments/Field Observations:	

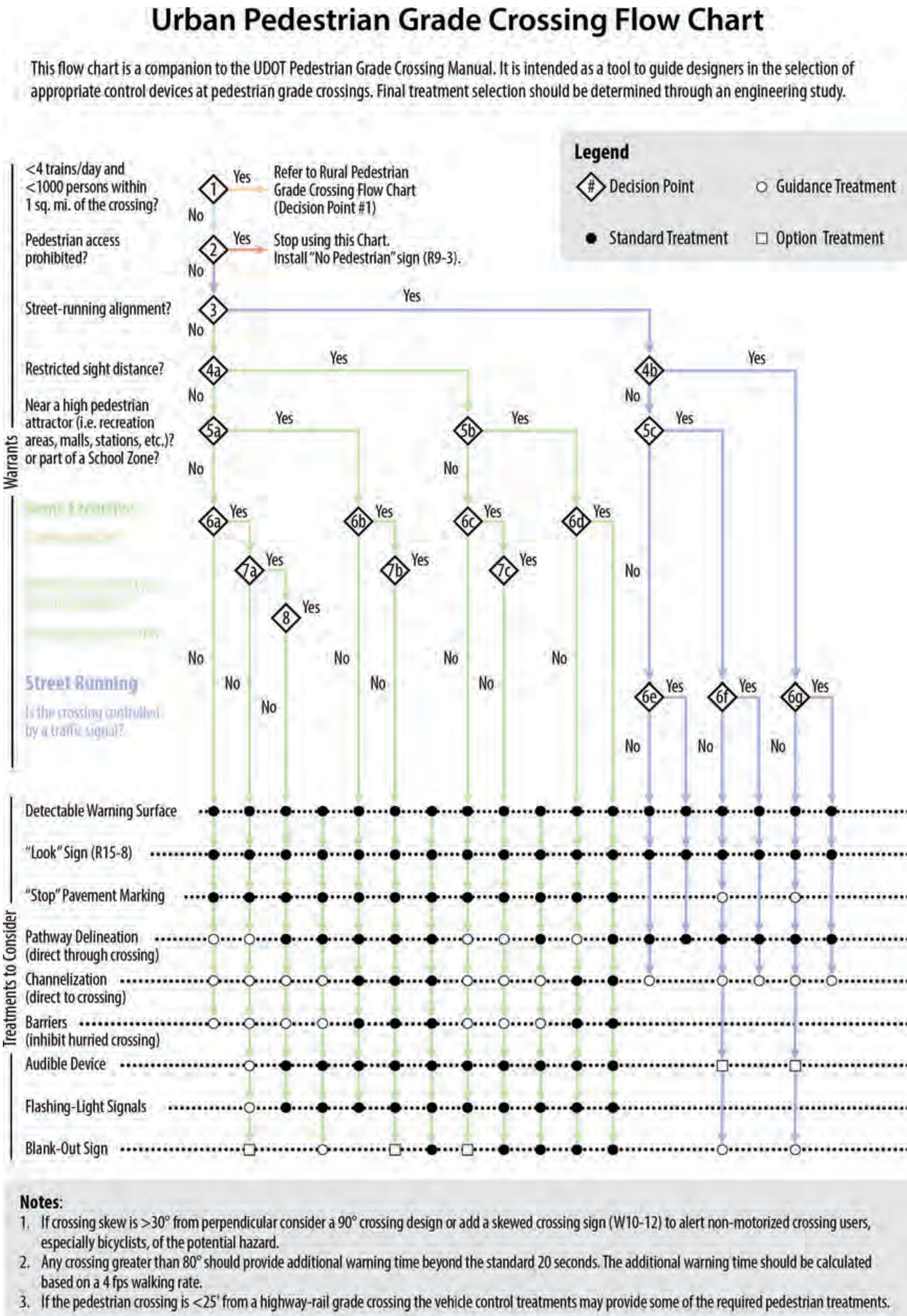
Source: UDOT, 2013 (*47*)

Figure 18. UDOT diagnostic team checklist, Part 1 of 2.

POTENTIAL HAZARD	HAZARD IDENTIFIER	COMMENTS/FIELD OBSERVATIONS
Skewed Crossing	☐ ≤ 30° from perpendicular ☐ > 30° from perpendicular	
Does Crossing have a Yard Track	☐ Yes Frequency of use ____ / ____ ☐ No	
Does the Crossing have a Side Track	☐ Yes Frequency of use ____ / ____ ☐ No	
At-Grade Crossing	☐ Active Control ☐ Passive Control ☐ N/A	
Street Running: Mid-Block Crossing	☐ Traffic Signal ☐ Unsignalized ☐ N/A	
Street Running: Intersection Crossing	☐ Traffic Signal ☐ Unsignalized ☐ N/A	
Multi-Use Path Crossing (Pedestrians and/or bicycles)	☐ Traffic Signal/Active Control ☐ Unsignalized/Passive Control ☐ Within 25' of Highway-Rail Grade Crossing ☐ N/A	
Intersection within 200' (Intersections within 200' should have preemption)	☐ Traffic Signal ☐ Unsignalized ☐ N/A	
Adequate Approach Landing for Pedestrian/Bicycles (4' × 4' or more)	☐ Yes ☐ No	
Restricted Bicycle Sight Distance (For pathway crossings only)	☐ Yes ☐ No	
Restricted Pedestrian Sight Distance	☐ Yes ☐ No	

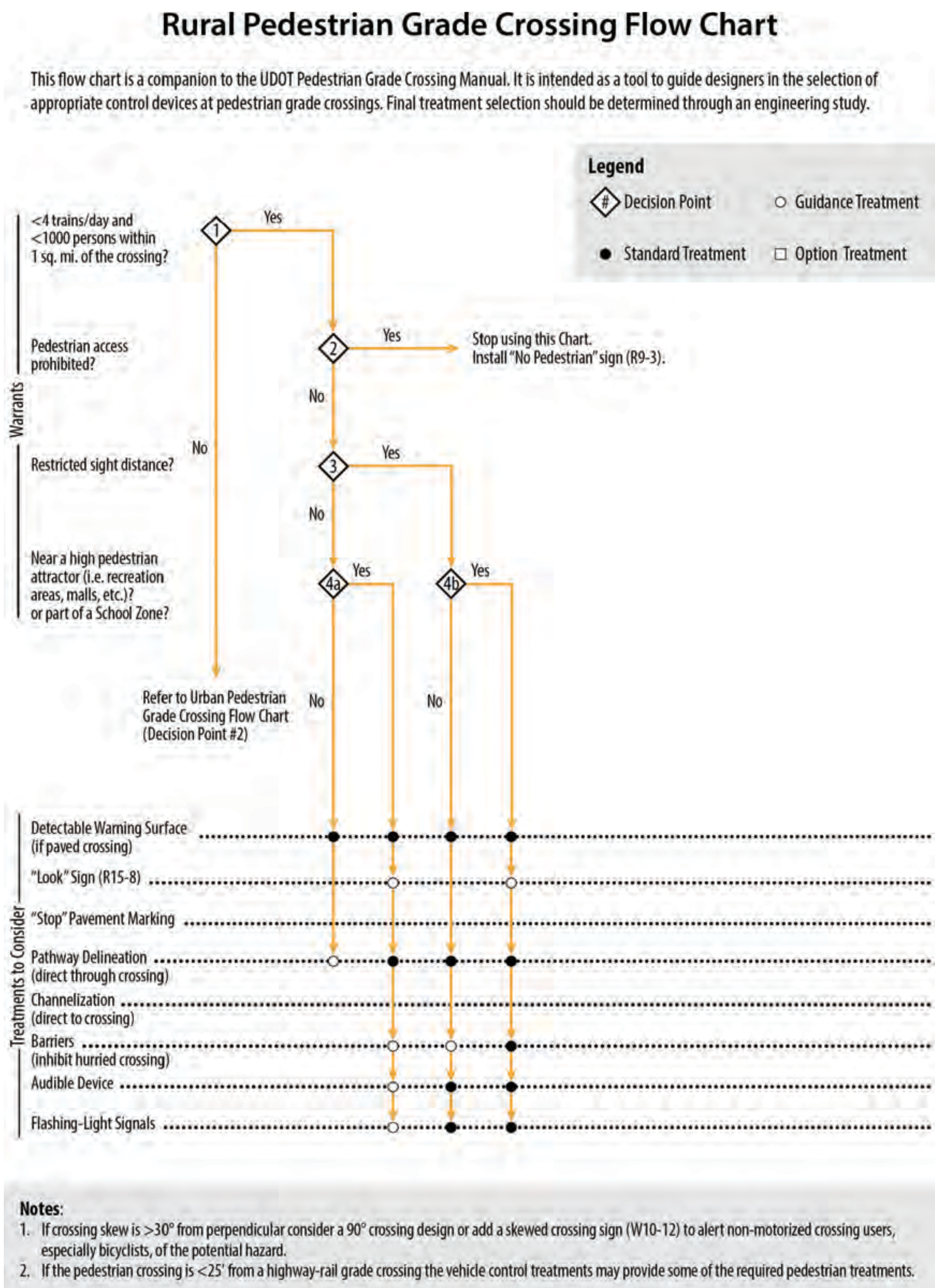
Source: UDOT, 2013 (*47*)

Figure 19. UDOT diagnostic team checklist, Part 2 of 2.



Source: UDOT, 2013 (*47*)

Figure 20. UDOT urban pedestrian grade crossing flowchart.



Source: UDOT, 2013 (*47*)

Figure 21. UDOT rural pedestrian grade crossing flowchart.

CHAPTER 7

Treatment Considerations

A number of pedestrian treatments were identified during this research effort and are described in Chapter 8. However, the installation of a specific pedestrian crossing treatment alone does not necessarily result in conflicts being reduced or pedestrians being more alert. A location may need several treatments to create an environment that communicates the conditions sufficiently to all users at the site. For example, in addition to traffic control devices (e.g., signs or markings), geometric improvements (e.g., a refuge island) may be needed. This chapter introduces the reader to considerations that should be a part of deciding whether to install one or more of the treatments described in Chapter 8 of the *Guidebook.*

Matrix Summarizing Treatment Characteristics

Table 17 provides a summary of the treatment characteristics discussed in the *Guidebook.* Table 18 provides explanations of the column headings and codes used in Table 17.

Section Headings Used in the Chapter 8 Pedestrian Treatments

Within each pedestrian treatment discussion in Chapter 8, the following sections are used:

- **Description.** Provides a short overview of the treatment.
- **Applications.** Discusses why this particular treatment would be installed (e.g., higher speed train operation or a large number of pedestrians on an intermittent basis). Discusses where it would be appropriate or not appropriate to use this treatment. Also discusses limitations of the treatment.
- **Implementation.** Discusses how the treatment functions and if there are any installation concerns. Provides examples of where the treatment has been installed and if there are any known lessons learned regarding the treatment.
- **Benefits.** Documents benefits (or disbenefits) of the treatment. Also includes any known effectiveness (safety, operations, motorist, or pedestrian behavior) of the treatment.
- **Cost.** Provides the typical cost for the treatment. Costs can vary widely depending upon whether additional infrastructure is needed in support of the treatment. For example, adding a median may mean modifying the drainage for an area to accommodate the changes in water flow caused by the raised median.

Overview of Case Studies

Four case studies were developed to illustrate specific treatments or situations. These case studies are presented in Chapter 9 and include

Table 17. Summary matrix for treatments used at pedestrian-rail crossings.[a]

Category	Treatment	Loc	Rail	NEPA	MUTCD	P / A	Cost
Channelization[b]		A	A	Yes		Pas	Low
Barriers	General	A	A	Yes		Pas	Low
	Offset pedestrian crossing	A	L, C		Yes	Pas	Med
	Maze fencing	A	L, C		Yes	Pas	Low
	Pedestrian fencing	A	L, C			Pas	Low
	Between-car barriers	2, 3	L, C			Pas	Low
	Temporary	A	A		Yes	Pas	Low
Design	Clearly defined pedestrian crossing	A	A			Pas	Med
	Smooth and level surface	A	A			Pas	Low
	Sight distance improvements	A	A	Yes		Pas	Varies
	Stops and terminal design	A	A			Pas	Varies
	Illumination	A	A			Pas	Med
	Flangeway filler	A	A			Pas	Low
	Pedestrian refuge	A	L, C			Pas	Varies
	Sidewalk relocation	A	L, C			Pas	Varies
	On-road bollards	1, 2	A			Pas	Low
Signs	Passive	A	A		Yes	Pas	Low
	Unique warning messages	A	A		Yes / NS	Pas	Low
	Enforcement	A	A		NS	Pas	Low
	Blank-out warning	A	A		Yes / NS	Act	Low
Signals	Timing considerations near railroad crossings	1, 2	A		Yes	Act	Med
	Flashing-light signal assembly	A	L, C		Yes	Act	Med
	In-pavement flashing lights	A	L, C		Yes	Act	Med
Pavement Markings	Pedestrian stop lines	A	L, C		Yes	Pas	Low
	Detectable warning	A	A		Yes	Pas	Low
	Word or symbol	A	A		Yes / NS	Pas	Low
	Dynamic envelope marking	A	A		Yes	Pas	Low
Infrastructure	Audible crossing warning devices	A	A	Yes	Yes	Act	Low
	Pedestrian automatic gates	1, 2, 4	L, C		Yes	Act	Med
	Pedestrian automatic gates w/ horizontal hanging bar	1, 2, 4	L, C		Yes / NS	Act	Med
	Pedestrian swing gates	A	L, C		Yes	Act	Med
Operations	Required stop	A	L, C			Act	Low
	Reduced train speed	A	A			Act	Low
	Rail safety ambassador	2, 3	A			Act	Med

[a] See Table 18 for explanation of column headings and table cell content.
[b] Channelization is both a category and a treatment.

- Case Study A: Review of Sound Wall
- Case Study B: Location of Station Entrance
- Case Study C: Consideration of Visually Impaired Pedestrians when Designing a Station Entrance to a Platform Located Between Tracks
- Case Study D: Control of Pedestrian Path

Traffic Control Device Experimental Process

Traffic control devices are one low-cost safety solution that can be used to better inform, warn, and regulate all road users. The FHWA, through the MUTCD (*8*), requires evaluations of the effectiveness of new traffic control devices. When determining whether these countermeasures are effective, most engineers and planners rely on anecdotal observations or their professional

Table 18. Explanation of column headings and codes used in Table 17.

- Column Heading
  - Codes

- Loc = Location where appropriate.
  - 1 = Pedestrian-rail grade crossings adjacent to a motor vehicle crossing.
  - 2 = Pedestrian-rail grade crossings at stations adjacent to motor vehicle crossings.
  - 3 = Pedestrian-rail grade crossings at stations.
  - 4 = Pedestrian-rail only crossings.
  - A = all pedestrian-rail grade crossing types.
- Rail = Type of rail transit service appropriate for treatment.
  - L = LRT system.
  - C = Commuter-rail-transit system.
  - S = Streetcar system.
  - A = All rail transit system types.
- NEPA.
  - Yes = Treatment could be associated with a NEPA issue.
- MUTCD.
  - Yes = Treatment is discussed in the MUTCD.
  - NS = Could be a nonstandard traffic control device.
- P / A = Passive or active.
  - Pas = Passive: treatment is fixed and does not change regardless of presence or absence of train or pedestrian.
  - Act = Active: treatment is activated when train is approaching or is an activity undertaken by rail transit personnel.
- Cost = Measure of cost, see treatment description for cost estimates.
  - Low = Generally less than $10,000; however, highly variable as it depends on the number of treatments needed at a site (e.g., fencing may only be for a few linear feet or could be for more than a mile).
  - Med = Medium costs, generally estimated as being between $10,000 and $100,000.
  - High = For treatments anticipated to have cost of more than $100,000.
  - Varies = The cost for the treatment is highly variable, as it depends on a number of site factors, such as the need for additional ROW or changes in drainage.

judgment. In some cases, a limited quantitative safety evaluation is conducted; however, these evaluations typically are limited in terms of scope, experimental design, and statistical rigor. This is often because many state and local agencies lack research funds or sufficient knowledge of experimental design and statistics to conduct reliable evaluations of new traffic control devices or other traffic features.

The MUTCD Section 1A.10: Interpretations, Experimentations, Changes, and Interim Approvals requires the design, application, or placement of any traffic control device that is not contained in the MUTCD to undergo evaluation, with permission from FHWA. A measure of engineering judgment is permitted in the MUTCD that allows some flexibility for traffic engineers (see MUTCD Section 1A.09). However, an agency that seeks to use a nonstandard traffic control device or make use of a nonstandard traffic control device application or placement must first seek permission to evaluate that device and then conduct a formal evaluation under permission granted by FHWA.

At times, it may be difficult to assess whether a variation of a traffic control device is inconsistent with the MUTCD, such as a nonstandard warning sign design for a unique situation not explicitly included in the MUTCD. Minor sign design variants, applications, or placement variations that are not contained in the MUTCD should not need to be tested as long as they do not conflict with a “Standard” provision in the MUTCD. Any variation of a “Standard” will normally require permission from FHWA for testing, along with an evaluation plan. If an agency is uncertain whether testing is needed, the agency should contact FHWA for an interpretation of the MUTCD or to determine whether an evaluation is needed, using the following e-mail address: MUTCDofficialrequest@dot.gov. Communications will be processed more quickly if they are submitted electronically.

If the agency has a question about a new application of a standard device, the official meaning of a standard device, or allowed variations of a standard device, a request for an Official Interpretation can be made from FHWA. FHWA keeps a public database of all requests for Official Interpretations. Section 1A.10 of the MUTCD discusses the information that should be contained in a request for interpretation of the MUTCD.

If an agency seeks to use a nonstandard traffic control device or make use of a nonstandard traffic control device application or placement that goes beyond a simple interpretation, it must first submit a "request for experimentation" for that device and then conduct a formal evaluation under permission granted by FHWA. Only a public agency (or private toll authority responsible for the operation of a road) can submit a request for permission to experiment with a new traffic control device or application. The public agency can partner with a manufacturer/vendor, consultant, or research agency to test a device and conduct the evaluation. The process and needed information for requesting and conducting experimentation for new traffic control devices or new applications of traffic control devices are provided in the MUTCD Section 1A.10.

FRA and FTA

The FRA addresses the use of non-MUTCD devices by encouraging agencies to participate in the MUTCD experimental process described above (*5, 6*).

Under federal railroad safety laws, FRA has jurisdiction over all railroads except "rapid transit operations in an urban area that are not connected to the general railroad system of transportation (49 CFR 209, Appendix A)" (*63*). A majority of commuter-rail transit services in the United States operate on the general railroad system; therefore, commuter-rail transit services fall under the regulatory jurisdiction of the FRA and are required to comply with FRA regulations for safety and warning devices. The FRA does not have jurisdiction over other types of rapid transit operations in urban areas, such as LRT or streetcar transit lines. However, because some rapid transit operations (including LRT or streetcar transit) do have connections to the general railroad system, the FRA will exercise its regulatory jurisdiction on the portion of such operations that are connected to the general railroad system. For example, a rapid transit line operating within the same ROW as a railroad that is part of the general railroad system would be required to comply with FRA safety regulations at highway-railroad grade crossings to ensure that motorists would have consistent warnings for both transit and railroad crossing events. By statute, the FRA may grant a waiver of any rule or order if the waiver "is in the public interest and consistent with railroad safety" (49 U.S.C. 20103(d)) (*63*). Appendix A of 49 CFR Part 211 describes the types of FRA regulations that may be specifically applicable to light-rail or streetcar operations, the process by which transit agencies may seek a determination of regulatory jurisdiction from the FRA, and the process by which transit agencies may seek a waiver of such requirements should it be determined that the FRA does retain jurisdiction for safety regulations of a rail transit system (*64*).

Making changes or upgrading treatments at crossings may require coordination with appropriate regulatory agencies. Rail transit systems under the purview of the FRA or FTA should involve regional agency representation from the regional offices of each administration. Listings of the regional offices for each agency are found at the following websites:

- FRA—https://www.fra.dot.gov/Page/P0244
- FTA—http://www.fta.dot.gov/12926.html

Additionally, state and local regulatory and/or transportation agencies should be contacted. In general, involving the appropriate agencies early in the process reduces the likelihood of inappropriate actions and allows for the process to proceed more quickly.

CHAPTER 8

Pedestrian Treatments

This chapter discusses the following 34 pedestrian treatments:

1. Channelization
2. Barriers—General
3. Barriers—Offset Pedestrian Crossing
4. Barriers—Maze Fencing
5. Barriers—Pedestrian Fencing
6. Barriers—Between-Car Barriers at Transit Platform Edges
7. Barriers—Temporary
8. Design—Clearly Defined Pedestrian Crossing
9. Design—Smooth and Level Surface
10. Design—Sight Distance Improvements
11. Design—Stops and Terminals
12. Design—Illumination
13. Design—Flangeway Filler
14. Design—Pedestrian Refuge
15. Design—Sidewalk Relocation
16. Design—On-Road Bollards
17. Signs—Passive
18. Signs—Unique Warning Messages
19. Signs—Signs for Enforcement
20. Signs—Blank-Out Warning
21. Signals—Timing Considerations near Railroad Crossings
22. Signals—Flashing-Light Signal Assembly
23. Signals—In-Pavement Flashing Lights
24. Pavement Markings—Pedestrian Stop Lines
25. Pavement Markings—Detectable Warnings
26. Pavement Markings—Word or Symbol
27. Pavement Markings—Dynamic Envelope Markings
28. Infrastructure—Audible Crossing Warning Devices
29. Infrastructure—Pedestrian Automatic Gates
30. Infrastructure—Pedestrian Automatic Gates with Horizontal Hanging Bar
31. Infrastructure—Pedestrian Swing Gates
32. Operations—Required Stop
33. Operations—Reduced Train Speed
34. Operations—Rail Safety Ambassador Program

Treatment 1: Channelization

Description

Channelization treatments guide pedestrians to appropriate crossing locations, minimize the area in which crossings can be physically completed, and reduce conflict points.

Applications

Minimizing the number of conflict points for pedestrians is an approach used to improve safety. One of the techniques used to limit conflict points is channelizing pedestrians by means of barriers. A wide variety of barriers, such as fencing, railing, and chains with bollards or posts, can be used to provide positive control over most pedestrian movements; however, the barrier needs to be readily detectable by pedestrians who are visually impaired.

Implementation

TCRP Report 137 (*4*) notes that the most restrictive form of channelization is the barrier. Barrier channelization can control pedestrian access to the tracks, thereby focusing pedestrian movements at a designated crossing location. Fixed barriers restrict the movements of pedestrians approaching a rail crossing and lead pedestrians toward a designated crossing location.

Figure 22 shows an example of fencing used to channelize pedestrians, and Figure 23 shows the use of curbs and fencing to channelize pedestrians (Figure 23 also shows a well-located APS).

Benefits

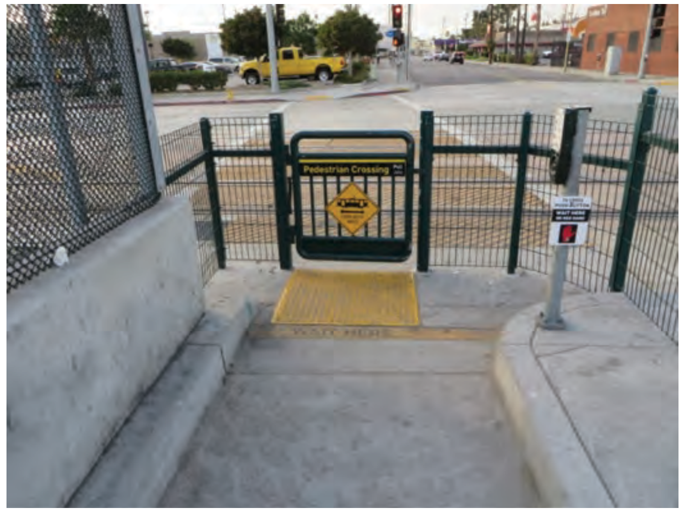
Minimizing the number of conflict points between pedestrians and rail vehicles should improve the safety of a crossing.

Cost

The typical cost of a pedestrian barricade is $683 each (*65*), and the typical cost of fencing is $334/linear ft (*66*).

Source: Fitzpatrick

Figure 22. Example of fencing used to channelize pedestrians to appropriate crossing location.



Source: Fitzpatrick

Figure 23. Fencing and curbs used to channelize pedestrians to crossing location; the photo also shows a well-located APS.

Treatment 2: Barriers—General

Description

Barriers physically restrict the movement of pedestrians.

Barriers are similar to pedestrian fencing, and in some cases the terms *pedestrian barriers* and *pedestrian fencing* are used interchangeably. Barriers can also be used to achieve desired channelization; see the previous section for a discussion of channelization.

Applications

Barrier devices are designed to control or restrict movement. They may involve parallel longitudinal barriers of various types used to separate the pedestrians and/or motorists from the tracks. Barriers restrict the path of pedestrians or motor vehicles and prevent them from crossing the tracks. Examples of barriers are medians, fences, landscaping, curbs, bollards with chains between them, and supplemental railing or handles configured to fit unique spaces.

The taller barriers, such as fences and some landscaping, prevent people from easily stepping over the restriction. Handles can be used to inhibit people from walking between the track and channelization, stepping around channelization to enter a street, or squeezing between light poles and fencing or bollards. In one example, a station was reviewed soon after a snowfall to identify pedestrian tracks indicating locations where people were bypassing existing fencing. This effort determined several locations for corrective measures, including finding that pedestrians were squeezing between channelization pillars and light posts. The handles shown in Figure 24 were added to the bollards to close the space between the bollards and the light post to minimize bypassing of the barrier.

Implementation

Barrier treatments must be installed in such a way that pedestrians (or vehicles) are not able to easily circumvent them. To have maximum effectiveness, they must not have gaps through which a pedestrian (or vehicle) may travel.

Source: Fitzpatrick

Figure 24. Example of handle barriers observed in Portland.

Several styles of barriers are used, depending upon the needs at a site. Examples of barriers include the following:

- Fencing that blocks pedestrians from crossing the tracks outside of the pedestrian crossing area (see Figure 25).
- Curbs or planters (see Figure 26).
- Bollards with chains between the posts (see Figure 27).
- Tubular barriers consisting of metal pipes that guide pedestrians to the correct crossing path (see Figure 28).
- Supplemental railing or handles configured to fit unique spaces (see Figures 29 and 30).

A consideration in choosing and installing barriers is ensuring that they are detectable by individuals who are blind or who have low vision and are not installed in a manner that results in a

Source: Fitzpatrick

Figure 25. Example of fencing used to create a barrier to limit crossings to the paved pedestrian crossing; the fence restricts passage across the tracks within a station.

Source: Fitzpatrick

Figure 26. Example of a planter used to restrict movement.

protruding object (see Chapter 5). The bottom edge of supplemental handles should be 27 inches or less from the ground or floor. Where chains, fencing, or railings are used for edge treatment, they should have a bottom edge that is a maximum of 380 mm (15 inches) above the sidewalk, per the *Proposed PROWAG* (*58*). Two chains are preferred, as shown in Figure 27.

Benefits

As reported in *TCRP Report 137* (*4*), Utah Transit Authority noted that its track sections with curbs experience less vehicle, pedestrian, and cyclist trespassing than alignments with transverse rumble strips.

Source: Fitzpatrick

Figure 27. Example of bollards with chains used to restrict movement.

Source: Fitzpatrick

Figure 28. Example of tubular barriers.

Source: Fitzpatrick

Figure 29. Example of a handle used to restrict movement between the pedestrian walkway and tracks/train.

Source: Fitzpatrick

Figure 30. Example of handles used to restrict movement between the pedestrian walkway and street.

Cost

The typical cost of barriers varies depending upon the style of the barrier. California 2012 contract data show $334/linear ft for pedestrian rail and $108/linear ft for barriers (*65*).

Treatment 3: Barriers—Offset Pedestrian Crossing

Description

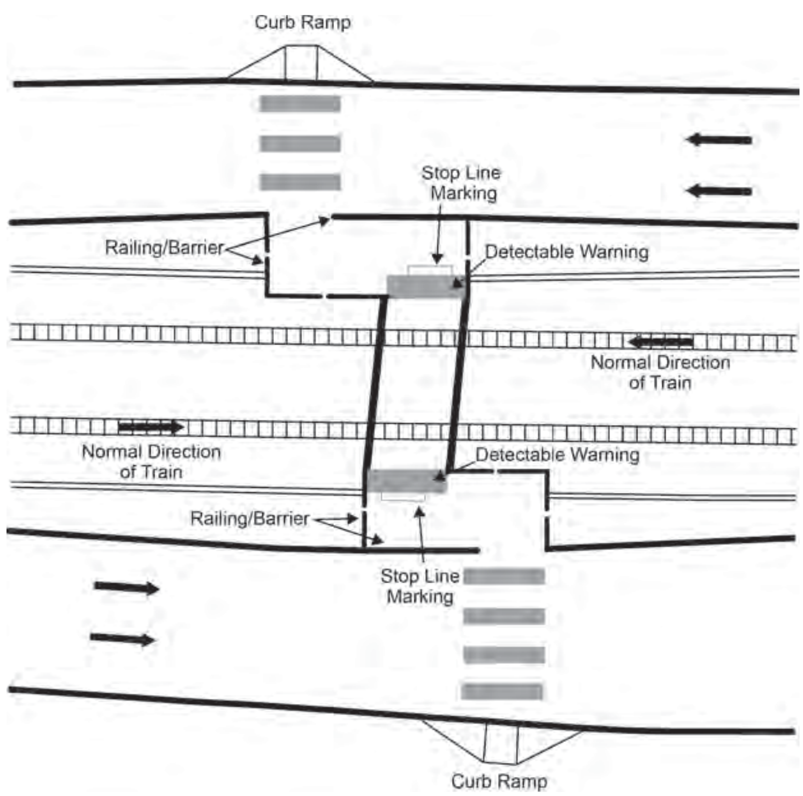
Barriers are used to create offset pedestrian crossings, also known as Z-crossings, to reorient pedestrians to face oncoming train traffic as they cross the rail tracks.

Applications

At an offset crossing, barriers or landscaping are used to reorient the pedestrian to face the direction of the anticipated train (see Figure 31). Offset pedestrian crossings include fencing or barriers designed to direct pedestrians to walk facing oncoming rail vehicles before crossing the tracks to increase pedestrian awareness of the oncoming rail vehicles. Pedestrian travel may also be constrained by landscaping or pavement.

Implementation

The configuration of an offset crossing forces pedestrians to face the direction of a potentially approaching rail vehicle. Offset crossings should be used only at pedestrian crossings with adequate



Source: Texas A&M Transportation Institute

Figure 31. Example of a typical offset crossing (also known as a Z-crossing) where a pedestrian must turn to the left and then to the right to maneuver through the barriers.

Source: Fitzpatrick

Figure 32. Example of an offset crossing.

sight distance (if pedestrians are turned to face approaching rail vehicles but cannot see them because of obstructions, the offset crossing loses its effectiveness). An example of an offset pedestrian crossing that needed to accommodate a change in elevation is shown in Figure 32.

A common type of fixed barriers is at Z-crossings (often tubular barriers). Z-crossings can be used in combination with other devices such as pedestrian signals or pedestrian automatic gates.

Benefits

Offset pedestrian crossings increase pedestrian safety and alertness by channeling pedestrian movements. Z-crossings and tubular barriers should not be used where rail vehicles operate in both directions on a single track because pedestrians may be looking the wrong way in some instances. Although pedestrians may also look in the wrong direction during rail vehicle reverse-running situations, reverse running should not negate the value of offset crossings and tubular barrier crossings because this type of operation is performed at lower speeds and is typically used only during maintenance or emergencies (*2*, *67*).

Cost

The cost of an offset crossing is variable, depending upon whether a crossing already exists, whether additional ROW is needed to accomplish the preferred design, the necessary length of the channelizing material, and the type of material used to direct pedestrians. Other considerations include elevation changes (the need for a ramp) and how the design may affect drainage in the area. The average cost of a fence is $130/linear ft, and the average cost of a median island is $10/square ft (*68*). Sriraj and Metaxatos (*69*) provide the typical cost of $106,000 for a pedestrian crossing.

Treatment 4: Barriers—Maze Fencing

Description

Fences are used to create a maze that slows pedestrians as they approach the crossing.

Applications

Proper channelization can be used to construct a crossing that pedestrians will use as intended. Channelization treatments must be installed in such a way that pedestrians (or bicyclists) are not able to easily circumvent them. The NCUTCD Railroad/Light Rail Transit Technical Committee developed recommended revisions to the MUTCD (*8*) for Section 8D on sidewalk and pathway rail grade crossings in June 2013 (*59*). Figure 33 shows the dimensions suggested for barriers used to slow and reorient pedestrians.

Implementation

Figures 34 and 35 show examples of pedestrian barriers installed in a maze or zigzag style pattern on sidewalks and at LRT stations. The configuration of the paths forces pedestrians to slow and face the direction of a potentially approaching rail vehicle. Maze fencing should be used only at pedestrian crossings with adequate sight distance.

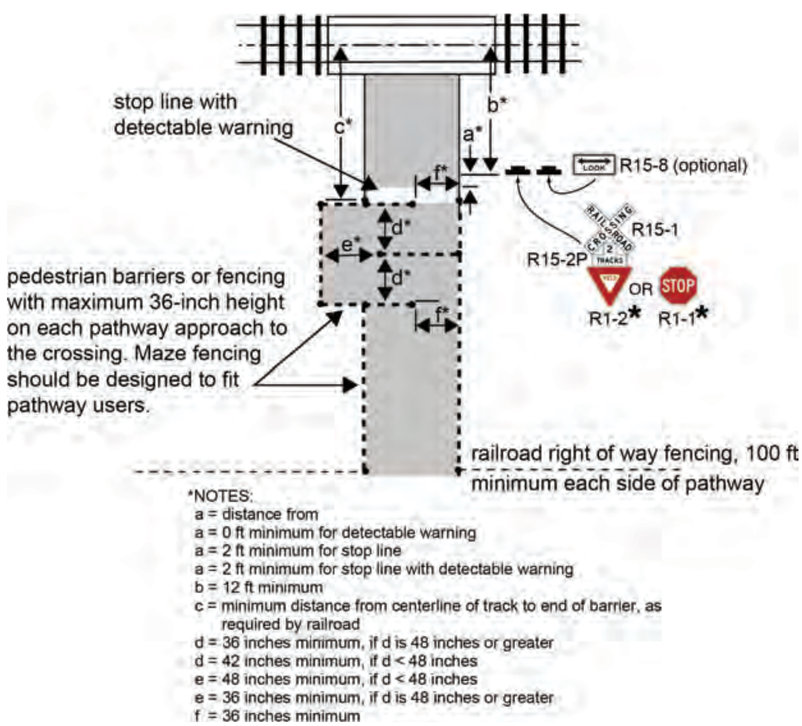
Benefits

Pedestrian crossings with maze fencing should increase pedestrian safety and alertness by slowing and channeling pedestrian movements. In some configurations, pedestrians can be forced to turn 180 degrees, thereby having a view of both directions as they approach the tracks (see the example in Figure 36).

Maze fencing on a crossing can caused pedestrian congestion because of limited crossing widths. A careful review of pedestrian movement and space available should be conducted when designing the maze fencing.

Cost

The average cost of a fence is $130/linear ft (*68*).



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee) Figure 8D-7, 2013 (*59*)

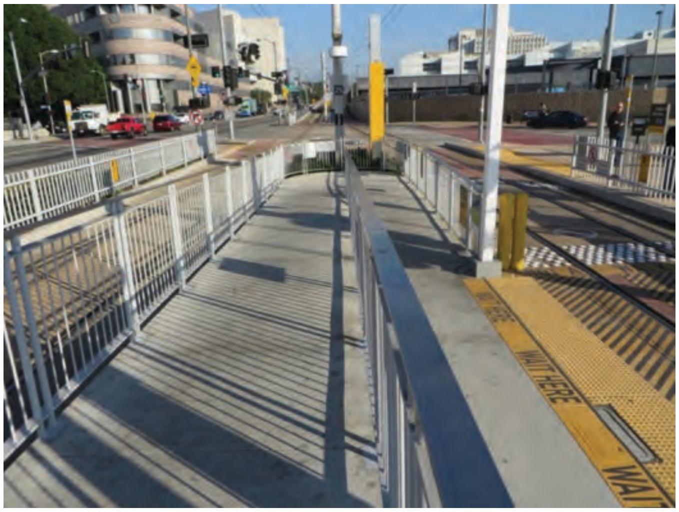
Figure 33. Suggested dimensions for barriers used to reorient pedestrians.

Source: Fitzpatrick

Figure 34. Example of railing used between fences to slow and reorient pedestrians at a crossing.

Source: Fitzpatrick

Figure 35. Example of tubular barriers used to slow pedestrians.



Source: Fitzpatrick

Figure 36. Extensive fencing channelizing pedestrians to the appropriate crossing.

Treatment 5: Barriers—Pedestrian Fencing

Description

Fencing is a channelizing treatment to guide pedestrians at crossings.

Fencing is similar to barriers, and in some cases the terms *pedestrian barriers* and *pedestrian fencing* are used interchangeably.

Applications

Pedestrian fencing is designed to channel pedestrian movements to designated crossing areas and limit the number of potential pedestrian-rail conflict points.

TCRP Report 17 (*1*) recommends "channel[ing] pedestrian flows on sidewalks, at intersections and at stations to minimize errant or random pedestrian crossings of the LRT track environment." Also reported in *TCRP Report 137* (*4*) is that "pedestrian-rail at-grade crossing design is only effective if pedestrians actually cross at the designated point and take a path that allows them clear observation of the warning devices." Fencing, along with signage and markings, encourages pedestrians to cross at designated crossings. Physical channelization is also necessary for the effective installation of all types of automatic or manual pedestrian gates. Pedestrians violate pedestrian gates at sites with inadequate channelization.

Implementation

Pedestrians must not be trapped within the dynamic envelope of the rail vehicle; it is important to leave room for a pedestrian between the fencing and the dynamic envelope (see the discussion in Treatment 14: Design–Pedestrian Refuge).

A consequence of a fence is that it could affect available sight distance. Figure 37 shows the decrease in height of a fence located between two tracks near a pedestrian-rail crossing to improve sight distance for the train operator to crossing pedestrians and for pedestrians to the train. In *Pedestrian-Rail Crossings in California* (*49*), a maximum height of 3 ft 7 inches is recommended.

Figure 22 provides an example of fencing channeling the pedestrian to the appropriate crossing location while also blocking the pedestrian from accessing the area near the gate arm. Figure 38 shows an example of fencing between tracks with a gap where a surface is provided for pedestrian crossing. Figure 39 shows another example of fencing at a station. For this station, the material selected was a reflection of the neighboring architecture.

Source: Fitzpatrick

Figure 37. Example of a change in fence height prior to pedestrian crossing to improve sight distance.

Source: Fitzpatrick

Figure 38. In-station pedestrian crossing where fencing is used to restrict crossing to a designated location.

Benefits

Specific research that documents the operational or safety benefits of this treatment was not identified.

Cost

The typical cost of fencing varies depending upon the style of the fence and materials used. The average cost of a fence is $130/linear ft (*65*).

Source: Fitzpatrick

Figure 39. Example of a fence designed to match the neighboring architecture.

Treatment 6: Barriers—Between-Car Barriers at Transit Platform Edges

Description

Between-car barriers are used at specific locations along transit platform edges or between rail cars to prevent passengers who are visually impaired from mistaking the space between the ends of rail cars for the doors into the cars.

Applications

Passengers who are visually impaired, especially passengers having little or no vision, and who travel with the aid of a long white cane, have fallen to the track bed between rail cars in a number of rail properties, sometimes resulting in injury, death, and/or expensive litigation. Flexible delineators, as seen in Figure 40, have been installed in Los Angeles and other cities to prevent visually impaired passengers from falling between rail cars because they mistake the gap between cars for the doorway into a car. Barriers attached to rail cars are also used in Los Angeles (see Figure 41).

FTA requires some treatment to prevent passengers who are visually impaired from falling between cars. Acceptable solutions "include, but are not limited to, pantograph gates, chains, motion detectors or similar devices" (48CFR38, Sec. 38.63. Between-car barriers).

Implementation

FTA envisioned that devices would be attached to cars as seen in Figure 41, and rail properties are experimenting with various treatments. Challenges are increased labor costs for coupling and uncoupling various devices and the need for multiple treatments to fit various car designs. Between-car barriers mounted at the edge of the platform do not have these challenges. The between-car barriers seen in Figure 40 are a type of flexible delineator requiring minimal labor

Source: Fitzpatrick

Figure 40. Flexible delineators as between-car barriers to prevent passengers who are blind from falling between rail cars.

Source: Gilleran. Permission granted by the owner for a one-time use of this photograph in the *Guidebook*. No right to otherwise reproduce this photograph is granted, and no rights of ownership of these photographs are transferred to TCRP.

Figure 41. Between-car barriers attached to rail cars to prevent passengers who are blind from falling between rail cars.

and maintenance. Between-car barriers are installed along platform edges where they line up with gaps between cars. The success of this treatment is dependent on precise stopping of trains, either automatically or by well-trained employees.

Benefits

When between-car barriers are correctly installed to align with gaps between rail cars and stopping of trains is precise, the barriers are a clear indication to pedestrians who are visually impaired, especially pedestrians traveling with the aid of a long white cane, that the gap between cars is not a place to board. Visually impaired passengers report that the between-car barriers not only effectively indicate the location of the between-car gaps, but that when trains stop reliably in relation to the between-car barriers, the barriers serve as a wayfinding aid. Passengers with visual impairments learn just how far from the ends of the barriers they need to wait so that they will be well positioned to board vehicles. Barriers attached to cars provide protection irrespective of whether the train stops at precise locations.

Cost

The typical cost of barriers located along platform edges varies depending upon the style of the bollard and materials used. The typical cost of 12 yellow delineators and needed bases and end caps is approximately $2,000.

Treatment 7: Barriers—Temporary

Description

Temporary barriers provide the same channelization benefits as permanent barriers, but they can be moved to meet specific needs during special events or peak periods and then removed when no longer needed.

Applications

Temporary barriers restrict the crossing movements of pedestrians and cyclists and prevent them from randomly walking onto the rail. The barriers can be installed temporarily to restrict pedestrian and cyclist movements for limited periods of time and/or for infrequent events, such as sporting events.

Temporary barriers enhance the existing safety treatments at stations and crossings during infrequent high pedestrian volumes. A transit agency using these devices should investigate and compare the specifications of multiple models of barriers from multiple vendors to confirm that the barrier selected for use will meet the needs for which it is being used, is designed for ease of use by agency employees, and can be conveniently stored while not in use. Described in MUTCD (*8*) Chapter 6, temporary barriers should meet the needs of all users, including persons with disabilities.

Implementation

As reported in *TCRP Report 137* (*4*), San Francisco Muni uses portable steel barriers and numerous transit staff and police to manage large crowds crossing the LRT alignment adjacent to the baseball stadium. Shown in Figure 42, the station adjacent to Portland's sports arena has a gate in the permanent fencing that can be adjusted to temporarily close access to the platform. Also shown in Figure 42 are stored temporary barriers.

Benefits

Temporary barriers allow for the enhancement of safety without the installation of permanent barriers and are adjustable to specific conditions. Because device specifications and usage conditions vary widely, specific safety or operational benefits have not been documented.

Cost

The typical cost varies depending upon the style of the barrier. California 2012 contract data show $683 for a pedestrian barricade (*65*).

Source: Fitzpatrick

Figure 42. Temporary barriers at the transit center station adjacent to Portland's sports arena.

Treatment 8: Design—Clearly Defined Pedestrian Crossing

Description

Clear definition of crosswalks is essential for encouraging pedestrians to cross at intended locations.

Applications

The preferred location for a pedestrian crossing is where it is expected, where it is easy to locate, and where it is convenient to use.

Pedestrian safety is enhanced when the crossing is designed such that it crosses the tracks at as close to a right angle as practical. It is desirable that the crossing be designed such that it maintains a relatively consistent horizontal alignment and profile for a distance of 12 ft from the nearest rail.

Treatments to define the pedestrian crossing make wayfinding at grade crossings easy for all pedestrians, including those who are visually impaired. Wayfinding tasks at grade crossings include locating the crossing, determining the direction of the crossing, and following the intended direction of travel on the crossing. Treatments should also minimize the likelihood that pedestrians will cross rails at unintended locations.

Implementation

All pedestrians should be able to readily locate pedestrian crossings, determine their direction, and remain on the intended path of travel. Figure 43 shows an example of an easily recognizable pedestrian crossing within a station. This crossing presents easy wayfinding due to its straight alignment and the contrasting surface materials of concrete and gravel. When crossings are located at four-way vehicular intersections, begin and end on opposite corners, and continue straight across the tracks along the same trajectory as the approaching sidewalks, most pedestrians will find wayfinding easy. However, where crossings do not begin at a corner, treatments such as

Source: Fitzpatrick

Figure 43. Example of visually contrasting surface materials, including detectable warnings, used within a clearly defined crossing surface for a pedestrian crossing within a station.

Source: Fitzpatrick

Figure 44. Three attempts to provide tactile guidance at a crossing.

fencing may help pedestrians locate the crossings. Where crossings at intersections, midblock, or in stations are diagonal, indicating the direction of travel on the crossing by some type of tactile markings, as seen in Figure 44, is helpful to visually impaired pedestrians. Three attempts to provide tactile markings can be seen in Figure 44. Outermost are strips of raised roadway markings that did not stay down well. Next is very worn thermoplastic paint. Originally, there were several layers of thermoplastic paint; the paint provided tactile guidance, but was not sufficiently durable. Innermost are raised "hotdogs," which provided good guidance and were durable; however, the product is no longer available.

When the full length of the crossing is not straight, as in offset or Z-crossings, channelizing fencing or landscaping can guide pedestrians to stay within the crossing. Figure 45 shows channelizing fencing with the opening at the end of the crosswalk. Figure 46 shows landscaping used to

Source: Billie Louise Bentzen

Figure 45. The channelizing fencing guides pedestrians who are visually impaired to the intended crossing location.

Source: Fitzpatrick

Figure 46. Landscaping channelizes pedestrians to the appropriate crossing location while the detectable warning at the bottom of the curb ramp is a good cue for visually impaired pedestrians that they have reached the edge of the street and are at a crosswalk.

channelize pedestrians at an offset crossing. Pedestrians who are visually impaired can find the opening to the channel easily if they cross straight within the crosswalk to the center-running tracks, as seen in Figure 45 and Figure 46. However, channelizing fencing can also be very confusing to both pedestrians who have unimpaired vision and pedestrians who are visually impaired if the opening in the channel is not located at the end of the crosswalk.

Where there is shared alignment at a crossing with a boarding platform, whether center or side running, detectable warnings should define the refuge at the end of the platform and help pedestrians with visual impairments to locate the platform (see Case Study C in Chapter 9). When detectable warnings are used at both edges of a refuge, pedestrians who are visually impaired are alerted to the presence of a refuge. Where crossings are midblock, and there is a curb ramp with a detectable warning at the bottom of the curb ramp as seen in Figure 46, visually impaired pedestrians who are familiar with the crossing can find it by looking for the curb ramp and detectable warning. If they are unfamiliar with the crossing, they may not find it.

Fencing is often used to prevent pedestrians from crossing tracks at an unintended location. When used for this purpose, fencing should be continuous and high enough to be an effective barrier. Figure 37 shows continuous high fencing that effectively prevents pedestrians from crossing the tracks outside the level crossing.

The extensive fencing shown in Figure 36 prevents pedestrians from crossing at unintended locations, and it also guides pedestrians from the track level to the platform level.

Benefits

Specific benefits of a clearly defined pedestrian crossing have not been documented; however, it seems likely that the treatment would attract pedestrians to cross at preferred locations and not at unintended locations.

Cost

The cost of a pedestrian crossing varies depending upon whether a crossing already exists, whether additional ROW is needed to accomplish the preferred design, and the type of material to be used around the tracks. Other considerations include elevation changes (e.g., the need for a ramp and how the design may affect drainage in the area). The average cost of a median island is $10/square ft (*65*). Sriraj and Metaxatos provide an estimated cost of $106,000 for a roadway/crossing surface renewal (*69*).

Treatment 9: Design—Smooth and Level Surface

Description

Smooth and level surfaces in pedestrian grade crossings enable safe and comfortable travel by all pedestrians, including those who are visually impaired and those who have mobility impairments.

Applications

Similar to minimizing the flangeway gap, there is a need to control the vertical difference between the rail and the adjacent surfaces. Vertical differences can be as critical as horizontal gaps because the vertical differences can cause the swivel casters of a wheelchair to turn sideways and drop into the flangeway gap.

The *Proposed PROWAG* (*58*) states that vertical alignment shall be generally planar within pedestrian access routes (including curb ramp runs, blended transitions, turning spaces, and gutter areas within pedestrian access routes), on surfaces at other elements, and in spaces that connect to pedestrian access routes. Grade breaks shall be flush. Where pedestrian access routes cross rails at grade, the pedestrian access route surface shall be level and flush with the top of the rail at the outer edges of the rails, and the surface between the rails shall be aligned with the top of the rail.

Pedestrian access route surfaces should be smooth. Surfaces should be chosen for easy rollability. Surfaces that are heavily textured, rough, or chamfered, and paving systems consisting of individual units that cannot be laid in plane, will greatly increase rolling resistance and subject pedestrians who use wheelchairs, scooters, and rolling walkers to the stressful and often painful effects of vibration. Such materials should be reserved for borders and decorative accents located outside of or only occasionally crossing the pedestrian access route. Surfaces should be designed, constructed, and maintained according to appropriate industry standards, specifications, and recommendations for best practice.

Implementation

The *Proposed PROWAG* (*58*) states that vertical surface discontinuities shall be a maximum of 0.5 inches. Vertical surface discontinuities between 0.25 inches and 0.5 inches shall be beveled with a slope not steeper than 50 percent. The bevel shall be applied across the entire vertical surface discontinuity.

When rail crossings are not at 90 degrees, the difficulties caused by vertical discontinuities are exacerbated. Vertical discontinuities also increase the likelihood that bicyclists will lose control of their bicycles. Special attention should be paid to ensure that vertical discontinuity is minimized at diagonal crossings.

The crossing at a station of the Los Angeles Gold Line uses solid red paving that matches the style of crosswalks for adjoining intersections. Most of the width of the rail crossing is stamped in a grid pattern; however, an area approximately 6 ft wide and the full length of the crossing has no stamped pattern (see Figure 47). The wheelchair symbol is placed on that part of the crossing.

Source: Fitzpatrick

Figure 47. A smooth area within a stamped crosswalk provides an ADA-compliant surface for pedestrians in wheelchairs.

The smooth section enables pedestrians who have difficulty traversing bumpy surfaces to have that part of the path be a smooth surface.

Benefits

Smooth and level surfaces at grade crossings reduce the likelihood of trips and falls for all pedestrians and bicyclists. This is especially true for people who travel with the aid of wheelchairs or other wheeled aids and for pedestrians who have difficulty raising their feet or who have drop foot, in which the ability to lift the front part of the foot is impaired.

Cost

This treatment may have no additional cost depending upon decisions made regarding the type of crossing material selected for the site.

Treatment 10: Design—Sight Distance Improvements

Description

Pedestrian-rail crossings need to provide adequate sight distance so that crossing pedestrians can see approaching trains from a sufficient distance to determine whether they can safely cross.

Applications

Adequate sight distance is critical regardless of the presence of active or passive warning devices. At crossings controlled by active devices, pedestrians may still enter the crossing if they do not see a train approaching. In addition, if one train has already passed, pedestrians may enter the crossing unaware of a second train approaching from the opposite direction.

At crossings controlled by passive devices only, the need for adequate sight distance becomes even more important. A pedestrian needs to be aware of an approaching train to determine the potential hazard at the crossing. For crossings controlled by either passive or active devices, if the sight distance is inadequate, then active positive control is essential.

Sight distance for both pedestrians and train operators is one of the most critical components in creating a safe pedestrian environment. Removing or redesigning sight obstructions is therefore a critical consideration in pedestrian safety. Sight obstructions are usually sound obstructions as well, making it difficult for pedestrians with visual impairments to hear oncoming vehicles or warning sounds. Removing sight obstructions could involve cutting back vegetation and tree limbs, but could also involve addressing impediments such as fencing, sound walls, and structures.

Case Study B in Chapter 9 provides a summary of a situation in which a sound wall was adjusted to improve sight distance. Portland replaced a brick shelter with a covered shelter to open up sightlines and surveillance by supervisors, transit police, and operators (*70*).

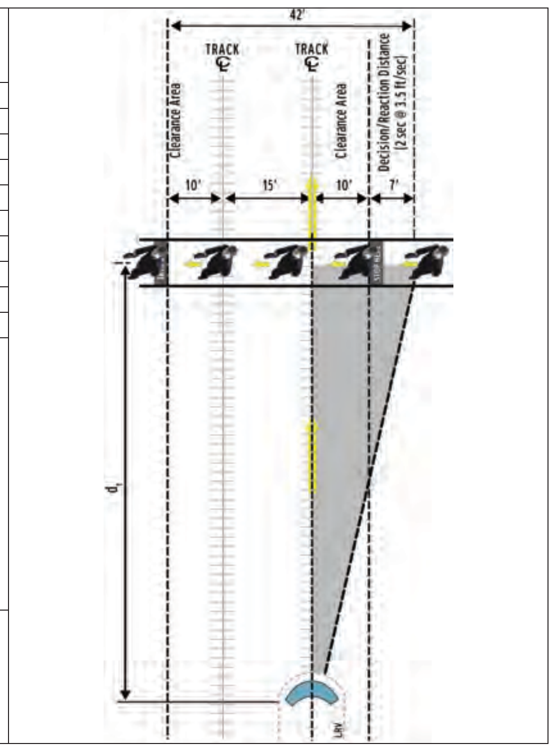
Implementation

Guidance is available from several sources including Irwin (*54*) and the CPUC's *Pedestrian-Rail Crossings in California* (*49*). Examples of guidelines for pedestrian clearing sight distance by train speed are provided in Figure 13 and Figure 48. Adequate pedestrian sight distance is based on the time necessary for a pedestrian to see an approaching train, make a decision to cross the tracks, and completely cross the trackway. Additional sight distance might be necessary in locations where pedestrians walk more slowly, such as near a retirement community or hospital. The values in Figure 48 assume a decision/reaction distance of 2 seconds at 3.5 ft/second (fps) and suggest that lower speeds, as low as 1.5 fps, should be used where slower moving pedestrians are expected.

Train Speed (mph)	Pedestrian Clearing Sight Distance* (ft)
10	180
20	355
25	440
30	530
40	705
50	880
60	1,060
70	1,235
80	1,410
90	1,585

*Walking 1.1 mph (3.5 fps) across two sets of tracks 15 ft apart, with a 2-second reaction time to reach a decision point 3 m (10 ft) before the center of the first track, and clearing 3 m (10 ft) beyond the center line of the second track. Two tracks may be more common in commuter station areas where pedestrians are found.

Note: 1 ft = 0.3048 m



Source: *Pedestrian-Rail Crossings in California* (49)

Figure 48. Clearing sight distance and sight triangle.

Benefits

Because specific treatments to improve sight distance can vary widely from site to site, specific safety or operational benefits have not been formally documented. Improvements in sight distance are likely to also result in improvements in the ability to hear oncoming vehicles, an important benefit for pedestrians with visual impairments.

Cost

The typical cost of a sight distance improvement is highly variable, depending upon the changes needed.

Treatment 11: Design—Stops and Terminals

Description

A change in the design of a stop or station terminal can improve pedestrian safety.

Applications

Examples of applications include the following:

- **Crossing angle.** Pedestrian safety is enhanced when the crossing is designed such that it crosses the tracks at as close to a right angle as practical.
- **Pedestrian flow.** Altering pedestrian flow may involve increasing channelization, installing barriers, or adding passive and active signs. More significant changes could combine treatments along with redesigning crossings. St. Louis Metro reconfigured pedestrian crossings within some stations from the inbound to outbound side of the platform after analysis showed an elevated level of incidents occurring while trains were entering stations. Los Angeles Metro adjusted the station entrance of the Little Tokyo station on the Gold Line to more easily allow access from the end, which required only one track crossing, instead of access along one side, which required crossing three sets of tracks for one of the approaches (see Case Study B in Chapter 9).
- **Median stops.** For some systems, passengers need to cross traffic lanes to reach the train operating between travel lanes. Currie and Smith (*71*) note that such stops are a well-known problem for LRT systems that operate in mixed traffic in Toronto (Ontario, Canada) and Melbourne (Victoria, Australia). Passengers sometimes wait on the street without protection from moving traffic. Similarly, when passengers alight, they often do so without protection from moving traffic. In addition to safety concerns, LRT systems of this type may not be accessible to persons with disabilities because level boarding may not be provided. Currie and Smith (*71*) offer several examples of alternative stop design solutions, including
  - **Safety zone stops.** A safety zone is a boarding area located in the center lanes of roads, where the zone has railings to protect waiting passengers from the traffic flow.
  - **Super stops.** Super stops are high-quality station-style designs located in the center lanes of roads that include platforms, shelters, and real-time passenger information.
- **Curbside stops.** Depending on system design, light-rail and streetcar stops could be designed for curbside stops, where passengers wait at the curb. Several treatments can be provided to improve the safety, access, and accessibility present at a curbside stop. Level access decreases boarding time while also permitting direct access for those in wheelchairs. Another example of an alternative stop design is a stop with a curb extension. The road is narrowed, and the sidewalk is widened to permit adding a platform on the edge of the extended curb to aid access.

  An additional approach to improving safety at curbside stops is requiring vehicular traffic to stop for boarding and alighting. Over the portions of Boston's Green Line E Branch that

Source: Fitzpatrick

Figure 49. Example of a vehicle sign at the approach to a curbside stop.

operate within traffic lanes, signs are posted at rail stops that instruct vehicle drivers to stop while passengers are loading and unloading from the inner lanes (see Figure 49). The LRVs also have red doors that when open present the words STOP and STATE LAW to instruct vehicle drivers to stop (see Figure 50). Another example of requiring vehicles to stop for curbside stop boarding and alighting is found along the McKinney Avenue Authority M-Line Trolley (Dallas, Texas), in which signs guide vehicles to stop at a specific location when the trolley is

Source: Fitzpatrick

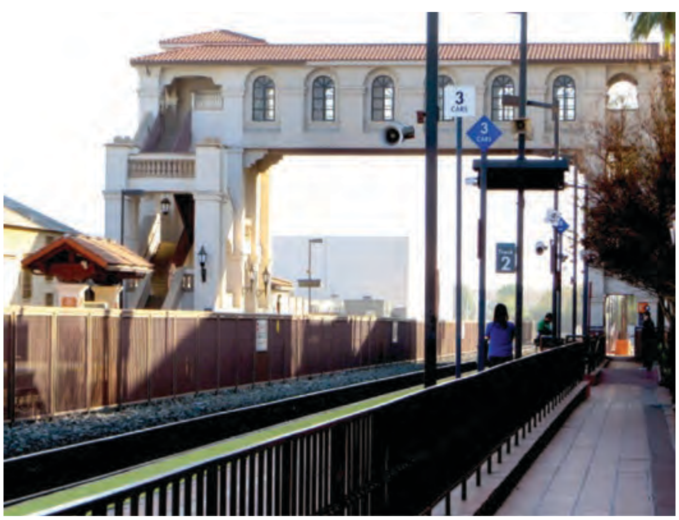
Figure 50. Example of train doors showing STOP and STATE LAW messages.

Source: Fitzpatrick

Figure 51. Example of a McKinney M-line trolley stop.

loading and unloading. These stops also have a visual designation within the inside lane of the trolley stop location, including a block section of hatched pavement markings or different colored brick pavement. An example of a curbside stop along the M-Line Trolley is shown in Figure 51. Similar to the trolleys in Boston, the M-Line Trolleys have a STOP sign that displays to vehicle drivers when the door is open.

- **Grade separation.** Some situations call for the separation of train activity and pedestrian movements. The SCRRA decision tree recommends grade separation if three or more main or controlled siding tracks exist (*13*). Other considerations for grade separations include the number of trains, the presence of trains that do not stop at a particular station, and the speed of those non-stop trains. Grade separations are very expensive and may require additional land acquisition and evaluation of environmental impacts. Grade separations may be overcrossings or undercrossings. Figure 52 shows the pedestrian overcrossing at the Metrolink Santa Ana Station.



Source: Fitzpatrick

Figure 52. Metrolink Santa Ana Station pedestrian overcrossing.

- **Improved lighting.** Improved lighting increases safety at crossings in stations, along with improving security at the locations. In a project to improve safety at the Gresham Transit Center, Portland improved lighting throughout the station (*70*). Additional discussion regarding lighting is provided in the following section.
- **Relocation and/or removal of stations.** Rail operational and pedestrian safety may be reasons for moving or removing stations.
- **Sight distance impediments.** Discussion regarding sight distance is provided in the previous section.
- **Widened track centers.** Widening track centers at stations allows for the installation of inter-track fencing while maintaining proper clearances. Inter-track fencing is used between tracks to direct pedestrians to proper crossing locations and prevent crossing at unintended locations. The Metrolink Burbank Downtown station is one location in which the track centers were widened to accommodate inter-track fencing (*72*). Figure 53 shows an example of fencing and a pedestrian crossing configuration for a Metrolink station in Burbank, CA.

Implementation

Station designs must incorporate not only national design standards but also any applicable local or regional standards or guidelines. Each design must also consider the specific characteristics (e.g., site constraints, train/pedestrian/vehicle traffic patterns, and traffic control) of the particular location in which it would be installed and must accommodate all pedestrians, including pedestrians with disabilities.

Benefits

Through continual safety reviews, it may become apparent that changing the geometry of stops or station terminals is required to improve the safety of pedestrians, with the benefits varying by treatment type and application.

Cost

The costs associated with adjusting stop and station terminal designs vary by treatment type and application. A presentation by a Metrolink representative provides a range of costs for grade separations—between \$2 and \$8 million for overcrossings and between \$1.5 and \$3.5 million for undercrossings (*72*).

Source: Fitzpatrick

Figure 53. View of the inter-track fence at the Metrolink Burbank Downtown Station.

Treatment 12: Design—Illumination

Description

Illumination at crossings is necessary to improve nighttime visibility.

Applications

Illumination of crossings refers to lighting systems installed to increase the visibility of the rail crossing at night. MUTCD Chapter 8 (*8*) suggests that

> illumination is sometimes installed at or adjacent to a grade crossing in order to provide better nighttime visibility of trains or LRT equipment and the grade crossing (for example, where a substantial amount of railroad or LRT operations are conducted at night, where grade crossings are blocked for extended periods of time, or where crash history indicates that road users experience difficulty in seeing trains or LRT equipment or traffic control devices during hours of darkness).

Where there are pedestrian accommodations at grade crossings, the pedestrian path of travel should be well illuminated so transit vehicle operators can easily see pedestrians.

Implementation

The MUTCD (*8*) provides the following recommendation: "types and locations of luminaires for illuminating grade crossings are contained in the American National Standards Institute's (ANSI) 'Practice for Roadway Lighting RP-8,' which is available from the Illuminating Engineering Society."

Figure 54 shows an example of street lighting between two sets of tracks in Portland.

Benefits

Specific safety or operational benefits of illumination at pedestrian-rail crossings were not identified.

Source: Fitzpatrick

Figure 54. Example of street lighting between two sets of tracks in Portland.

Cost

Per the 2012 California contract data, the average cost of lighting is $70,000 per project (*65*). Bushell et al. (*68*) note that lighting costs can vary depending on the fixture type and service agreement with the local utility, as well as whether other improvements are made to the street at the same time. Bushell et al. provide an average per-unit cost of $4,880.

Treatment 13: Design—Flangeway Filler

Description

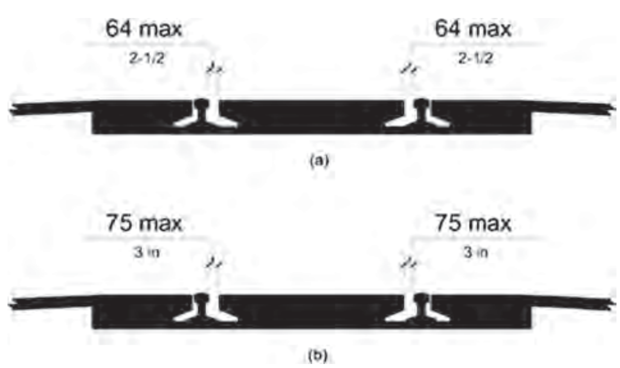
Flangeway fillers reduce the gap between the pedestrian surface and the rail, reducing the likelihood that a wheeled device such as a wheelchair, wheeled walker, or bicycle will become trapped in the gap and cause a fall.

Applications

Flangeway gaps are necessary to allow the passage of train wheel flanges, but flangeway gaps pose a potential hazard to pedestrians who use wheelchairs because the gaps can entrap the small front wheels or casters. Flangeway gaps can also entrap the small wheels on wheeled walkers, and they can trap bicycle tires. People using these devices can fall, sometimes resulting in serious injury, where flangeway gaps are not kept to a minimum. The *Proposed PROWAG* (*58*) from the United States Access Board limits the flangeway gap to 2.5 inches maximum on non-freight rail track and 3 inches maximum on freight rail track, as shown in Figure 55. The 2.5- and 3-inch dimensions are a reflection of the industry's efforts to minimize gaps. These dimensions are still a potential trap for wheels. Rubber flangeway fillers at light-rail tracks are sometimes used to mitigate the gap problem, as shown in Figure 56.

The FHWA publication *Designing Sidewalks and Trails for Access* (*73*) notes that flangeway gaps can cause loss of control and entrapment for people who use wheelchairs or for bicycles. The problem is exacerbated if the crossing is not at 90 degrees.

Wheels are much more likely to be entrapped when crossings are diagonal. Therefore, where tracks must be crossed on a diagonal, flangeway fillers are especially needed. When the crossing is not at 90 degrees, a wide crossing can enable wheelchair users to orient their chairs to approach the rails at 90 degrees.



Source: adapted from the *Proposed PROWAG*, R302.7.4 Flangeway Gaps (*58*)

Figure 55. Illustration of the maximum flangeway gap.

Source: Fitzpatrick

Figure 56. Rubber flangeway filler used to minimize the gaps at a rail.

Implementation

As mentioned above, freight railroad requires a 3-inch flangeway gap at installation. This 3-inch gap is also applicable where commuter-rail transit systems operate on freight rail lines (*13*).

Figure 55 illustrates the maximum flangeway gap of 2.5 inches (64 mm) for non-freight rail track and 3 inches (75 mm) for freight rail track.

Numerous rubber and synthetic fillers have been developed (see the example in Figure 56), but research to identify more durable and versatile products is ongoing.

Benefits

Flangeway fillers assist in maintaining the required flangeway gap and benefit users by providing a relatively smooth and level surface for grade crossings.

Cost

Flangeway filler is usually installed as a component of a major new construction or reconstruction project. General estimates provided by vendors range from $15/linear ft ($30/track ft) for a low-volume, low-speed application to $60/linear ft ($120/track ft) for a heavy-duty application.

Treatment 14: Design—Pedestrian Refuge

Description

Pedestrian refuge areas provide places for pedestrians to safely wait between rails or automobile travel lanes.

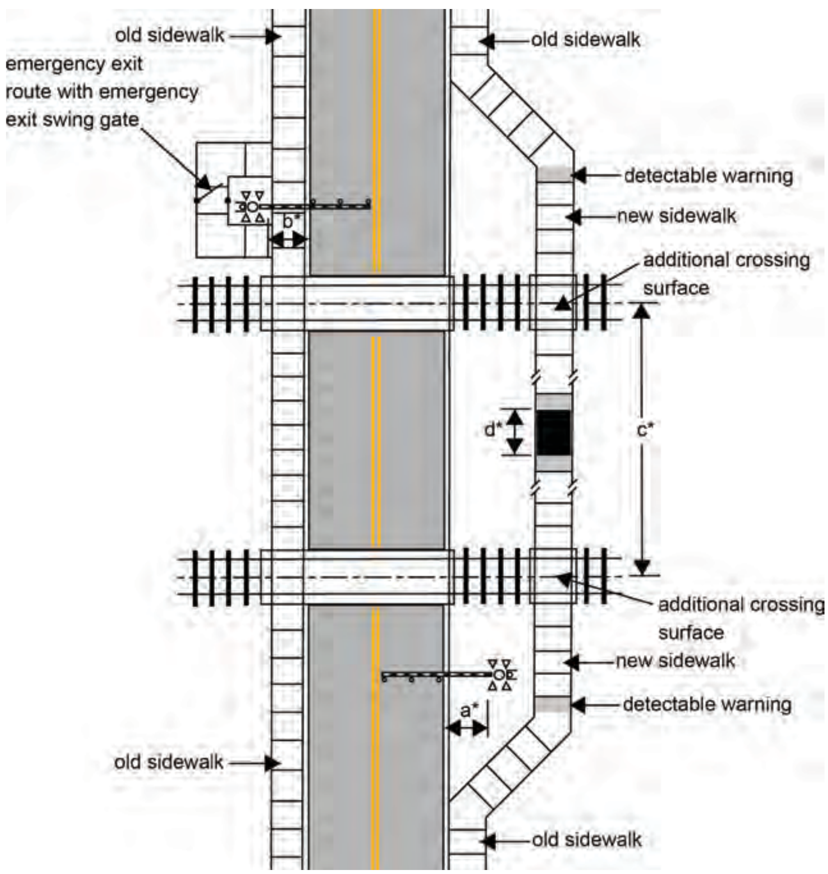
Applications

Pedestrian refuge areas are to be considered at locations where pedestrians must cross multiple modes of traffic. For example, when light rail operates in the median, pedestrians are required to cross motorist traffic, the train tracks, and then another set of motorist traffic lanes to travel from one curb to the other. The design should be such that pedestrians are not standing too near the tracks, or in the roadway, when a train approaches.

Implementation

The pedestrian refuge area should be clearly defined with contrasting materials, and the area needs sufficient dimension to allow pedestrians to wait safely between approaching rail vehicles and/or automobiles. The *Proposed PROWAG* (*58*) states that the clear width of pedestrian access routes within medians and pedestrian refuge islands shall be a minimum of 5 ft. When designing a refuge area, consideration should also be given to providing appropriate length to store the number of pedestrians anticipated to wait in the refuge area during peak periods.

One of the changes the Railroad/Light Rail Transit Technical Committee (*59*) has proposed for the MUTCD (*8*) is to include a figure that shows an example of a refuge area (see Figure 57).



NOTES:
a = Clearance distance from face-of-curb to warning device, 2 ft with a sidewalk relocation.
b = The existing sidewalk location requires greater than 2 ft clearance, pushing the warning device farther away from the traveled way.
c = Between track centers. If 38 ft or greater, optional additional detectable warnings with optional refuge area may be used.
d = Refuge area between tracks, 48 in. minimum.

Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-9 (*59*)

Figure 57. Example of a refuge area and the use of markings, including detectable warnings, on a sidewalk grade crossing.

A pedestrian refuge area between tracks is required to be defined by detectable warnings, as shown in Figure 57. See also Treatment 25: Pavement Markings—Detectable Warnings in this chapter and Case Study C in Chapter 9.

Benefits

Studies on the operations or safety effectiveness of this treatment were not identified.

Cost

In addition to construction, this treatment could include additional ROW costs. California 2012 contract data show $422/cubic yard for minor concrete (sidewalk) (*65*).

Treatment 15: Design—Sidewalk Relocation

Description

Installation of other crossing treatments may require relocating the sidewalk to accommodate the treatments.

Applications

Treatments to facilitate pedestrian (or vehicle) crossings are often added to existing crossings. In some cases, providing the necessary space to install these treatments may require relocating the adjacent sidewalk so that the gate arm counterweight or other treatments do not interfere with the pedestrian access route. Per FRA's *Compilation of Pedestrian Safety Devices in Use at Grade Crossings* (*5*), Oregon routes any pedestrian facility 5 ft behind any crossing gate arm assembly to account for the position of the gate arm counterweight when the gate is horizontal.

Implementation

Relocating a sidewalk should follow the accessibility guidelines described by the *Proposed PROWAG* (*58*). Examples of reasons to relocate a sidewalk include providing a better angle of crossing when the rail tracks are at a skew to the sidewalk (see Figure 58) or avoiding the counterweight of the gate arms (see Figure 59).

Benefits

The effectiveness of this treatment on operations or safety has not been formally documented.

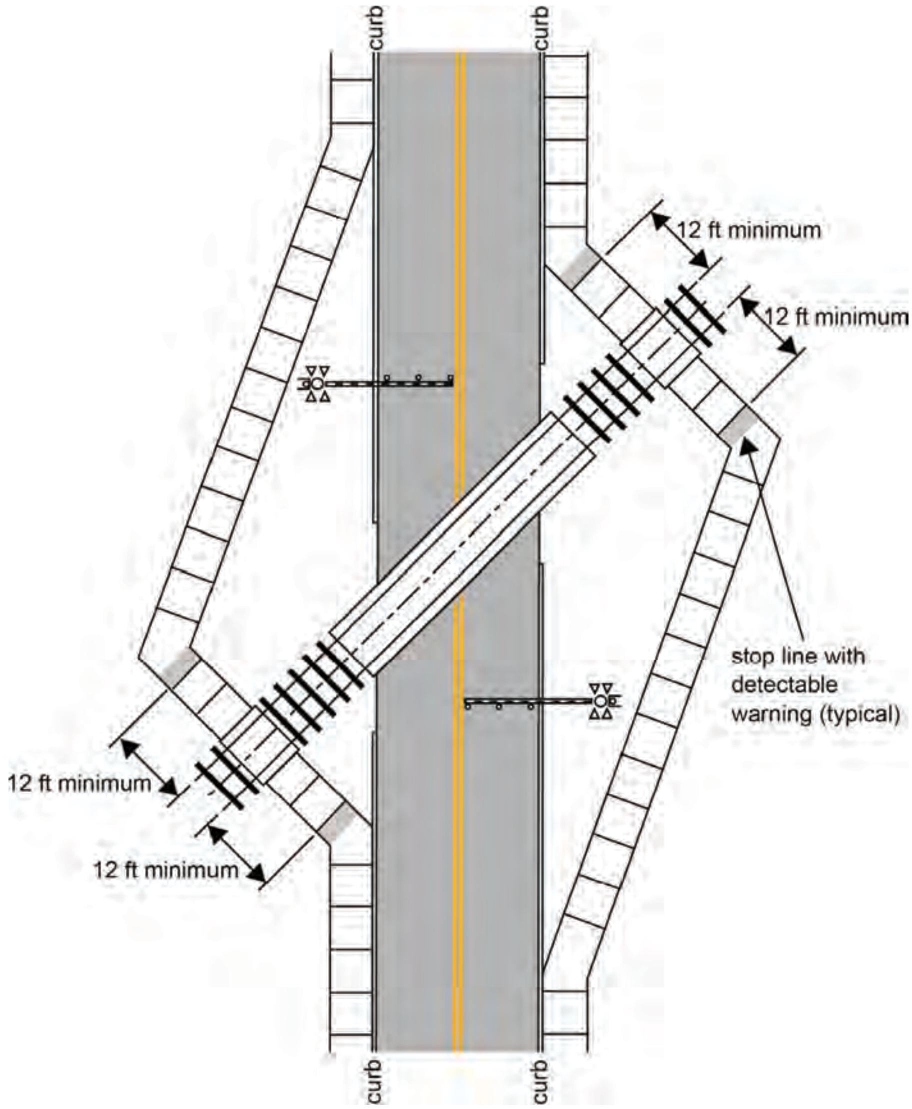
Cost

In addition to construction, this treatment could include additional ROW costs. California 2012 contract data show $422/cubic yard for minor concrete (sidewalk) and $2.59/linear ft to remove concrete (sidewalk) (*65*).

Treatment 16: Design—On-Road Bollards

Description

Bollards are installed at the end of an in-roadway station to prevent left-turning vehicles from entering the station area.



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-3, (*59*)

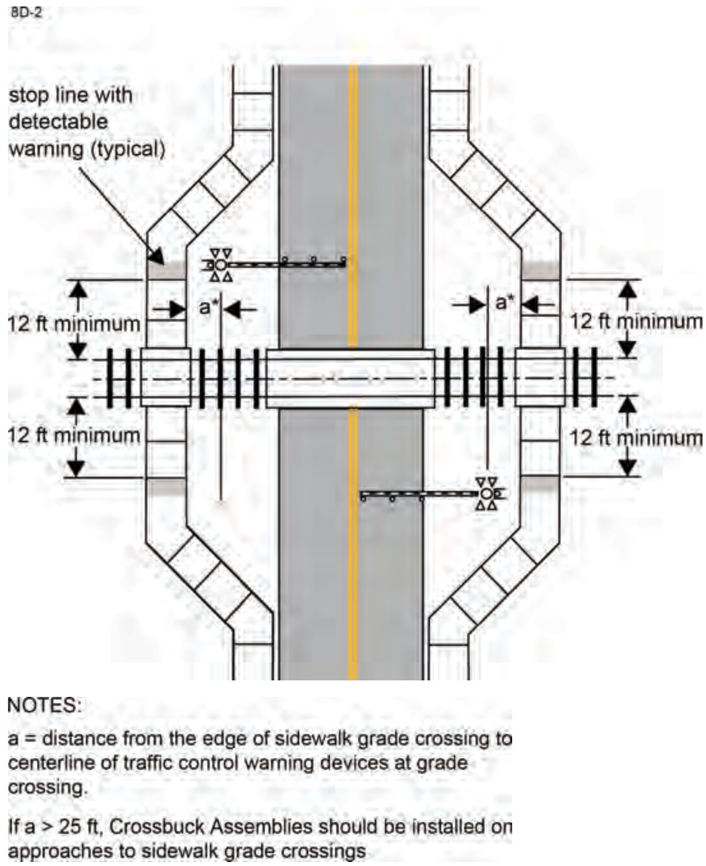
Figure 58. Example of sidewalk placement outside of a grade crossing gate (skewed crossing).

Applications

Where trains are center running, the side of the pedestrian crossing closest to a motor vehicle crossing can be marked with small break-away bollards. These bollards were recently installed in Los Angeles to reduce the likelihood of left-turning vehicles striking pedestrians in the crossing. The bollards can also serve to indicate the edge of the crosswalk to pedestrians who are visually impaired.

Implementation

Figure 60 shows a pedestrian crossing in Los Angeles where flexible bollards are installed at the edge of the station. The bollards provide a vertical warning to left-turn motorists. Figure 61 shows a closeup of the bollards.



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-2 (*59*)

Figure 59. Example of sidewalk placement outside of a grade crossing gate (right angle).

Source: Fitzpatrick

Figure 60. Flexible bollards on the end of the median refuge.

Source: Fitzpatrick

Figure 61. Closeup of flexible bollards on the end of the station.

Benefits

While formal evaluations are not available, the anecdotal information is that the bollards are effective in separating left-turning vehicles and people either crossing the roadway or accessing the rail station.

Cost

The typical cost varies depending upon the style of bollard and materials used. The average cost of bollards is $730 (*65*).

Treatment 17: Signs—Passive

Description

Passive signs provide a permanent and unchanging message to pedestrians about the presence of a crossing and the appropriate or required pedestrian actions.

Applications

Passive signs inform pedestrians about conditions that require their attention as they approach pedestrian pathway or sidewalk grade crossings. The signs in this treatment category are typically regulatory signs, which are required by law to be installed and/or tell approaching pedestrians the action they are required to take when they reach the crossing. Passive signs may also be warning signs that are not legally binding but do provide important information to the pedestrian (see Treatment 18: Signs—Unique Warning Messages).

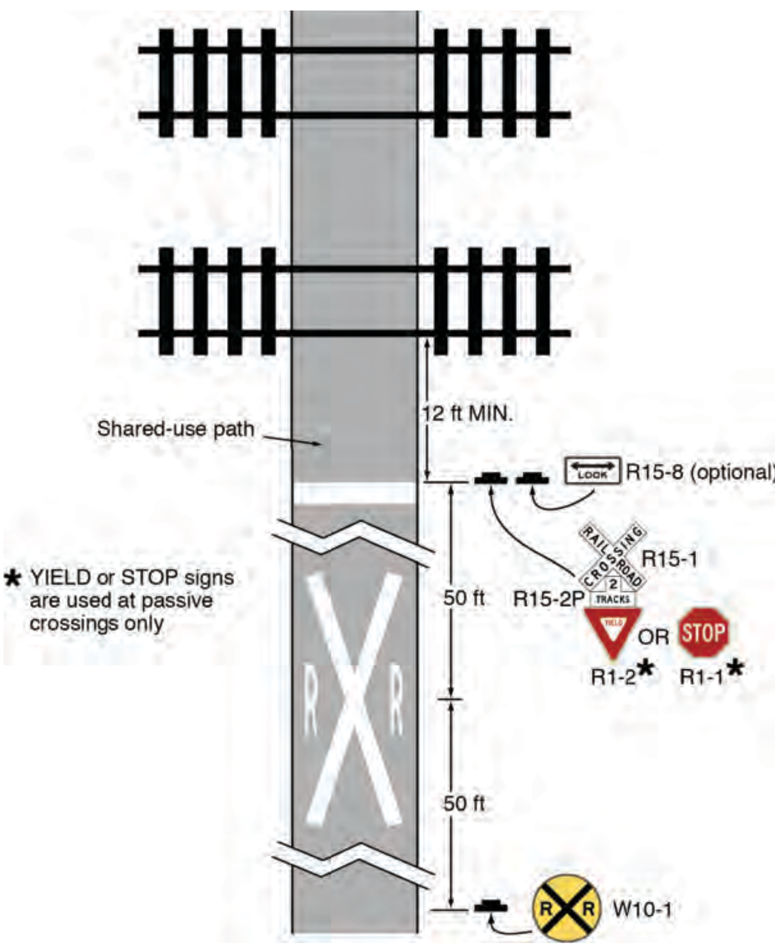
Passive signs are applicable at pedestrian-rail crossings for all types of transit services, but different signs may be used at streetcar crossings than at light-rail or commuter-rail crossings. Signs may be found at virtually any type of pedestrian-rail crossing, whether at a station or not; crossings adjacent to motor vehicle crossings may have integrated treatments that apply to both pedestrians and vehicles.

Examples of specific signs and associated treatments used at railroad and LRT grade crossings are found in Part 8 of the MUTCD (*8*). A variety of passive signs may be used at a pedestrian pathway or sidewalk grade crossing; examples include the advance Railroad Crossing sign (W10-1), the Crossbuck assembly (R15-1) with a YIELD sign (R1-2) or a STOP sign (R1-1), and the LOOK sign (R15-8). The Number of Tracks plaque (R15-2P) is placed beneath the Crossbuck sign and helps to communicate the number of tracks. The light-rail DO NOT PASS sign (R15-5) is used to indicate that motor vehicles are not allowed to pass LRVs that are loading or unloading passengers when there is no raised platform or physical separation from the lanes upon which other motor vehicles are operating. Instead of the R15-5 symbol sign, a regulatory sign with the word message DO NOT PASS STOPPED TRAIN (R15-5a) may be used. The MUTCD (*8*) provides guidelines and standards on the proper installation of these and other signs.

Implementation

Figure 62 shows an example of signing and markings for a pathway grade crossing from the 2009 MUTCD (*8*). Examples of some of the other signs in the MUTCD that could be used to communicate the conditions at the crossing are shown in Figure 63. Figure 64 shows a combination of the NO TRAIN HORN warning plaque and the LOOK sign used on an approach to a pedestrian crossing in Los Angeles.

CPUC General Order 75-D provides regulations for warning devices for at-grade highway-rail crossings in California (*74*). It has several graphics and regulations for pedestrian treatments including a sign that is to be posted at at-grade crossings exclusively used by pedestrians and/or bicyclists. The sign says: RAILROAD [R X R symbol] CROSSING PEDESTRIANS AND BICYCLES ONLY.



Source: *Manual on Uniform Traffic Control Devices* (MUTCD) (*8*)

Figure 62. Example of signing and markings for a pathway grade crossing from MUTCD Figure 8D-1.

Number of Tracks (plaque) (R15-2P) | **Light Rail DO NOT PASS (R15-5)** | **DO NOT PASS STOPPED TRAIN (R15-5a)**

Source: *Manual on Uniform Traffic Control Devices* (MUTCD) (*8*)

Figure 63. Examples of MUTCD regulatory signs for rail crossing.

Benefits

Passive signs can provide standardized messages at approaches to pedestrian-rail crossings to inform pedestrians that trains are or may be approaching the crossing. As a result, pedestrians are advised to pay particular attention at the crossing and take specific actions to avoid crashes with trains in the crossing. Passive signs do not benefit pedestrians who are unable to see or read them.

Cost

Per the 2012 California contract data, the average cost of a sign is $18/square ft (*65*). Bushell et al. (*68*) provide an average of $300 for STOP/YIELD signs and a range of $530 to $2,150 for trail wayfinding/information signs.

Source: Fitzpatrick

Figure 64. Examples of signs used at a quiet zone near Los Angeles.

Treatment 18: Signs—Unique Warning Messages

Description

In addition to the MUTCD-compliant signs discussed in Treatment 17: Signs—Passive in this chapter, some transit agencies are using signs with messages unique to the area to communicate specific warnings to people who can see and understand the messages.

Applications

MUTCD (*8*) signs provide information through standardized text and symbols that are applicable nationwide. There are situations, however, when an MUTCD sign does not contain the message most applicable to a particular location or set of conditions. In these situations, transit agencies may develop their own sign that provides needed information to the pedestrian on conditions specific to that transit agency's jurisdiction, or transit agencies may test a sign that they think has wider application and could, after successful experimentation, eventually be included in the MUTCD.

Signs must be installed so that their presence improves the information provided to the pedestrian. Signs that have an unclear message (through unfamiliar symbols and/or vague text) may actually exacerbate the problem they are intended to address. Signs must also be installed in appropriate number to convey the necessary message where they are needed, but not installed where they are not needed; too many signs can be a distraction causing pedestrians to look at all the signs and fail to notice the oncoming train. Finally, because these signs are not found in the MUTCD (*8*), a transit agency may require permission from FHWA to experiment before installing a particular sign, depending on the nature and location of the sign.

Implementation

Common applications include warning signs advising pedestrians to look in both directions before crossing the tracks, particularly at crossings with multiple tracks, where a second train may arrive shortly after a train passes through the crossing area. A variety of LOOK BOTH WAYS signs are in use:

- Figure 65 shows an example of using both the MUTCD LOOK sign and the Tri-Met LOOK BOTH WAYS sign at a crossing in Portland.
- Figure 66 shows a closeup of the Tri-Met sign.
- Figure 28 (see Treatment 2) shows a pedestrian crossing in Portland where a STOP sign was placed above the LOOK BOTH WAYS sign for the pedestrian approaching the crossing.
- The Los Angeles version of the LOOK BOTH WAYS sign is shown on a swing gate in Figure 67 and on the road in Figure 68.
- Like Los Angeles, Dallas also uses the side view of a train with the LOOK BOTH WAYS sign located at an in-station pedestrian crossing, as shown in Figure 69.
- Figure 70 shows an example of the LOOK sign used in Boston.
- Figure 71 shows the sign used in Austin.
- Figure 72 shows a sign in which Baltimore uses white lettering on a red background.

These signs are being installed where pedestrians and motorists may not look for a train, especially a second train, approaching. The main purpose of train warning signs is to increase motorist, pedestrian, and cyclist awareness of the possibility of a train approaching from either direction, even when a visible train is already present on the track. The signs are intended to remind pedestrians to look both ways and to prevent crashes with a train. Such signs could

Source: Fitzpatrick

Figure 65. Example of the MUTCD LOOK sign (left side) and Tri-Met LOOK BOTH WAYS sign (right side) at a Portland crossing.

Source: Fitzpatrick

Figure 66. Portland Tri-Met LOOK BOTH WAYS sign on a tubular fence.

Source: Fitzpatrick

Figure 67. Example of a LOOK BOTH WAYS sign on a swing gate in Los Angeles.

Source: Fitzpatrick

Figure 68. Example of a LOOK BOTH WAYS sign used on the roadway in Los Angeles.

Source: Fitzpatrick

Figure 69. Example of a LOOK BOTH WAYS sign used in a Dallas station.

Source: Fitzpatrick

Figure 70. Sign used at several pedestrian-rail crossings in Boston.

Source: Fitzpatrick

Figure 71. Closeup of a LOOK FOR TRAINS sign used in Austin.

conceivably be used for any type of transit service and at any type of rail transit crossing with multiple trains in multiple directions.

Warning signs are used on the roadway to warn drivers of the need to stop for streetcar users loading or alighting. An example of a sign used in Boston is shown in Figure 49 (see Treatment 11), and signs from Dallas are shown in Figure 73 and Figure 51 (see Treatment 11).

Because of the number of suicides occurring in Los Angles, the city created a sign to provide the phone number for the suicide crisis line (see Figure 74).

Benefits

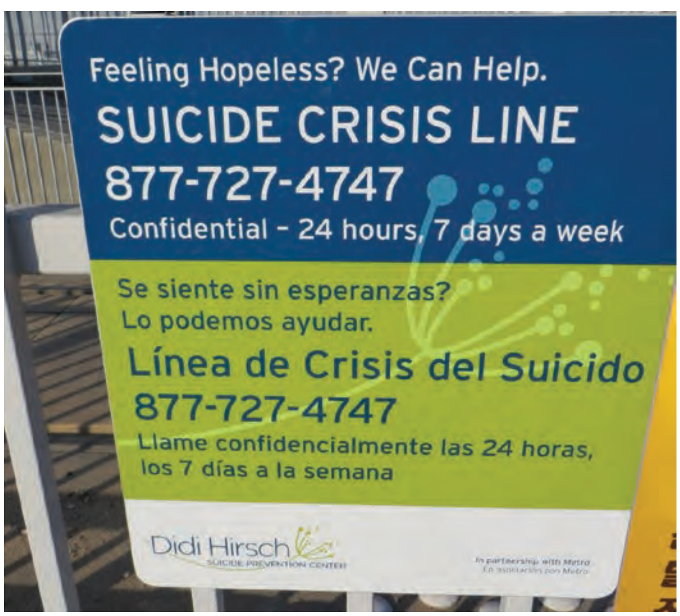
Warning signs draw pedestrians' attention to potentially hazardous conditions and advise them of the appropriate behavior to take in response. The specific safety benefits can vary greatly depending on the sign and how it is used, but signs have the potential to reduce crashes and improve operations in and around crossings.

Source: Fitzpatrick

Figure 72. LOOK BOTH WAYS BEFORE CROSSING warning sign in Baltimore.

Source: Brewer

Figure 73. Example of a LOADING AND UNLOADING AHEAD sign and plaque used on the roadway in Dallas.



Source: Fitzpatrick

Figure 74. Suicide crisis sign used at stations in Los Angeles.

Cost

Per the 2012 California contract data, the average cost of a sign is $18/square ft (*65*). Bushell et al. (*68*) provide an average of $300 for STOP/YIELD signs and a range of $530 to $2,150 for trail wayfinding/information signs.

Treatment 19: Signs—Signs for Enforcement

Description

As with warning message treatments, transit agencies are using unique signs that describe specific enforcement messages that are not found on a widespread basis.

Applications

MUTCD regulatory and warning signs provide information through standardized text and symbols that are applicable nationwide. There are situations, however, when an MUTCD sign does not contain the message most applicable to a particular location or set of conditions. In these situations, transit agencies may develop their own sign that provides needed information to the pedestrian on the consequences of improper crossing or other illegal or unsanctioned behavior.

Common applications include signs that advise pedestrians of punishments for violating traffic control devices or entering restricted locations. The main purpose of these warning signs is to provide a conspicuous message to pedestrians about the ramifications of improper behavior at or near the crossing. Such signs could conceivably be used for any type of transit service and at any type of rail transit crossing with multiple trains in multiple directions.

Implementation

Signs must be installed so that their presence improves the information provided to the pedestrian. Signs must have a clear message and must be maintained so that they encourage pedestrians' respect for the sign and the desired behavior. Signs with an unclear message will likely do little to encourage compliance. As with warning message signs, because these signs are not found in the MUTCD, a transit agency may require permission from FHWA to experiment before installing a particular sign, depending on the nature and location of the sign.

Examples of observed signs include the following:

- Figure 75 shows signs located along the pedestrian crossing informing pedestrians to not cross when the lights are active and where to wait when the lights are flashing.
- At a station with a history of loitering, Portland installed a TRANSIT USE ONLY sign that noted "Subject to fine exclusion or arrest" (see Figure 76).
- Los Angeles uses an in-station sign cautioning patrons to stay behind the yellow line on the platform and that trespassers are subject to arrest (see Figure 77).
- Figure 78 shows the words DO NOT CROSS TRACKWAY in black on a white background used at a station in Portland.
- Portland has a No Pedestrian Crossing sign that also includes a train track graphic (see Figure 79 and Figure 80).
- Dallas pairs a sign with a No Pedestrian symbol (R9-3) with a yellow warning sign that says CAUTION STAND AWAY FROM PLATFORM EDGE (see Figure 81).
- Figure 82 shows an example of a NO TRESPASSING sign in Austin.

Source: Fitzpatrick

Figure 75. Example of signs used at a Los Angeles station to communicate the need to not cross when the lights are flashing and that pedestrians should stop behind the yellow detectable warning stripe.

Source: Fitzpatrick

Figure 76. TRANSIT USE ONLY sign used in Portland.

Source: Fitzpatrick

Figure 77. Example of the sign used at a Los Angeles Metrolink station to reinforce the pavement marking message of staying behind the yellow line.

Source: Warner

Figure 78. DO NOT CROSS TRACKWAY message used in Portland.

Source: Fitzpatrick

Figure 79. Portland No Pedestrian Crossing sign that includes a train track symbol.

Source: Fitzpatrick

Figure 80. A NO TRESPASSING sign used in Portland also showing the No Pedestrian on Track symbol along with DO NOT ENTER on the pavement at the edge of a pedestrian crossing.

Source: Fitzpatrick

Figure 81. Example of warning and regulatory signs used within a station in Dallas.

Source: Fitzpatrick

Figure 82. NO TRESPASSING sign in Austin prohibiting pedestrians.

Source: Fitzpatrick

Figure 83. Pedestrian prohibition signing and pavement marking.

- To increase the emphasis on the pedestrian restriction, Los Angeles adds a word message sign mounted on a fence that says PEDESTRIANS PROHIBITED to a sign with the No Pedestrian symbol (R9-3). Los Angeles also shows the No Pedestrian symbol on the pavement (see Figure 83).
- Portland includes a NO TRESPASSING sign at one of its crossings (see Figure 84).
- Examples of signs used in Baltimore show one including the No Pedestrian Crossing symbol on a sign that also says NOT A PEDESTRIAN WALKWAY (see Figure 85) and another using only words (see Figure 86) to prohibit pedestrians and to note that violators will be prosecuted.

Source: Fitzpatrick

Figure 84. NO TRESPASSING sign along with other signs at a Portland crossing.

Source: Fitzpatrick

Figure 85. Not a Pedestrian Walkway warning sign in Baltimore.

Source: Fitzpatrick

Figure 86. Signs in Baltimore prohibiting pedestrians.

Benefits

Signs draw pedestrians' attention to potentially hazardous conditions and inform them of the appropriate behavior that they should take in response. In addition to improving compliance, safety benefits are realized as well if pedestrians heed the signs and reduce risky crossing behaviors. Benefits vary greatly depending on the sign and how it is used, but signs have the potential to reduce crashes and improve operations in and around crossings.

Cost

Per the 2012 California contract data, the average cost of a sign is $18/square ft (*65*).

Treatment 20: Signs—Blank-Out Warning

Description

Blank-out warning sign treatments have a display that activates when a train is approaching.

Applications

MUTCD signs provide information through standardized text and symbols that are applicable nationwide. There are situations, however, when an MUTCD static sign does not sufficiently capture the attention of approaching pedestrians or contain the message most applicable to a particular location or set of conditions. In these situations, transit agencies may install signs with a display that changes depending on the conditions at a particular crossing. In contrast to passive signs that continually show symbols and/or text on a metal material, blank-out signs only provide a message when relevant.

Common applications include warning signs that advise pedestrians of an approaching train. These signs are blank by default and only show a display as trains approach, or these applications may be composed of passive signs with beacons that flash as a train approaches. Other applications include advising pedestrians to look in both directions before crossing the tracks, particularly at crossings with multiple tracks, where a second train may arrive shortly after a train passes through the crossing area. Such signs could be used for any type of transit service and at any type of rail transit crossing with multiple trains in multiple directions.

LRT approaching-activated blank-out warning signs (W10-7) (see Figure 87) are also known as train-activated signs or blank-out signs. They supplement the traffic control devices to warn road users crossing the tracks of approaching LRT equipment and may be used at signalized intersections near highway-LRT grade crossings or at crossings controlled by STOP signs or automatic gates.

Source: FHWA, 2009 (*8*)

Figure 87. LRT approaching-activated blank-out warning sign from the MUTCD.

Implementation

These signs must have access to electrical power in order for their active elements to function; signs must therefore be connected to wired power, have a solar power source, and/or have a battery power source. Signs must be installed so that their presence improves the information provided to the pedestrian. Signs that have an unclear message (through unfamiliar symbols and/or vague text) may actually exacerbate the problem they are intended to address. The message on the sign must be visible to its intended audience; for example, signs that are blank by default must be sufficiently bright when activated to attract the pedestrian's attention. The signs are more effective when the warning is within a short time of the second train approaching. Signs that are on for too long may be ignored. Because some of the signs being used are not found in the MUTCD (*8*), a transit agency may need permission from FHWA to experiment before installing a particular sign, depending on the nature and location of the sign.

A variety of blank-out signs and sign assembles with flashing beacons have been used to warn pedestrians of the presence of a second train, which has resulted in several different active signs being used, as documented by FRA (*75*). Figure 88 shows an example of a blank-out sign being used in Baltimore, and Figure 89 shows a blank-out sign in Dallas being used on a roadway. An innovative blank-out sign used to communicate the need to look in both directions because there are trains on multiple tracks is shown in Figures 90 and 91.

Los Angeles is installing blank-out signs next to a pedestrian signal head since that is the location toward which pedestrians will look. Figure 92 shows an example of an installation.

Benefits

The specific safety benefits of blank-out signs can vary greatly depending on the signs and how they are used, but signs have the potential to reduce crashes and improve operations in and around crossings. A demonstration project in Los Angeles (*76, 77*) investigated whether risky pedestrian crossing behavior would change due to a train-activated warning sign. The project was conducted on the south sidewalk at the Vernon Avenue intersection with the Metro Blue Line and Union Pacific Railroad (UPRR) tracks. The sidewalk crosses two LRT tracks and two UPRR freight tracks. Through the analysis of before and after video data, the demonstration project showed that the warning sign was effective in reducing risky behavior by pedestrians. Overall,

Source: Fitzpatrick

Figure 88. Example of an active blank-out sign with audible warning on the side in Baltimore.

Source: Brewer

Figure 89. Example of a blank-out sign in Dallas on signal mast arm.

Source: Fitzpatrick

Figure 90. The pictogram within this blank-out sign in Los Angeles shows a side view of trains approaching from the left.

Source: Fitzpatrick

Figure 91. The pictogram within this blank-out sign in Los Angeles shows a side view of trains approaching from the right.

the number of pedestrians crossing the LRT tracks at less than 15 seconds before an LRT train entered the crossing was reduced by 14 percent after the warning sign was installed. The number of pedestrians crossing the tracks at 6 seconds or less before an LRT train entered the crossing was reduced by about 32 percent. The number of pedestrians crossing the tracks at 4 seconds or less before an LRT train entered the crossing was reduced by 73 percent.

Blank-out signs are illuminated to display a message to motorists, pedestrians, and cyclists when an event has occurred such as the approach of a train. The signs may also be used to notify

Source: Fitzpatrick

Figure 92. Example of train blank-out signs mounted above the pedestrian signal head.

motorists, pedestrians, and cyclists of a left- or right-turn prohibition due to a train coming. According to *TCRP Report 137* (*4*), transit agencies reported improved performance with blank-out signs because they provide more specific, useful, and timely information to motorists, pedestrians, and cyclists. In addition, the *TCRP Report 137* project team heard more positive feedback about turn-restriction blank-out signs than about blank-out signs with the train symbol. Blank-out signs should be illuminated long enough to allow motorists and pedestrians to respond and to clear the tracks, but not so long that the sign becomes ineffective (perceived as incorrect) or easy to ignore.

Cost

Considering the wide variety of sizes and complexity of available blank-out signs, vendors indicate a cost range of between $1,800 and $5,500 per sign.

Treatment 21: Signals—Timing Considerations near Railroad Crossings

Description

Signals provide an indication to tell pedestrians (or motorists) when they are allowed and not allowed to proceed.

Applications

When the train operates within the street alignment, traffic control signals may be present to control both vehicle and pedestrian movements. Several characteristics of the traffic control signals can affect the safety and operations of pedestrians crossing both the roadway and the tracks. Information about traffic control signals is available in Chapter 4 of the MUTCD (*8*).

MUTCD 4E (*8*) requires the use of countdown signal heads at crossings where the pedestrian change interval is longer than 7 seconds; the countdown signal informs pedestrians of the number of seconds remaining in the pedestrian change interval. While some transit agencies are using pedestrian signals (as discussed in *TCRP Report 137* [*4*]), the proposed revisions to the MUTCD developed by the Railroad/Light Rail Transit Technical Committee (*59*) include the following:

> Standard: Pedestrian signals as described in Chapter 4E utilizing Upraised Hand and Walking Person symbols shall not be used at a pathway or sidewalk grade crossing except as provided in the following option.
>
> Option: A pedestrian signal may be used at a pathway or sidewalk grade crossing where the movements of LRT vehicles are controlled by a traffic control signal.

This proposed revision to the MUTCD (*8*) will eliminate the use of pedestrian signals at pathway or sidewalk grade crossings with the exception of locations where LRT vehicles are controlled by a traffic control signal (*59*).

Implementation

Examples of signal timing considerations include the following:

- **Pedestrian signal heads.** Pedestrian signal heads are active signal devices that tell pedestrians when it is permissible to begin or to continue a crossing. The MUTCD pedestrian crossing signal heads are composed of a walk symbol (walking person) that indicates the interval during which crossings should be initiated, a flashing upraised hand that indicates that a crossing

Source: Fitzpatrick

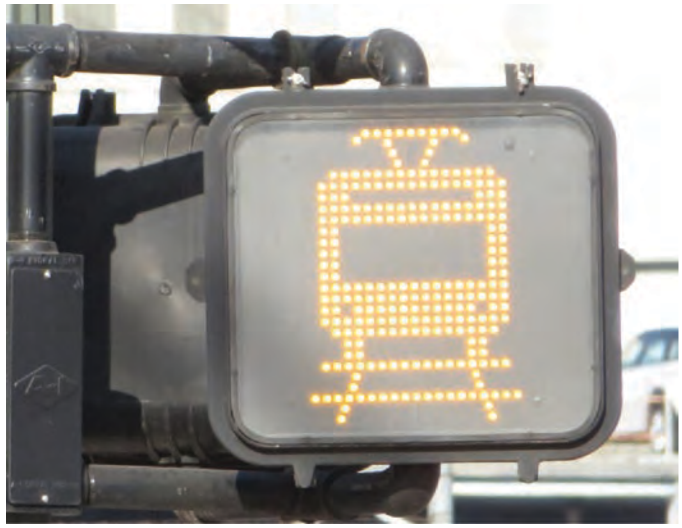
Figure 93. Example of the pedestrian signal head used at a pedestrian crossing near a station in Los Angeles with a blank-out sign showing the train.

should not be started but may be completed, and a solid upraised hand that indicates when pedestrians should not enter the roadway. Los Angeles, in some locations, has added a blank-out sign next to the pedestrian signal head that illuminates a train symbol when a train is entering, exiting, or in the station. An example of this can be seen in Figure 93, where next to the solid upraised hand symbol (closeup shown in Figure 94) indicating that pedestrians should not start a crossing, is a blank-out sign showing the train (closeup shown in Figure 95).

- **Priority control of traffic signals near rail transit crossings.** Priority control may be used at rail transit grade crossings to decrease delay for rail vehicles. This treatment is potentially

Source: Fitzpatrick

Figure 94. Closeup of a countdown indication used in conjunction with a blank-out sign.



Source: Fitzpatrick

Figure 95. Closeup of a blank-out sign used in conjunction with a pedestrian signal head.

applicable to any pedestrian-rail crossing at a signalized intersection and may be achieved by numerous signal timing strategies. MUTCD 4D.27 states that priority control is typically given to "LRT vehicles." During transition into priority control, the omission of the entire pedestrian phase is permitted; however, shortening or omission of a pedestrian change interval during the transition is not permitted. Omission or shortening of the pedestrian change interval places all pedestrians at risk, but especially pedestrians with disabilities who may not be able to increase their rate of travel across the tracks or to quickly reverse direction. When temporary alterations to the normal timing sequence at an intersection are being considered for a rail crossing, special attention should be paid to ensuring that approaching trains are both visible and audible.

- **One- versus two-stage crossings.** At complex intersections, such as those where major turning movements are present or the light rail operates within the street alignment, signal timing to accommodate all modes can result in a very long cycle. At intersections with long cycles and thus long wait times for the pedestrians, pedestrians may frequently initiate crossings during the flashing or steady Don't Walk intervals. A potential approach for addressing the long wait times for pedestrians when the light rail is operating in the median is to accommodate the pedestrian crossing movement in two stages. For example, in Portland, the city standard is to provide one-stage crossings; however, Portland has a location where the longer clearance interval results in fewer opportunities to cross (more delay) for pedestrians. Implementation of a two-stage crossing was beneficial for most of the people at this particular location because the majority of users were traveling to the median. Rather than having a phase with a long crossing time that would permit the crossing of the entire street/rail, the city timed the signal so pedestrians could cross to the median. The pedestrian would then need to push the pedestrian button in the median to obtain the walk signal for the second-stage crossing. The two-stage pedestrian signal timing has a shorter pedestrian flashing upraised hand interval, resulting in a shorter cycle. A shorter cycle allows the pedestrian walk signal to occur more times within a given time period.
- **Pedestrian push button.** When the train station is located in the median, pedestrian push buttons should be present; otherwise, pedestrians, especially blind pedestrians, could be stranded in the median. Figure 96 shows an example of a pedestrian push button at the end of a station located within the median of a street. At this station, the pole used to house the push button also includes a blank-out sign with a train symbol that is viewable for those pedestrians leaving the station.

Source: Fitzpatrick

Figure 96. Example of a pedestrian push button located in a median between tracks.

Benefits

The use of similar traffic control devices at rail crossings and roadway crossings provides uniformity in communicating the same message of when it is appropriate to walk or not walk through a crossing.

Cost

California 2012 contract data show an average cost of $33,467 for a traffic control signal (*65*).

Treatment 22: Signals—Flashing-Light Signal Assembly

Description

Flashing lights provide additional notice to pedestrians that a train is approaching the crossing.

Applications

The typical railroad flashing-light assembly can warn motorists and pedestrians that a train is present or about to enter the crossing area. The flashing lights are intended to capture approaching pedestrians' attention more readily than passive signs alone. This treatment could be used at any pedestrian-rail crossing where pedestrians would benefit from additional visual confirmation of approaching trains; specific locations could include those where trains do not stop and the pedestrian-rail crossing has limited sight distance such that an approaching train is not always visible to crossing pedestrians.

Implementation

The concept for the railroad flashing-light assembly has a long history of use on roadways. Portland is installing several of the devices. Figure 97 shows an installation located along a pedestrian-only crossing (i.e., a pedestrian-rail grade crossing not adjacent to motor vehicle crossing or in a station) and Figure 98 is a closeup of the treatment. A pedestrian-scale version has recently been explored and developed. The pedestrian-scale device is not currently in the

Source: Fitzpatrick

Figure 97. Flashing-light signal assembly example installed in Portland.

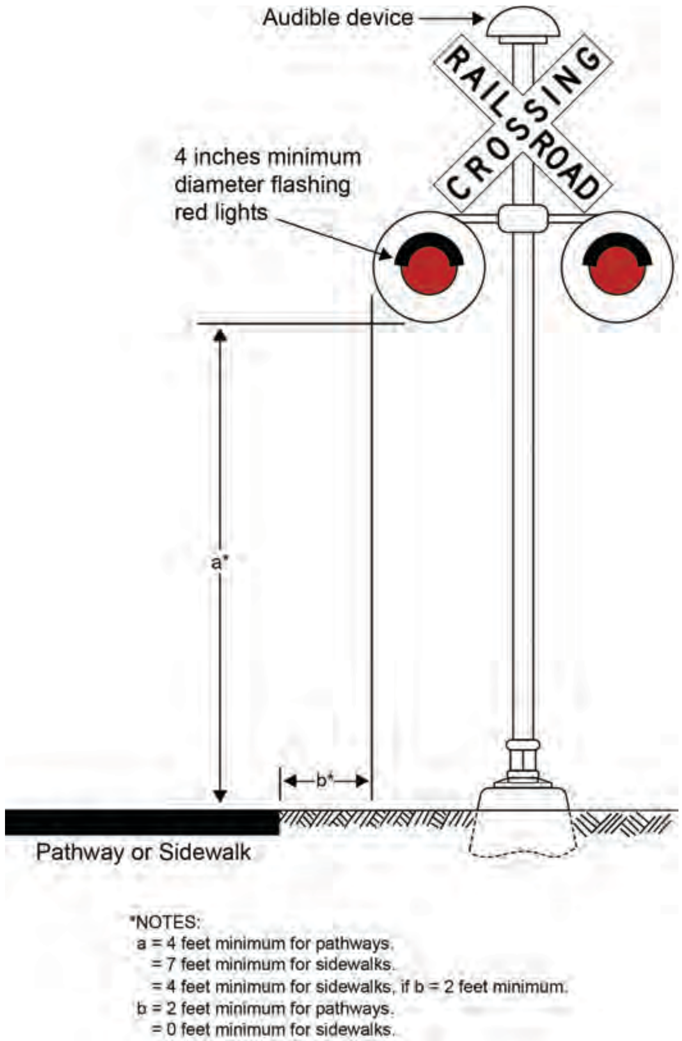
MUTCD (*8*) but has been proposed for consideration (see Figure 99) by the NCUTCD Railroad/Light Rail Transit Technical Committee (*59*).

Benefits

Specific benefits have not been documented because the treatment is new, but it is anticipated that the treatment will help inform pedestrians of the presence of the crossing and encourage pedestrians to not cross in front of approaching trains.

Source: Fitzpatrick

Figure 98. Closeup of a flashing-light signal assembly example installed in Portland.



Source: adapted from *RRLRT No 2a (9-08012) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-11 (*59*)

Figure 99. Example of a flashing-light signal assembly for a pathway or sidewalk grade crossing.

Cost

Sriraj and Metaxatos (*69*) provide an estimated railroad cost of $65,169 for the installation of pedestrian flashing-light signals, crossing gates, and bells along with advance warning signs and pavement markings for a site in Illinois.

Treatment 23: Signals—In-Pavement Flashing Lights

Description

In-pavement flashing lights are lights embedded into the pavement that flash when activated.

Applications

In-pavement flashing lights supplement traditional pavement markings. The MUTCD (*8*) provides guidance regarding yellow in-pavement flashing lights in Chapter 4N, "In-Roadway Lights."

Yellow flashing lights embedded in the walking surface illustrate the location of the crossing to motorists. Similar to crosswalk markings, these yellow flashing lights can also show the appropriate path for pedestrians to take through a crossing. This treatment has been used in various pedestrian crosswalks on streets across the United States, with the purpose being more to encourage driver compliance rather than provide pedestrian guidance. Several examples exist of the use of yellow in-pavement lights in roadway crosswalks. Currently, use of this treatment with respect to rail crossing is not identified; however, per the FRA's *Compilation of Pedestrian Safety Devices in Use at Grade Crossings* (*5*), Oregon has expressed interest in the use of train-activated, in-pavement flashing lights at high-profile, high-traffic pedestrian locations.

Red in-pavement flashing lights are not in the MUTCD (*8*); however, they have been used on an experimental basis to supplement the message of STOP. They were used at the Paramount Boulevard and Rosecrans Avenue highway-rail crossing in Paramount, California. As documented in *NCHRP Synthesis 380* (*78*), red in-pavement lights were installed because the railroad crosses diagonally across the intersection, the intersection is too wide for regular railroad crossing gates, and there are sight distance challenges. When the train has a green indication, all vehicle traffic approaches receive a red indication, and the red in-pavement markers flash.

Red in-pavement flashing lights have also been used by Houston Metro at intersections on the Main Street Line to supplement the stop message. As documented in *NCHRP Synthesis 380* (*78*), stop-bar systems at 13 approaches were installed between 2006 and 2007. Four of the approaches also have red light-emitting diode (LED) back plates added to the signal head to help reinforce the stop message (see Figure 100). Houston Metro is also using the in-pavement flashing red lights to indicate left-turn restrictions. The red in-pavement flashing lights were installed on the northbound and southbound approaches of Fannin Street at Dryden to supplement a dynamic lane control assignment system (see Figure 101). A single row of red in-pavement flashing lights was placed along the lane line between the left-turn lane and the left through lane.

Implementation

While there are examples of red in-pavement flashing-light installations as an additional method of communicating the need to stop for trains; this treatment is experimental. Because of promising motorist-yielding results for roadside sign assemblies with yellow beacons (*79*), roadside and overhead sign assemblies with beacon installations are now viewed more favorably than crosswalk in-pavement flashing lights, especially due to in-pavement maintenance concerns (e.g., the effects of rain, snow, and road grime/debris on visibility).

Source: Fitzpatrick

Figure 100. Example of red back plates added to signal heads to help reinforce the stop message in Houston (the mast arm also includes a blank-out sign showing a train).

Source: *NCHRP Synthesis 380* (*78*)

Figure 101. Left-turn-restriction, in-pavement, flashing-light system application in Houston (IPM = in-pavement markings).

Benefits

Documented safety benefits for a pedestrian-rail-related installation were not identified.

Cost

The demonstration project at Paramount Boulevard and Rosecrans Avenue was reported in 2008 to have cost between $55,000 and $60,000 (*78*).

Treatment 24: Pavement Markings—Pedestrian Stop Lines

Description

Pedestrian stop lines are pavement markings that show pedestrians where to stop before entering the crossing.

Applications

Stop lines indicate where pedestrians should wait on the approach to a crossing in order to be a safe distance from the dynamic envelope of rail vehicles in the crossing and from gates, counterweights, or flashing-light assemblies. Stop lines can be used at any pedestrian-rail crossing that would benefit from additional guidance to waiting pedestrians, particularly locations where a large number of pedestrians frequently gather while waiting to cross.

Implementation

The MUTCD (*8*) provides the following guidance regarding stop lines:

> [I]f used at pathway grade crossings, the pathway stop line should be a transverse line at the point where a pathway user is to stop. The pathway stop line should be placed at least 2 ft further from the nearest rail than the gate, counterweight, or flashing-light signals (if any of these are present) is placed, and at least 12 feet from the nearest rail.

Graphics illustrating where stop line and detectable warnings are often located are shown in the following figures:

- Figure 33 (see Treatment 4) in relation to barriers used to reorient pedestrians.
- Figure 58 (see Treatment 15) for tracks at a skew to the sidewalk.
- Figure 59 (see Treatment 15) for tracks at a right angle to the sidewalk.
- Figure 62 (see Treatment 17) for a pathway grade crossing.

Figure 102 shows an example of a stop line in conjunction with other signing and marking at a pathway grade crossing, including a detectable warning. Portland consistently maintains a STOP HERE pavement stop bar behind detectable warning strips (see Figure 102) and also behind swing gates (see Figure 103). Los Angeles uses the message WAIT HERE (see Figure 104) to indicate where pedestrians should stand while a train crosses. None of these photographs shows a stop line placed as far as 12 ft from the nearest rail, as recommended by MUTCD 8D.04 guidance (*8*). Where transit is in mixed-use or semi-exclusive alignment, it is rarely feasible to place stop lines as far as 12 ft from the nearest rail.

Benefits

Pedestrian stop lines provide positive guidance to keep pedestrians a safe distance from passing trains.

Cost

Per the 2012 California contract data, the average cost of thermoplastic crosswalk and pavement marking is $2.00/square ft (*65*).

Source: Fitzpatrick

Figure 102. Example of STOP HERE pavement marking used with detectable warning at a Portland station pedestrian crossing.

Source: Fitzpatrick

Figure 103. Example of STOP HERE pavement marking in conjunction with a swing gate in Portland.

Source: Fitzpatrick

Figure 104. WAIT HERE stripe along with detectable warning and diagonal striping to indicate the dynamic envelope of train cars in Los Angeles.

Treatment 25: Pavement Markings—Detectable Warnings

Description

Detectable warnings are a standardized walking surface, detectable by visually impaired pedestrians, that is installed at pedestrian-rail crossings to provide a boundary between a pedestrian walkway, boarding platform, or refuge and a vehicular travel area.

Applications

The surface texture for detectable warnings is defined in ADA standards (*57*, *58*,) and is sometimes referred to as truncated domes or truncated dome detectable warnings.

The approach to a pedestrian-rail crossing may not be apparent to a pedestrian who is blind or who has low vision. Detectable warning surfaces are standardized surfaces comprised of small truncated domes that provide an underfoot warning of the edge of the street or rail crossing and that contrast visually with adjacent walking surfaces, either light on dark or dark on light. Detectable warnings are required to warn pedestrians of level crossing locations and are appropriate for all types of pedestrian-rail crossings for any type of transit service (see an example in Figure 105). Detectable warnings are also required on platform edges in rail stations, as shown in Figure 106, and on curb ramps and hazardous vehicular ways where there is no difference in elevation between the roadway and the pedestrian way.

Implementation

The MUTCD (*8*) references the *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities* (*61*) for "specifications for design and placement of detectable warning surfaces." More recent publications, like *ADA Standards for Transportation Facilities* (*57*) and the *Proposed PROWAG* (*58*), provide additional information regarding the use of detectable warnings at rail crossings.

The specifications for detectable warning surfaces, which are the same in all three documents referenced above, require a surface of truncated domes, with a center-to-center spacing of 41 mm (1.6 inches) minimum and 61 mm (2.4 inches) maximum, and a base-to-base spacing of 17 mm (0.65 inches) minimum, measured between the most adjacent domes.

Source: Warner

Figure 105. Example of white detectable warnings used at an in-station pedestrian-rail crossing.

Source: Fitzpatrick

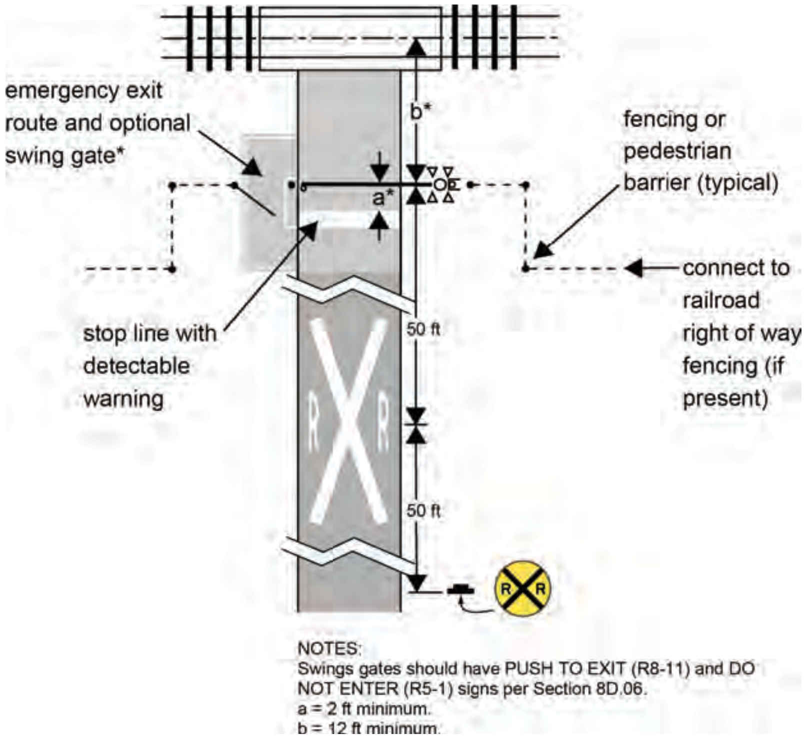
Figure 106. Example of a yellow detectable warning strip used at the edge of a platform.

The *Proposed PROWAG* (*58*) provides the following specifications regarding detectable warning placement at pedestrian at-grade rail crossings:

> **R305.2.5 Pedestrian At-Grade Rail Crossings.** At pedestrian at-grade rail crossings not located within a street or highway, detectable warning surfaces shall be placed on each side of the rail crossing. The edge of the detectable warning surface nearest the rail crossing shall be 1.8 m (6.0 ft) minimum and 4.6 m (15.0 ft) maximum from the centerline of the nearest rail. Where pedestrian gates are provided, detectable warning surfaces shall be placed on the side of the gates opposite the rail.
>
> **R305.2.6 Boarding Platforms.** At boarding platforms for buses and rail vehicles, detectable warning surfaces shall be placed at the boarding edge of the platform.
>
> **R305.2.7 Boarding and Alighting Areas.** At boarding and alighting areas at sidewalk or street level transit stops for rail vehicles, detectable warning surfaces shall be placed at the side of the boarding and alighting area facing the rail vehicles.

A graphic accompanies the text. The *Proposed PROWAG* (*58*) states that the edge of the detectable warning shall be 6 to 15 ft from the centerline of the nearest rail. The NCUTCD Railroad/Light Rail Transit Technical Committee developed recommended revisions to the MUTCD (*8*) for section 8D on sidewalk and pathway rail grade crossings in June 2013 (*59*). The committee recommended that the detectable warning be placed a minimum of 12 ft (rather than between 6 and 15 ft) from the nearest rail (see examples in Figure 59 for right-angle crossings [Treatment 15], Figure 58 for skewed crossings [Treatment 15], Figure 62 for pathway crossings [Treatment 17], and Figure 107 for location relative to a pedestrian gate).

Detectable warning surfaces are properly installed in pairs to indicate the beginning and end of travel within a hazardous area. Visually impaired pedestrians who detect the truncated dome detectable warning surface in the vicinity of a rail crossing are expected to understand that if a train is approaching, they should stand behind the truncated domes to avoid both being too close to the track when a train crosses and being struck by a descending gate arm. The contrasting truncated dome surfaces should be placed across the full width of the pedestrian way and, if there is a gate arm, be installed on the side of the gate arm opposite the tracks, as shown in Figures 107 and 108. In Figure 108, the small fence to the right of the detectable warning is a more effective treatment for preventing pedestrians who are visually impaired from being struck by the counterweight than extending the detectable warning farther to the right.



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-5 (*59*)

Figure 107. Example of detectable warning placement in association with a pedestrian gate.

Source: Fitzpatrick

Figure 108. Detectable warnings installed across a sidewalk at an automatic gate arm on the side opposite the tracks.

Detectable warnings are sometimes placed where there are swing gates; however, it is unclear whether detectable warnings are really needed at these locations because the presence of the swing gates communicates the warning message to the pedestrian. The *Proposed PROWAG* (*58*) does not distinguish between automatic gates and swing gates. When used, the detectable warnings should be on the side away from the tracks.

Where there is shared alignment at a crossing with a boarding platform, whether center or side running, truncated dome detectable warnings should define the refuge at the end of the platform and help pedestrians with visual impairments to locate the platform. Case Study C in Chapter 9 discusses detectable warning considerations for this situation.

In some locations, detectable warnings seem to have been installed to indicate to pedestrians who are visually impaired that they could be walking into an area where they could be struck by the counterweight of either a pedestrian or vehicular gate arm. However, this use may not be as effective or clear to pedestrians who are blind as other types of treatments such as providing a barrier or installing the counterweight outside the pedestrian circulation path, as shown in graphics developed by NCUTCD (see Figure 59 [Treament 15]).

Benefits

Detectable warnings provide information to pedestrians with visual disabilities and pedestrians who are distracted, improving their ability to recognize the existence of a crossing. This, in turn, is intended to improve safety by reducing the likelihood that pedestrians will unknowingly enter a crossing in front of an approaching train.

Cost

A representative cost of detectable warning material is $35/square ft (*65*).

Treatment 26: Pavement Markings—Word or Symbol

Description

Symbol or word messages can be placed on the pavement in appropriate locations to communicate a message.

Applications

Word or symbol markings on the pavement are used for the purpose of guiding, warning, or regulating traffic. These pavement markings can be helpful to pedestrians in some locations by providing additional emphasis on where they should or should not be walking or standing.

Implementation

The 2009 MUTCD (*8*) provides guidance regarding pavement word, symbol, and arrow markings in Section 3B.20. Figure 109 is a photo of a station in Los Angeles where the No Pedestrian symbol was added to the pavement to inform pedestrians that they should not be in that area. The pavement marking supplements the sign located on the nearby fence. In addition to the symbol, the words NOT A WALK are provided on the yellow crossing edge line. Raised white buttons were also installed in the area. They provide a tactile warning that the pedestrian or bicyclist has strayed from the appropriate path. Portland has a DON'T STAND HERE message along with a line through a pair of footprints to indicate where pedestrians should not stand

Source: Fitzpatrick

Figure 109. Symbol and word pavement markings that supplement signs indicating where pedestrians should not be walking.

(see Figure 110). Another example of the use of a word message is in Baltimore where LOOK with an arrow was installed (see Figure 111). Additional examples of messages used with stop lines are shown in Figures 103 and 104 [Treatment 24].

Benefits

Symbol or word pavement messages provide supplemental information or warning at the location where the pedestrian is looking.

Cost

Bushell et al. (*68*) provide an average cost of $360 for a pedestrian crossing pavement marking symbol. They note that costs vary due to the type of paint used and the size of the symbol, as well as whether the symbol is added at the same time as other road treatments.

Source: Fitzpatrick

Figure 110. Pavement markings in Portland informing pedestrians DON'T STAND HERE.

Source: Fitzpatrick

Figure 111. ***LOOK pavement markings near detectable warning in Baltimore.***

Treatment 27: Pavement Markings—Dynamic Envelope Markings

Description

Dynamic envelope markings indicate the area that a train occupies and advise nearby pedestrians to remain clear of that area.

Applications

Dynamic envelope markings indicate the clearance required for the train or LRT equipment overhang resulting from any combination of loading or lateral motion. Pavement marking, pavement striping, and pavement appearance or texture changes are used to denote the dynamic envelope of rail vehicles. These treatments indicate the extent of the area in which pedestrians or vehicles are in danger of being struck by a rail vehicle.

Implementation

If used for indicating the dynamic envelope, pavement markings shall comply with the provisions of MUTCD Part 3 (*8*) and shall be a 4-inch normal solid white line or contrasting pavement color and/or contrasting pavement texture. Pavement marking and texturing require ongoing maintenance. They are effective in areas where snow and/or ice do not cover the markings. Rain can make markings difficult to see.

Some of the in-street operations in the downtown Portland area have a different surface to show visually and tactually where the train operates. Figure 112 shows the brick pattern surface for vehicles with a smooth concrete surface for the train in downtown Portland. Figure 113 shows a white lane line between the train and vehicle parking to indicate the dynamic envelope for the train. Figure 114 shows an example of raised curbs to delineate the dynamic envelope in Los Angeles. Figure 115 shows raised buttons on the pavement being used in Austin, and Figure 116 provides a closeup of the Austin buttons. Figure 117 shows the buttons in use in Dallas (and visual and textural differentiation between the dynamic envelope of the train and the adjoining surface).

Source: Fitzpatrick

Figure 112. Example of using smooth concrete for the train as compared to the brick pattern in the neighboring lanes.

Source: Fitzpatrick

Figure 113. Example of a dynamic envelope surface treatment along with a white line between the train and parking lane.

Source: Fitzpatrick

Figure 114. Example of a raised curb used alongside tracks in Los Angeles.

Source: Fitzpatrick

Figure 115. Example of raised buttons used alongside tracks in Austin.

Source: Fitzpatrick

Figure 116. Closeup of raised buttons used alongside tracks in Austin.

Source: Fitzpatrick

Figure 117. Example of raised buttons in Dallas along with visual and texture differentiation between the dynamic envelope of the train and the adjoining surface.

None of the pavement markings here are reliably detectable underfoot or with a long white cane to pedestrians who are visually impaired or blind, with the exception of the raised curbs used in Los Angeles. The raised buttons used in Austin and Dallas are sufficiently far apart that a person who is visually impaired may not encounter them either underfoot or with a long white cane.

Benefits

Pavement marking, texturing, and striping are assumed to be effective in conveying information, but the effect of pavement marking, texturing, and striping on pedestrian and LRT crashes has not been quantified.

Cost

The typical linear-foot cost for installing pavement markings is low; however, this treatment could be applied to the entire length of the rail system. Per the 2012 California contract data, the average cost of 4-inch thermoplastic traffic stripe is $0.49/linear ft (*65*).

Treatment 28: Infrastructure—Audible Crossing Warning Devices

Description

Audible crossing warning devices emit an audible warning that supplements other treatments at pedestrian-rail crossings.

Applications

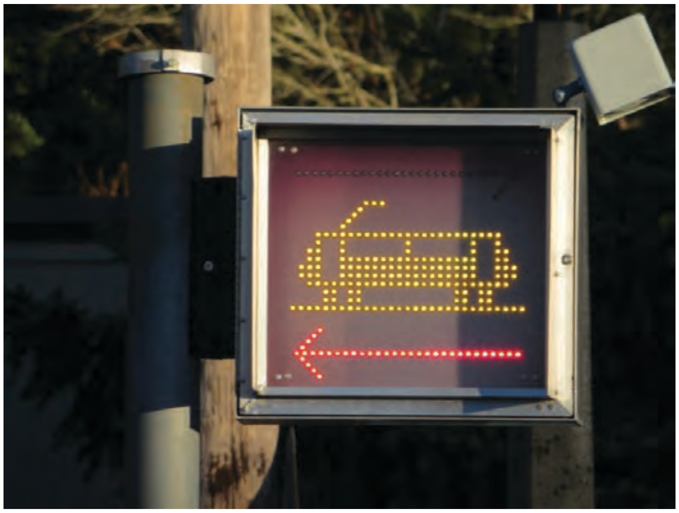
Audible signals are another active measure for pedestrian safety. Audible signals can be attached to other warning devices at the crossing, or on-vehicle audible warnings can be used. *TCRP Report 137* (*4*) provides the following summary about audible crossing warning devices:

> Audible crossing warning devices provide supplemental warning for pedestrians and cyclists. Audible warning devices such as bells, horns, and synthesized tones installed either onboard the LRV or wayside along the tracks or in association with automatic pedestrian or vehicular gates are used in conjunction with flashing light signals at grade crossings. The key design issues to consider are appropriate placement of the device, and tuning the sound produced so that the warning sound can easily be distinguished from the environmental noise in the area. Improving placement and the type of tone are believed to be more effective than simply increasing the device volume.

Figure 118 provides an example of an audible warning device installed near a blank-out sign.

Implementation

Extensive recommendations about the design and installation of audible signals can be found in *TCRP Research Results Digest 84* (*3*). Rules regarding the sounding of on-vehicle warning devices are usually outlined at the agency level and vary greatly depending on the agency. Many rail vehicles are equipped with multiple sound types, and operators may use different levels of sound in different situations. Because audible warnings may disturb residents, the warning may be limited or prohibited in quiet zones where there is residential development near the transit line. The report acknowledges that different transit agencies have different philosophies about sounding audible warnings and outlines a general overall practice for evaluating rules for sounding onboard audible warning devices at crossings. The evaluation system is based on three characteristics: emergencies, sight distance, and surrounding conditions.



Source: Fitzpatrick

Figure 118. Example of an audible warning device (upper right corner) installed near a blank-out sign.

In Portland, Oregon, an orientation and mobility specialist (a person qualified to teach independent travel skills to people who are visually impaired) and a pedestrian advocate who is blind independently mentioned that warnings that sound when automatic pedestrian gates are going down or up should sound throughout the time that trains are at the crossing or station. When the warning stops, pedestrians who are visually impaired may assume that the train has left, and it is safe to cross.

Benefits

Audible warning treatments are extremely helpful to travelers who are visually impaired, who may not hear approaching transit vehicles. This is especially true where transit vehicles are particularly quiet and the ambient noise level is high.

TCRP Research Results Digest 84 (*3*) describes the development and testing of two alternative audible warnings. The first is a conventional bell sound, while the second is a "blended staircase" signal that combines the sounds of an approaching train and a conventional crossing bell. The sounds were processed so that the pedestrian approaching the intersection hears a bell sound that rises in pitch and an approaching train that increases in loudness. The study did not produce conclusive evidence of the effectiveness of the audible warnings.

Cost

The typical cost of this treatment is approximately $385 each (*69*).

Treatment 29: Infrastructure—Pedestrian Automatic Gates

Description

Pedestrian automatic gates provide a physical block across the pedestrian path when a train approaches the crossing, is stopped within the crossing, and leaves the crossing.

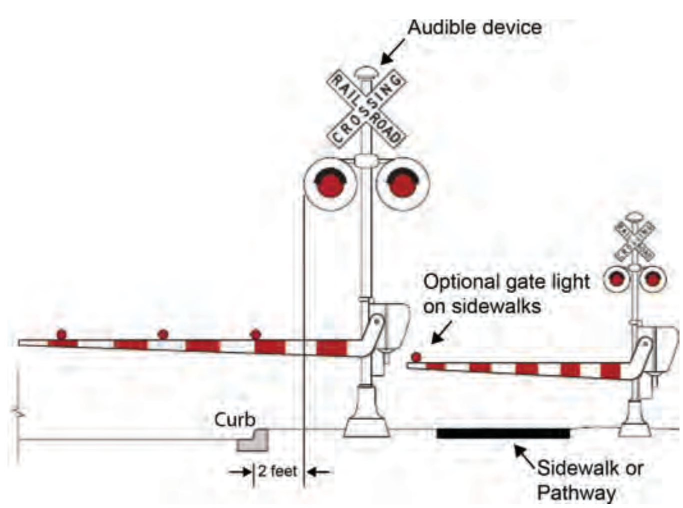
Applications

Pedestrian automatic gates descend when activated by train activity, blocking the pedestrian path across the tracks throughout the train activity duration. Figure 119 shows an illustration of a pedestrian gate placement separate from the automatic gate for vehicles at a sidewalk grade crossing. Figure 120 provides suggested dimensions for the pedestrian automatic gate.

The principle for the use of pedestrian automatic gates is similar to that for the use of gates on roadways—to stop motorists and cyclists when a train is approaching—except that a pedestrian automatic gate stops pedestrians. MUTCD Section 8C.13 (*8*) states that if an engineering study shows that flashing-light signals with a Crossbuck sign and an audible device would not provide sufficient notice of an approaching train, the LOOK sign and/or pedestrian gates should be considered. Based on the guidance for installing flashing-light signals when an engineering study determines that the sight distance is not sufficient for pedestrians and bicyclists to complete their crossing prior to the arrival of the train at the crossing, or where speeds exceed 35 mph, these are also the criteria for installing pedestrian gates. Figure 121 illustrates the installation of a pedestrian automatic gate at a crossing with pedestrian sight distance issues (the detectable warning is placed where it will be encountered by pedestrians who are traveling toward the rails, in advance of the gate).

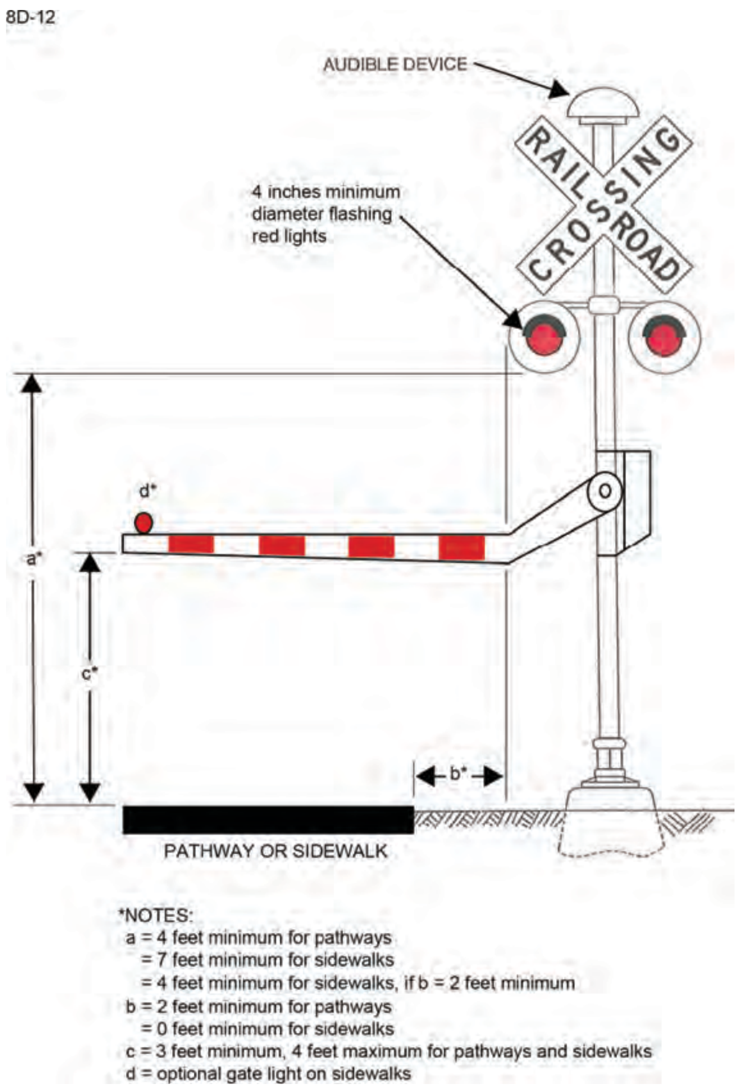
Pedestrian automatic gates may be provided in addition to roadway gates. On narrow streets, the pedestrian gate may be a part of the vehicle gate, with both pedestrians and vehicles blocked by a single gate for which the mechanism is placed outside the sidewalk, on the side farther from the roadway. A second gate is required on the downstream side of the rail crossing for pedestrians approaching the crossing from the opposite direction (see the example in Figure 122). Figure 123 shows another example of pedestrian automatic gates; in this example, the fence to the right of the gate arm prevents pedestrians from walking into the mechanism.

Korve et al. (*2*) recommend that pedestrian automatic gates be installed at all pedestrian crossings (sidewalks or other designated pathways) where sight distance is limited and leads to situations in which pedestrians are unable to see an approaching LRV until it is very close to the crossing, and/or LRV operators are unable to see pedestrians in the vicinity of the crossing until the LRV is very close. The pedestrian-controls decision tree from *TCRP Report 69* (see Figure 16 [Chapter 6])



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-15, (*59*)

Figure 119. Example of a separate automatic pedestrian gate for a sidewalk.



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-12 (*59*)

Figure 120. Suggested dimensions for pedestrian gate placement for a sidewalk.

also warrants pedestrian automatic gates at locations with high pedestrian surges/high pedestrian inattention and within school zones.

Implementation

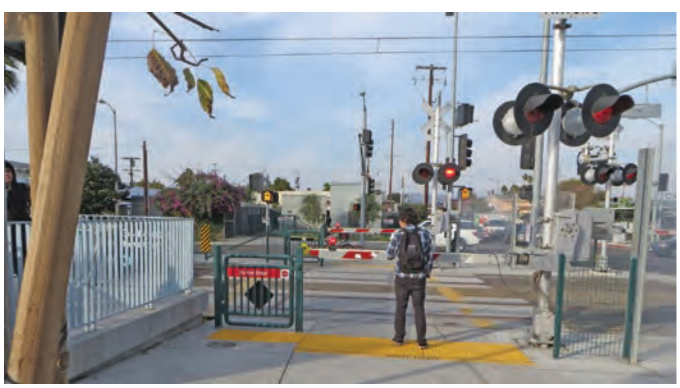
In locations where pedestrian safety concerns cannot be mitigated by other available treatments or when train speeds exceed 35 mph, pedestrian automatic gates should be considered in addition to vehicle gates. In some instances, placing the vehicle gate mechanism beside the sidewalk, on the side further from the roadway, will block pedestrians on the sidewalk along with vehicle traffic. A barrier, however, should be placed around the gate mechanism to prevent pedestrian interaction with (and possible injury from or damage to) the gate mechanism (see Figure 124). A consideration with using such a rigid barrier is that the barrier should only be used if the item to be shielded is a greater hazard than the barrier itself.

Source: Fitzpatrick

Figure 121. Limited sight distance site with installation of pedestrian automatic gate and detectable warning (placed where it will be encountered by pedestrians who are traveling toward the rails, in advance of the automatic gate).

Source: Fitzpatrick

Figure 122. Example of a downstream pedestrian automatic gate.



Source: Fitzpatrick

Figure 123. Example of a pedestrian automatic gate with an exit gate.

Source: Fitzpatrick

Figure 124. Barrier installed around a counterweight.

A clear zone is needed to serve as a pedestrian refuge between the automatic gate and the train's dynamic envelope so that pedestrians in the crossing are not trapped on the trackway when the gates are activated. The setback distance should be wide enough to accommodate a wheelchair. Additionally, pedestrian swing gates can be provided together with pedestrian automatic gates to allow pedestrians and cyclists to exit the ROW if they began crossing before the gates went down and also in the case of an emergency. An example of an exit swing gate is provided in Figure 123. Pedestrian automatic gate arms installed on the SCRRA Metrolink system include the word EXIT with an arrow pointing to the exit gate, as seen in Figure 122.

Much like vehicles driving around lowered gates, pedestrians can walk around pedestrian automatic gates in the lowered position. Channelization can be installed along sidewalks, at the end of the gate arm, and behind the mechanism to keep people from walking around the gate arm or stepping into the parallel roadway. Examples of pedestrian automatic gates with and without channelization are shown in Figures 125 and 126, respectively.

Flashing lights on the pedestrian gate arm provide a visual warning that the gates are descending and are in place. Uses of lights on the gate arm include a single red flashing light at the end of the arm or multiple flashing lights along the gate arm. The gate arm in Figure 125 contains multiple alternating flashing LEDs.

Benefits

Pedestrian automatic gates provide pedestrians with additional warning regarding the tracks. Pedestrian automatic gates are designed to limit access to the track until the train passes and are to be considered at locations with sight distance concerns, train speeds in excess of 35 mph, pedestrian surges or inattention, or school zones.

Cost

Sriraj and Metaxatos (*69*) provide an estimated railroad cost of $65,169 for the installation of pedestrian flashing-light signals, crossing gates, and bells along with advance warning signs and pavement markings for a site in Illinois.

Source: Fitzpatrick

Figure 125. Example of pedestrian automatic gates with channelization and a swing gate for emergency exit.

Source: Warner

Figure 126. Example of pedestrian automatic gates without channelization.

Treatment 30: Infrastructure—Pedestrian Automatic Gates with Horizontal Hanging Bar

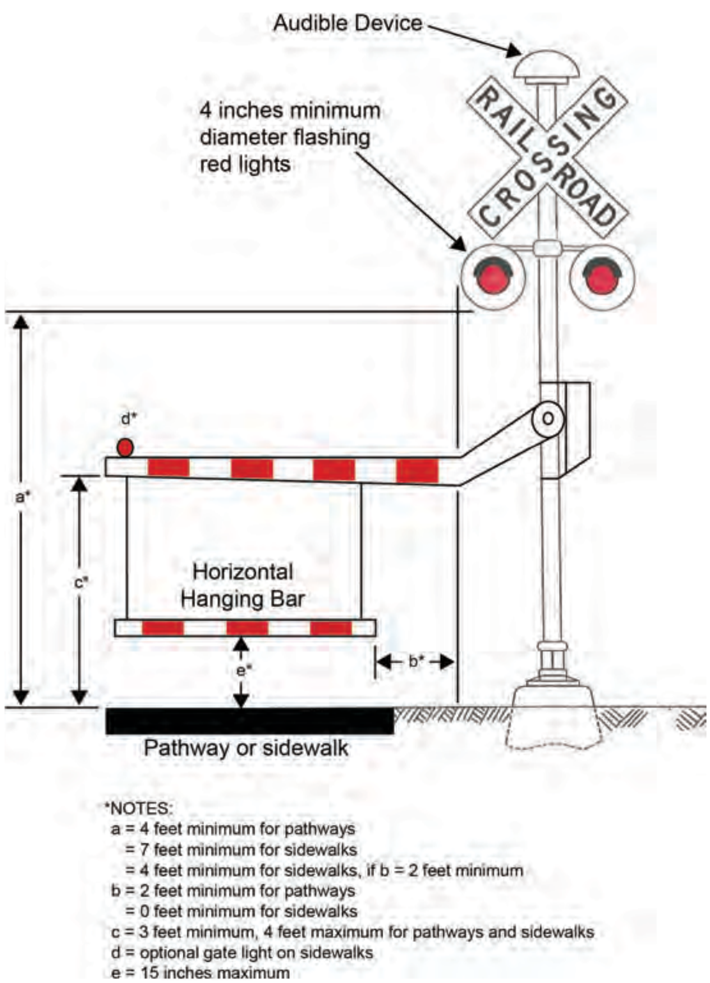
Description

Pedestrian automatic gates with horizontal hanging bars, also known as gate skirts, consist of secondary horizontal hanging bars suspended from the existing pedestrian automatic gates to better block access to the crossing by pedestrians.

Applications

Horizontal hanging bars are added to pedestrian automatic gates to decrease the number of unauthorized entries under a deployed automatic gate. Figure 127 provides suggested dimensions for the pedestrian automatic gate with horizontal hanging bar.

The addition of hanging bars is thought to be beneficial at locations where evidence exists of pedestrians going under existing pedestrian automatic gate arms or at crossings that many children use. An FRA report released in December 2013 (*39*) examined the effectiveness of a



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-13 (*59*)

Figure 127. Suggested dimensions for a pedestrian gate with horizontal hanging bar placement for a sidewalk.

Source: Warner

Figure 128. Example of a horizontal hanging bar on a pedestrian automatic gate at a DART crossing adjacent to a school zone.

hanging bar at a location in New Jersey where there had been evidence of pedestrians going under the existing pedestrian automatic gate arm.

Implementation

Horizontal hanging bars can be added to existing pedestrian automatic gate mechanisms, as demonstrated in the FRA report (*39*), or incorporated within the design of a new pedestrian automatic gate system.

Figure 128 shows a pedestrian automated gate with a horizontal hanging bar application at a crossing in close proximity to a school on the Dallas Area Rapid Transit (DART) light-rail system. An FRA presentation indicates the treatment was installed in 1996 because of concerns about the presence of children walking to and from a nearby elementary school (*75*). A second crossing location, also near the school, uses the hanging bar on the vehicle gate arm (see Figure 129).

Source: Warner

Figure 129. Example of a horizontal hanging bar on a vehicle gate arm at a DART crossing.

Horizontal hanging bars have the additional benefit of enabling pedestrians who are visually impaired to detect a lowered gate with a long cane, if used, and come to a stop prior to bodily encountering the gate.

Benefits

The FRA report (*39*) found that the addition of the horizontal hanging bar at the location in New Jersey reduced the total number of pedestrian violations while the gates were descending or horizontal by 78 percent and 55 percent, respectively.

Cost

For the installation of the experimental hanging bars in New Jersey, the addition of hanging bars to two existing pedestrian gate mechanisms cost $15,000 to $20,000 (*80*).

Treatment 31: Infrastructure—Pedestrian Swing Gates

Description

Pedestrian swing gates are gates that pedestrians and cyclists must open before crossing the tracks or that enable escape from the tracks if a pedestrian arm descends when a pedestrian has not yet completed the crossing.

Applications

Pedestrian swing gates, sometimes called pedestrian fence gates, are gates that pedestrians and cyclists must open manually to cross the tracks (see Figure 130 and Figure 131 for examples). Pedestrian swing gates, like other pedestrian barriers and gates, are installed to discourage pedestrians and cyclists from making inappropriate crossing movements. The gates force crossing users to have additional time to check for an approaching LRV. Pedestrian swing gates are also used for an emergency exit from a crossing with automatic pedestrian gate arms. Figure 132 shows an example of a swing gate located next to a deployed automatic pedestrian gate arm. Figure 133 shows a closeup of an emergency exit gate. Note that a kick plate should be present on the exit gate.

Source: Fitzpatrick

Figure 130. Example of swing gates with a STOP sign.

Source: Fitzpatrick

Figure 131. Examples of swing gates used at a pedestrian crossing near a station in Los Angeles.

Pedestrian swing gates should be considered in the following situations:

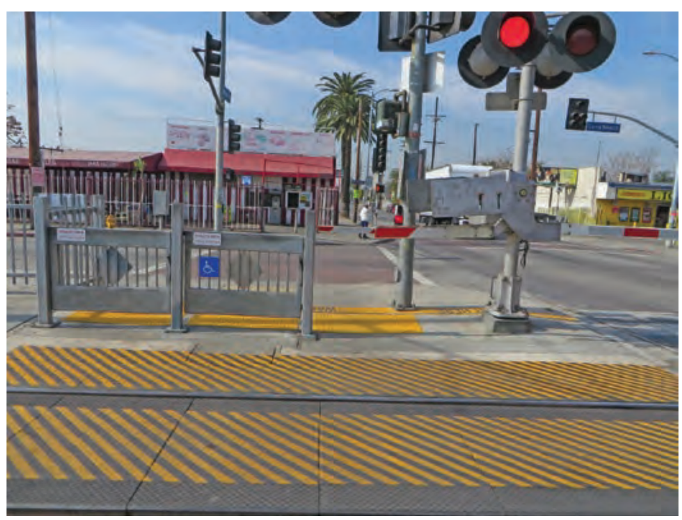
- Pedestrian-to-train sight lines are restricted.
- There is a high likelihood that pedestrians will quickly cross the tracks without looking.
- The area has high levels of distracted pedestrians.
- Channelization/barriers reasonably prevent pedestrians from bypassing the gates.
- Acceptable provisions for opening the gates by disabled persons can be provided.

Gates should open away from the tracks; this allows easier exit for pedestrians on the crossing, and it requires pedestrians to make additional effort before entering the crossing. Gates should be wide enough to accommodate wheelchairs and other assistive devices.

Figure 134 shows the suggested dimensions for swing gates with automatic pedestrian gate arms on two approaches and vehicle automatic gate arms on two other approaches. Suggested dimensions for swing gates with automatic pedestrian gate arms on all approaches are shown in Figure 135.

Implementation

According to *TCRP Report 137* (*4*), Calgary Transit installed various combinations of gates and barriers at a number of stations. The installations included active overhead railroad flashers.

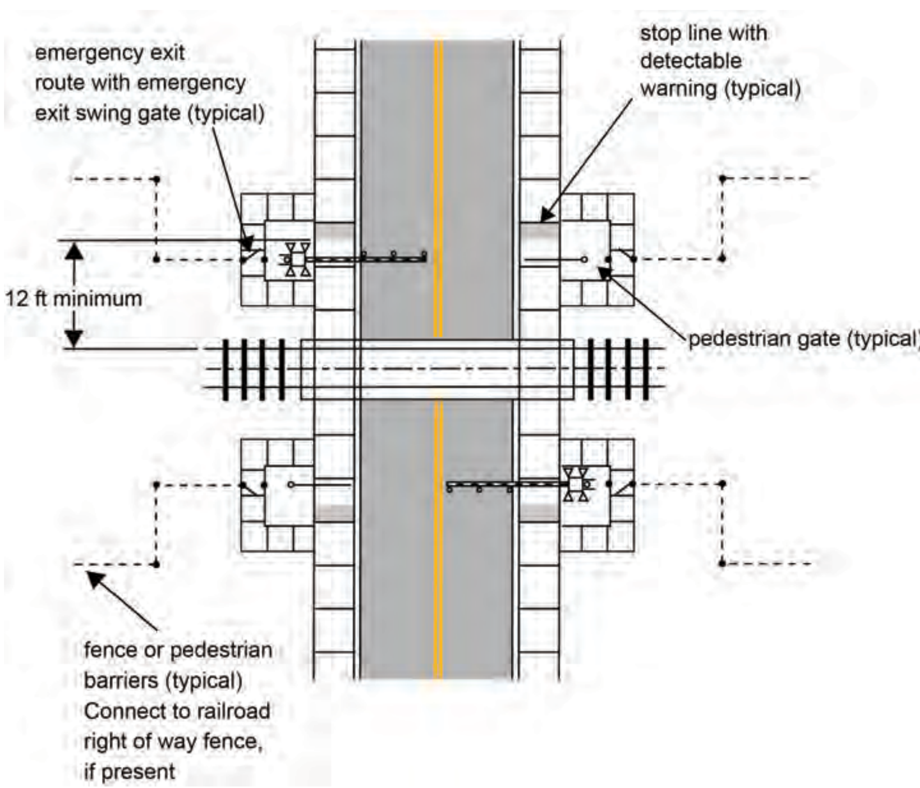


Source: Fitzpatrick

Figure 132. Example of a swing gate for emergency exit next to an automatic pedestrian gate arm.

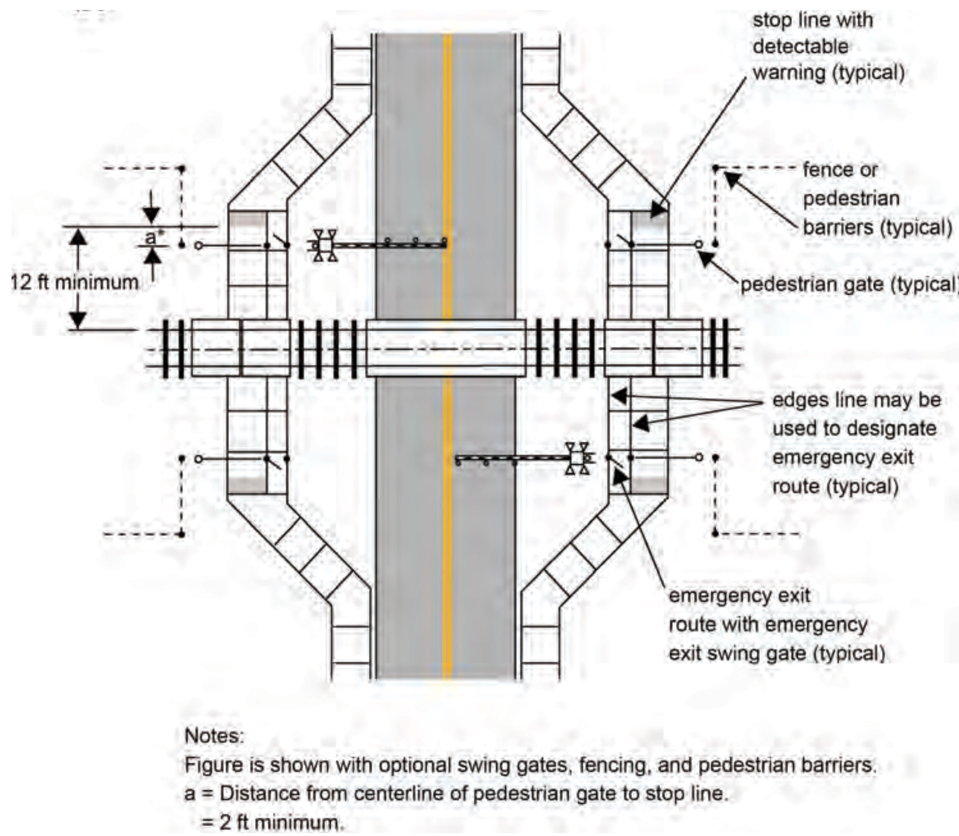
Source: Fitzpatrick

Figure 133. Example of a swing gate for emergency exit from the rail side (note that a kick plate should be present).



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-10 (*59*)

Figure 134. Suggested dimensions for swing gates with automatic pedestrian gate arms on two approaches and vehicle automatic gate arms on two other approaches.



Source: adapted from *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee), Figure 8D-8 (*59*)

Figure 135. Suggested dimensions for swing gates with automatic pedestrian gate arms on all approaches.

The swing gates are intended to prevent pedestrians from crossing into the track area without pausing and checking. Because pedestrians are required to actively open the gates, they are forced to be more alert to the risks associated with crossing the LRT tracks. The gates also provide a positive barrier between where it is and is not appropriate to stand when an LRV is approaching (*4*).

In some cases, the gate is held open (under power), exposing a walkway across the tracks. In these situations, the automatic swing gates do not require action on the part of the pedestrian to enter the crossing. When activated by an LRV approaching the grade crossing, the gate closes. As the gate closes, it exposes an emergency exit. After the LRV passes, the gate opens, and access to the walkway across the tracks is permitted. As the gate opens, the emergency exit is closed. If there is a power failure, the swing gate automatically closes under spring tension. Used widely in Australia, automatic swing gates have been successful in fatality prevention and operational reliability (*4*).

Benefits

Transit officials in Calgary have reported that pedestrian violations of the swing gates (opening the gates while the warning devices are flashing) have increased following the initial reductions in risky behavior that occurred immediately after the gates were installed (*2*).

Cost

Sriraj and Metaxatos (*69*) provide a 2013 cost estimate of $49,000 for pedestrian swing gates.

Treatment 32: Operations—Required Stop

Description

As a policy, some stations or crossings may require the train operator to come to a complete stop.

Applications

Using required stops on the rail system may occur inside and outside stations. Documented instances of this crash-avoidance measure within a station include a second train scenario where the first train stops and blocks a pedestrian crossing while the second train enters the station. According to Korve et al. (*2*):

> Where possible, LRV operators should be trained to minimize the occurrence of accidents resulting from pedestrians crossing behind one LRV and into the path of a second, opposite direction LRV. Where LRVs routinely pass one another at or near a pedestrian crossing, one strategy to minimize the second LRV conflict is to have the first LRV operator slow or stop to physically block the pedestrian path until the second, opposite direction LRV enters the crossing. In this manner, pedestrians cannot enter the crossing before the second LRV arrives.

For a station configuration where an inbound platform may have access from only one side, requiring pedestrians to cross the outbound rail tracks to access the platform, *Compilation of Pedestrian Safety Devices in Use at Grade Crossings* (*5*) states that a transit system may elect to have a safety stop prior to the pedestrian crossing for all outbound vehicles.

Scenarios outside of stations include isolated stops for rail vehicles based on an isolated safety risk or holding trains prior to the station when another train is already in the station. This may occur at pedestrian-only crossings (i.e., pedestrian-rail grade crossings not adjacent to motor vehicle crossings or in a station) or at roadway intersections for a variety of reasons, such as sight distance restrictions or high levels of improper pedestrian and/or motor vehicle behavior. Figures 136 and 137 show examples in which trains have a required stop marked with a STOP sign. Additionally, transit agencies may incorporate a policy to restrict a train from entering a station while another train is within the station. The Boston-area commuter-rail agency maintains the "Hold Out" rule where the second approaching train must not enter the station while the station

Source: Fitzpatrick

Figure 136. Example in Boston of a required stop for LRV operators at a station pedestrian crossing.

Source: Gilleran. Permission granted by the owner for a one-time use of this photograph in the *Guidebook*. No right to otherwise reproduce this photograph is granted, and no rights of ownership of these photographs are transferred to TCRP.

Figure 137. Example of a required stop for LRV operators in a station.

is occupied. This may not always require a full stop in advance but could also be accomplished by slowing, depending on the timing and spacing between the trains.

Implementation

Transit system policy may dictate required stops for dedicated purposes. However, continual safety reviews may identify locations where a required stop may improve pedestrian safety. Figures 136 and 137 show the use of STOP signs at a station pedestrian crossing to instruct the operators to stop.

Benefits

Specific safety or operational benefits have not been documented for this treatment.

Cost

Specific costs associated with this crash-avoidance measure are not documented. However, Korve et al. (*2*) say that the implementation of the blocking of a pedestrian crossing by the first train while the second train enters the station only affects operating schedules slightly, especially since it would only be used when the two opposing trains are in close proximity and in the necessary locations.

Treatment 33: Operations—Reduced Train Speed

Description

As a policy in some locations, the train operator may be required to reduce speed.

Applications

Adjusting train speeds when entering or exiting stations could improve pedestrian safety.

Source: Fitzpatrick

Figure 138. Example of trains entering/exiting a marked school zone.

Implementation

Transit system policy may dictate reduced speeds for dedicated purposes, such as school zones. Figure 138 shows an end school zone sign installed for the train operators in Portland where the train's operating speed is to be reduced to 20 mph within the school zone. Los Angeles Metro has improved safety levels by reducing the approach speed to 25 mph along the Blue Line mid-corridor stations.

Benefits

Specific safety or operational benefits have not been documented for this treatment.

Cost

Specific costs associated with this treatment are not documented.

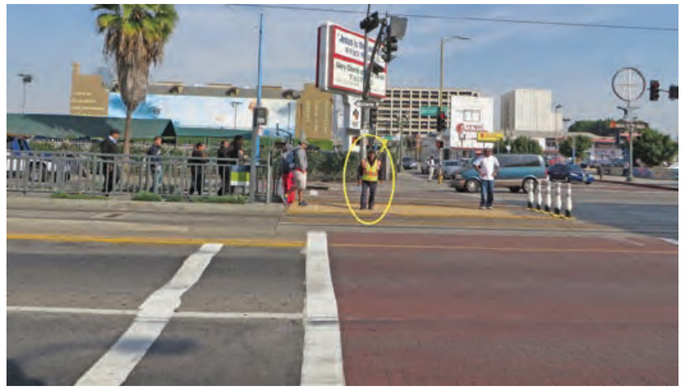
Treatment 34: Operations—Rail Safety Ambassador Program

Description

The Rail Safety Ambassador Program administered by the Los Angeles County Metropolitan Transit Authority positions an ambassador at light-rail crossings to highlight improper behavior and educate the public on proper behavior, to provide assistance to users, and to identify and report any perceived safety concerns/hazards at stations and crossings.

Applications

Originally conceived as a short-term educational tool for the opening of a new light-rail alignment, the Rail Safety Ambassador Program is now regularly used throughout the Los Angeles



Source: Fitzpatrick

Figure 139. Example of an ambassador stationed in the median (near the center of the photograph).

light-rail system. Ambassadors are former light-rail operators who are hired to be at key stations during times of significant use. The ambassadors act as eyes and ears about how users are responding to the crossings. For the opening of a new line, assistance to the public and interpretation of any safety concerns provide valuable input into any possible safety enhancements at the crossing. Use of ambassadors on an existing line reinforces proper behavior and provides a continual review of perceived safety concerns that could be addressed by the agency. Ambassadors are trained to blow a whistle, explain the improper behavior, and provide instructions on the appropriate behavior required to safely traverse the system. Figures 139 and 140 contain examples of ambassadors (in reflectorized vests) positioned to assist transit users.

Los Angeles Metro originally used the ambassadors 6 months before and 6 months after the opening of a new line, but now maintains 44 ambassadors that can work up to 30 hours/week. They are safety trained every 2 years and are equipped with radios for immediate response.

Implementation

This program uses retired bus and rail operators, a valuable resource that most transit agencies also have available. The use of retired operators reduces the amount of training required for

Source: Fitzpatrick

Figure 140. Example of an ambassador stationed at a crossing (near the left edge of the photograph).

this specific activity since each ambassador already has over 20 years of training as an operator. The Rail Safety Ambassador Program provides continued education every 2 years. It currently maintains 44 ambassadors who are able to work up to 30 hours/week on two shifts—6:00 a.m. to 11:30 a.m. and 11:30 a.m. to 6:00 p.m. Wages are set according to a negotiated rate with the local operator union.

Benefits

This program provides direct personal interaction between trained individuals and system users to convey safety messages, encourage proper behaviors, and assist users as needed. Ambassadors also identify and report any safety concerns or hazards associated with stations and crossings. Additionally, each ambassador is suicide-prevention trained, and there have been documented incidents where ambassadors were able to prevent suicides on the transit rail system.

Cost

The Los Angeles Metro ambassadors are paid a union-cleared wage of $18/hour with no benefits, with each ambassador eligible to work up to 30 hours/week.

CHAPTER 9

Case Studies

Case Study A: Review of Sound Wall

Context

In accordance with NEPA, the West Rail Line in Denver, Colorado, received an ROD in April 2004 and a Revised EA/FONSI in November 2007. Due to noise impacts along the alignment and at at-grade crossings, mitigation commitments by the Regional Transportation District (RTD) for Denver included constructing sound walls along sections adjacent to residential properties and not including warning bells or sounding of horns at the at-grade crossing. Figure 141 shows one such crossing of a two-lane road (Independence Street) within a residential subdivision. Figure 142 shows the sound wall along the southwest corner.

Design Considerations

In 2011, the West Rail Grade Crossing Task Force was convened with members from all departments at RTD to review each at-grade crossing for possible changes for safety enhancements. Recommendations included the following (*81*):

- Fencing extension between the sound wall and signal mast.
- Bollards between the wall and signal mast.
- A swing gate between the signal mast and sound wall.
- Removal of track panels where they were not needed for walking.
- Removal of 100 ft of sound wall on the southwest corner at Independence as well as a 24/7 speed restriction of 20 mph.
- NO TRESPASSING signs at each corner.

As part of the recommendations, RTD proposed to remove 100 ft of sound wall on the southwest corner of the Independence Street intersection. Due to an adjacent elementary school, RTD also committed to slow the train speed to 20 mph approaching and through the intersection. RTD completed an additional noise analysis to assess the impacts associated with these changes. Due to the slower speed, there was no longer any noise impact on the property adjacent to the sound wall in question. RTD then submitted a reevaluation memo to FTA for review and approval documenting the changes and noise impacts associated with removal of the sound walls. FTA approved the changes in October 2012.

Typically, the specific design elements of at-grade crossing equipment are not included in a NEPA document; however, the overall reason for the equipment or mitigation commitment made during the NEPA process drove the need to re-analyze any changes.

Source: Google Earth

Figure 141. Plan view of the crossing.

Results

For this crossing, treatments in addition to removal of part of the sound wall and slowing the train included quad gates, flashing lights, swing gates, audible signals, signs, and pavement markings (LOOK BOTH WAYS text on the pavement near the detectable warning), as can be seen in Figure 143 and Figure 144.

As part of a Safe Routes to School grant, RTD West Rail, the City of Lakewood, Operation Lifesaver, Bicycle Colorado, and the West Metro Fire District held safety roadshows at elementary schools four blocks within the West Rail Line alignment. RTD created an interactive mock-up display to demonstrate how to properly navigate a light-rail crossing (see Figure 145). The display includes all items that could be at a real light-rail crossing: swing gates, rail signals, appropriate signage, and the crossing sound. The safety roadshows educated students on safety when walking or biking in these areas before RTD started testing and operating rail cars.

Source: Google Earth

Figure 142. View of the southwest corner sound wall prior to removal.

Source: Pitts

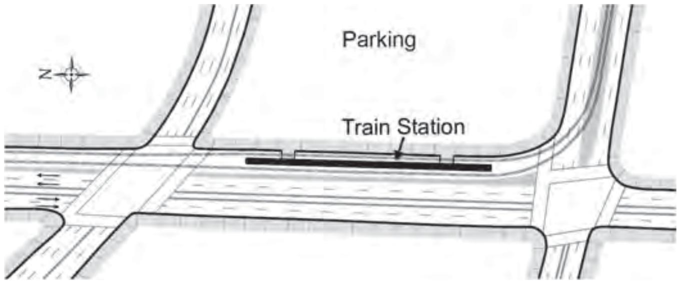
Figure 143. A swing gate, along with quad gate improvements, at the crossing of Independence Street.

Source: Pitts

Figure 144. A swing gate and sign at the Independence Street crossing.

Source: Pitts

Figure 145. An interactive mock-up display to demonstrate how to properly navigate a light-rail crossing.



Source: Texas A&M Transportation Institute

Figure 146. Plan view of the crossing.

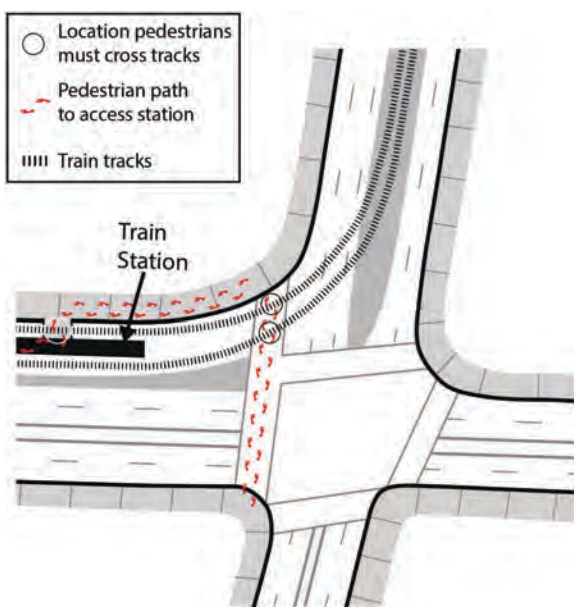
Case Study B: Location of Station Entrance

Context

For the Los Angeles Little Tokyo community, the location of the light-rail station is between the tracks on one side of the street and on one side of the intersection (in other words, the platform is not a split or staggered platform). For those patrons who start their trip via automobile, they can park in the neighboring lot and not cross a street to access the platform regardless of the direction they are traveling on the light rail. Figure 146 shows the plan view of the station.

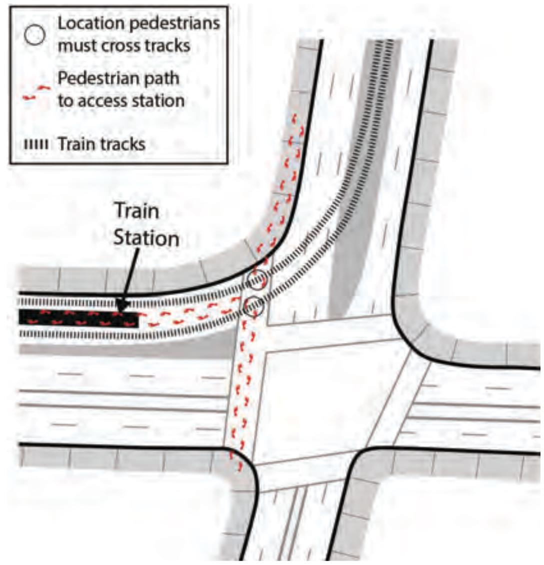
Design Considerations

Prior to modification, users of the station originating from the southwest commented that they did not want to cross the tracks three times to be able to access the station. In the original design, these patrons crossed the street, crossed both tracks, walked parallel to the tracks for a short distance, and then entered the platform after re-crossing the easternmost set of tracks (illustrated in Figure 147). Los Angeles Metro decided to redesign the entrance to the southern part of the station to eliminate the multiple crossings of the tracks. Figure 148 shows the revised



Source: Texas A&M Transportation Institute

Figure 147. Illustration of the original patron path to access the station.



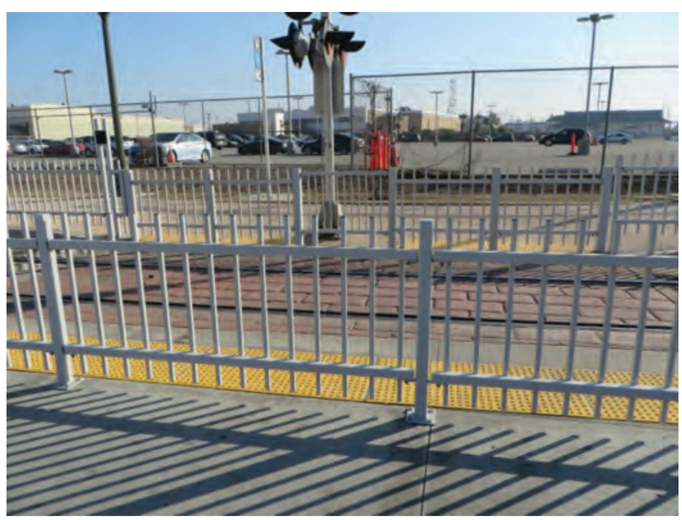
Source: Texas A&M Transportation Institute

Figure 148. Illustration of the revised patron path to access the station.

patron path for accessing the station from the south. With the modification, patrons only cross one set of tracks whether they are approaching from the southwest or from the southeast.

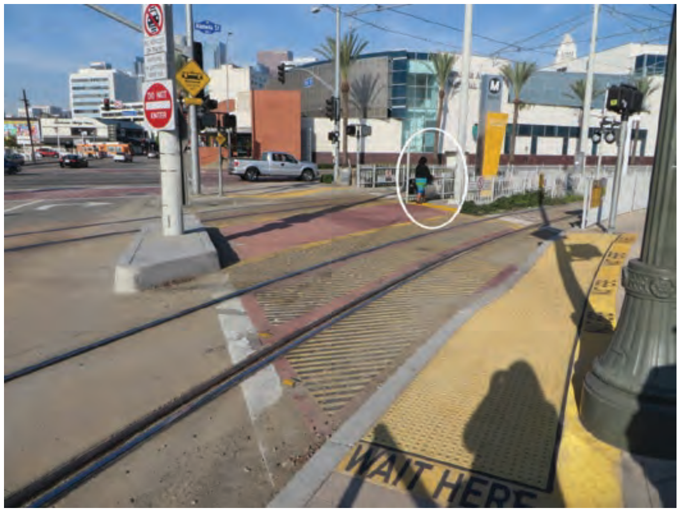
Results

The modifications to the station were ongoing in February 2014. Figure 149 shows the previous entrance to the station where fencing has been installed to redirect the patrons to the new entrance, which is illustrated in Figures 150 and 151. Figure 152 shows the new entrance from the perspective of a patron exiting the train station. The new entrance allows a patron from the southwest to cross only the western tracks before entering the station. The path for pedestrians not accessing the station remains unchanged; they still cross two sets of tracks in addition to crossing the road.



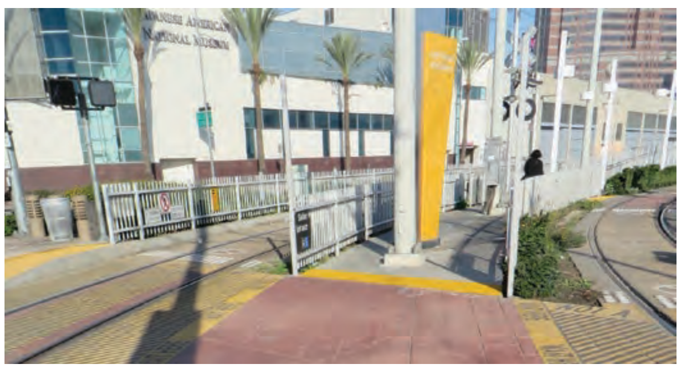
Source: Fitzpatrick

Figure 149. Previous crossing now fenced to prevent use.



Source: Fitzpatrick

Figure 150. New southern entrance to the platform (highlighted on photo with a circle).



Source: Fitzpatrick

Figure 151. Closer view of the southern entrance.

Source: Zohbi

Figure 152. View of the new southern entrance from the train station.

Source: Fitzpatrick

Figure 153. Sign used at the southern entrance.

An example of the sign used at the station entrance is shown in Figure 153, and Figure 154 shows the signs presented to patrons exiting the station at the southern end. These signs are on a post embedded in a raised median. The raised median helps to restrict vehicles from inappropriately entering the station, along with providing a clear edge for the pedestrian crossing (see additional discussion of this concept in Case Study C). Treatments used to communicate that pedestrians should not be on the tracks are shown in Figure 155 and include raised buttons, pavement markings that include the words NO WALK WAY, horizontal signing on the pavement, and passive signs on the fence.

Case Study C: Consideration of Visually Impaired Pedestrians When Designing a Station Entrance to a Platform Located Between Tracks

Context

Passengers exiting a train platform that is located within an intersection (as shown in Figure 156) need to be directed to turn right or left to cross the roadway. When passengers are trying to find and use the station, visually impaired or blind passengers need an indication of the location of the platform entry. For example, a passenger walking north from the southwest corner of the

Source: Fitzpatrick

Figure 154. View of the treatment along the street edge upon exiting from the southern portion of the platform.

Source: Fitzpatrick

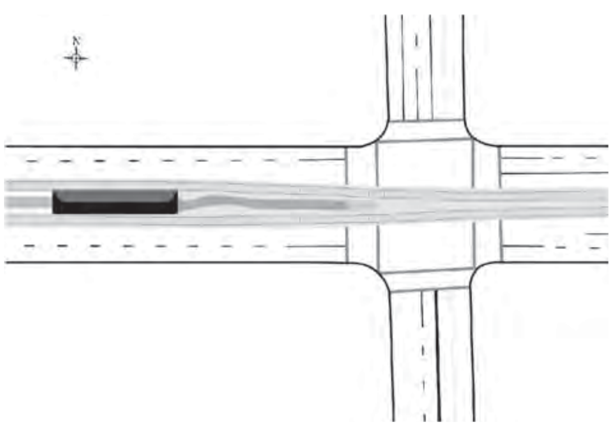
Figure 155. Examples of treatments used at the southern entrance to indicate pedestrians should not be on the tracks.

intersection shown in Figure 156 needs an indication of when to turn left (as opposed to right or forward) to enter the station.

Very little guidance exists on this issue. Solutions are needed because blind and visually impaired users state that the lack of information prevents their using some stations. None of the treatments currently installed satisfy all the wayfinding needs; however, several treatments do provide sufficient cues so that a blind or visually impaired user who is familiar with the station can locate the entrance. In addition, consistent treatment will likely result in more predictable pedestrian behavior and provide adequate cues to blind or visually impaired pedestrians of the location of the station and of the track or roadway area.

Design Considerations

Various methods can be used to block pedestrians from walking straight forward into the street as they exit the station. A clear barrier helps all pedestrians, but it is particularly important



Source: Texas A&M Transportation Institute

Figure 156. Overhead view of a train station for median- or side-running tracks.

Source: Warner

Figure 157. Metal fence used to mark the edge of the crossing.

to pedestrians who are blind. Pedestrians who are blind do not receive orientation to every station that they might use, and they may not realize that they are at a center platform station and must turn and cross the street or rail lines upon exiting the station.

Defining the edge of the crossing with respect to the roadway provides several benefits, including the following:

- Physically preventing a pedestrian from walking into the intersection.
- Clearly delineating the space reserved for pedestrians from the space for vehicles and the space to be shared by pedestrians and vehicles.
- Enabling visually impaired pedestrians to find the edge using a long cane.
- Providing a visual cue to train operators that pedestrians are not walking within designated areas.

Several examples of methods to delineate the edge of the crossing were observed, including the following:

- Yellow fence (see Figure 157).
- Flexible bollards (see Figure 158).
- Raised curb (see Figure 159).
- Raised curb with a higher profile that is also used for a power pole, as shown in Figure 160. Signs are attached to the pole, providing warning to look both ways and to watch for trains.
- Figure 161 shows another raised island example. This location has a pole for the signal head in the raised island. The figure also shows a trash can that was placed within the crossing. While the trash can may provide a needed amenity for the location, it may hinder pedestrian movement.
- Figure 162 illustrates several treatments including the raised island, sign, and bollards.

In addition to clearly defining the edge of the crossing, detectable warnings are needed for median stations. Detectable warnings indicate the junction between pedestrian and vehicular

Source: Fitzpatrick

Figure 158. Bollards used to mark the edge of the crossing.

Source: Fitzpatrick

Figure 159. Raised island used to mark the edge of the crossing.

Source: Fitzpatrick

Figure 160. Raised island with a higher profile used to mark the edge of the crossing and for the power pole.

Source: Fitzpatrick

Figure 161. Raised island with a signal used to mark the edge of the crossing (trash can placed within the crossing).

Source: Fitzpatrick

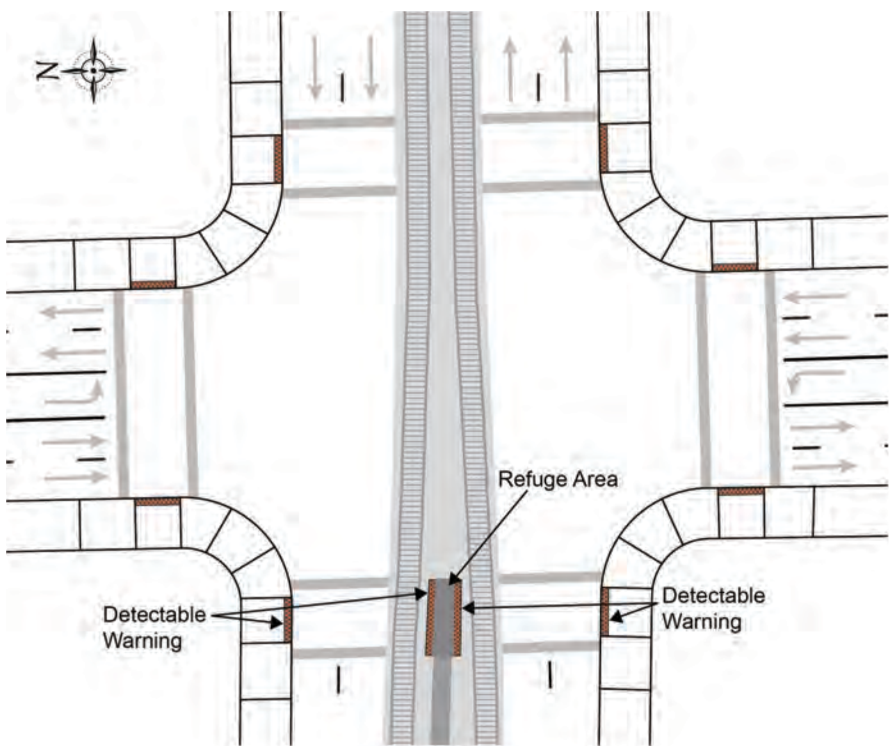
Figure 162. Several treatments used to mark the edge of the crossing, including a raised island, a sign, and bollards.

ways. They are properly installed in pairs to indicate the beginning and end of travel within a hazardous area. Pedestrians who are visually impaired who detect the truncated dome detectable warning surface in the vicinity of a rail crossing are expected to understand that if a train is approaching, they should stand behind the truncated domes to avoid either being too close to the track when a train crosses or being struck by a descending gate arm. Where there is shared alignment at a crossing with a boarding platform, whether center or side running, truncated dome detectable warnings should define the refuge area.

Figure 163 illustrates the locations where detectable warnings should be installed when there is a refuge area at the end of a median- or side-running station. When detectable warnings are used at both edges of the refuge, pedestrians who are visually impaired are alerted to the presence of a refuge and platform and can recognize when they are stepping into the street or rail area as they leave the platform.

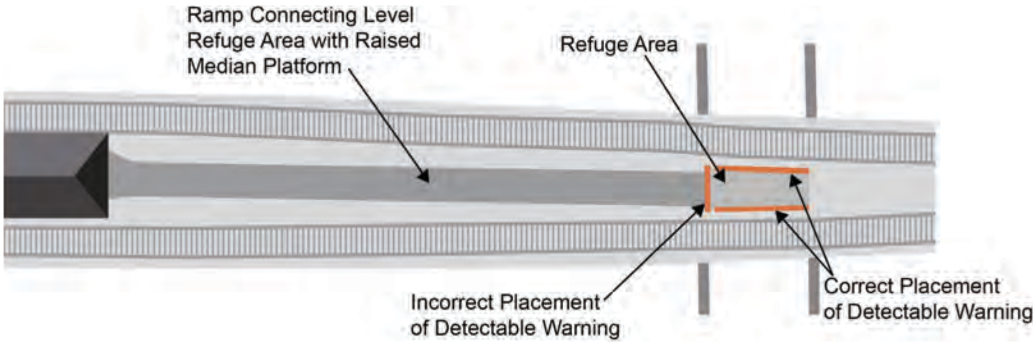
The detectable warning surface that is installed at the bottom of a ramp from a platform is not needed, as illustrated in Figure 164. Detectable warnings indicate the junction between pedestrian and vehicular ways. Pedestrians coming down the ramp and exiting the station do not enter directly onto a vehicular way; they enter a refuge. Placing a detectable warning at the bottom of this ramp could therefore be confusing to blind pedestrians who contact it as they enter or exit the station.

Another example of detectable warning installation that could be confusing to blind or visually impaired pedestrians is a U-shaped installation as illustrated in Figure 165. The location of the detectable warning material closest to the pole could be understood by blind pedestrians as indicating where they should wait to cross the street in front of them, rather than turning to cross the tracks and then the street, as intended. Some type of barrier is needed at the edge of



Source: Texas A&M Transportation Institute

Figure 163. Overhead view of locations for detectable warnings when there is a refuge area at the end of a median- or side-running station.

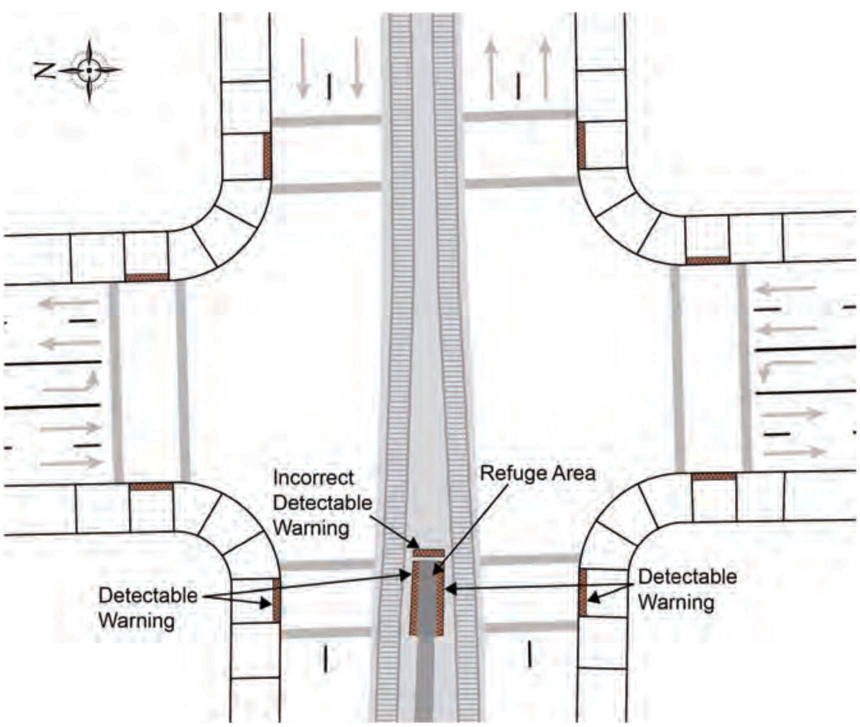


Source: Texas A&M Transportation Institute

Figure 164. Illustration showing where a detectable warning should not be located (at the bottom of a ramp leading from a raised median platform) and where detectable warnings should be located (at the sides of the pedestrian refuge).

the refuge closest to the side of the crossing, as shown in Figures 157 through 162, not a detectable warning.

Another example of an incorrect detectable warning is when the entire refuge area is covered. The message of where it is appropriate to stand or when a pedestrian is entering or leaving a protected area is lost when a large area is covered with detectable warning material. The refuge should be treated in the same way as a pedestrian refuge island, as described in *Proposed PROWAG* R305.2.4 (*58*). There should be a detectable warning at each edge of the refuge, indicating the limit of the area where pedestrians can safely wait outside the dynamic envelope of trains, as illustrated in Figure 163.



Source: Texas A&M Transportation Institute

Figure 165. Illustration showing a U-shaped detectable warning installation for a median platform that could be confusing to a pedestrian.

If there is no platform or station entry within the crossing, there is no need to indicate the track crossing separately from the roadway, as noted in the *Proposed PROWAG* (*58*). A portion of R208.1 states: "Where pedestrian at-grade rail crossings are located within a street or highway, detectable warning surfaces at the curb ramps or blended transitions make a second set of detectable warning surfaces at the rail crossing unnecessary." Locations with station platform entrances and associated pedestrian refuges in the middle of a roadway or between the tracks, however, need correct detectable warning placement.

When the train station is located in the median, pedestrian push buttons should be present; otherwise, pedestrians, especially blind pedestrians, could be stranded in the median. Figure 96 (Treatment 21 in Chapter 8) shows an example of a pedestrian push button at the end of a station located within the median of a street. At this station, the blank-out sign with a train symbol is viewable for those pedestrians leaving the station.

Results

Both the barrier to walking into the roadway and the detectable warnings to mark the edges of the pedestrian refuge where it is level with the trackway or street are needed, as shown in Figures 157 and 162. Barriers to continuing into the roadway can be provided by a curb, flexible delineators, fencing, or other methods. Where pedestrian passage is intended at the crossing, detectable warnings installed for the full width of the crosswalk area that is level with the street or trackway give notice to pedestrians who are blind of the beginning and ending of a roadway or railway crossing.

Case Study D: Control of Pedestrian Path

Context

Many identified safety concerns exist with unimpeded passage of pedestrian movements through crossings. Controlling pedestrian paths through the use of channelization and barriers, or maze fencing, slows movement through crossings and forces pedestrians to face the oncoming train prior to entering the trackway.

In Portland, Tri-Met's Renew the Blue campaign began in 2011 to upgrade the 30-year old Blue Line to new design standards and ADA requirements in order to improve safety and security. The Gateway Transit Center is Tri-Met's busiest transit station, with pedestrians transferring between trains and buses. Three train platforms serve the three light-rail lines that use the station. In addition, multiple buses transfer at the station, the I-205 multi-use path accesses the station, and a medical complex is adjacent to the station.

Design Considerations

With the update of the light-rail design criteria in 2010 based on lessons learned and operating experience, Tri-Met completed a review of all pedestrian crossings in order to plan to meet upgraded criteria in the existing parts of the system (*70*). The Gateway Transit Center was the first location along the Blue Line to see pedestrian safety improvements based on the new criteria. Design change elements for the new criteria included better guiding and channeling of pedestrians and bicyclists into "controlled and predictable crossing paths" (*82*). Additionally, the changes were designed to improve ADA accessibility and help train operators better identify pedestrian intent at crossings.

Elements within the new design standards implemented as part of the Gateway Transit Center project include channelization that directs users to the designated crossing locations and barriers

Source: Saporta, 2012 (*70*)

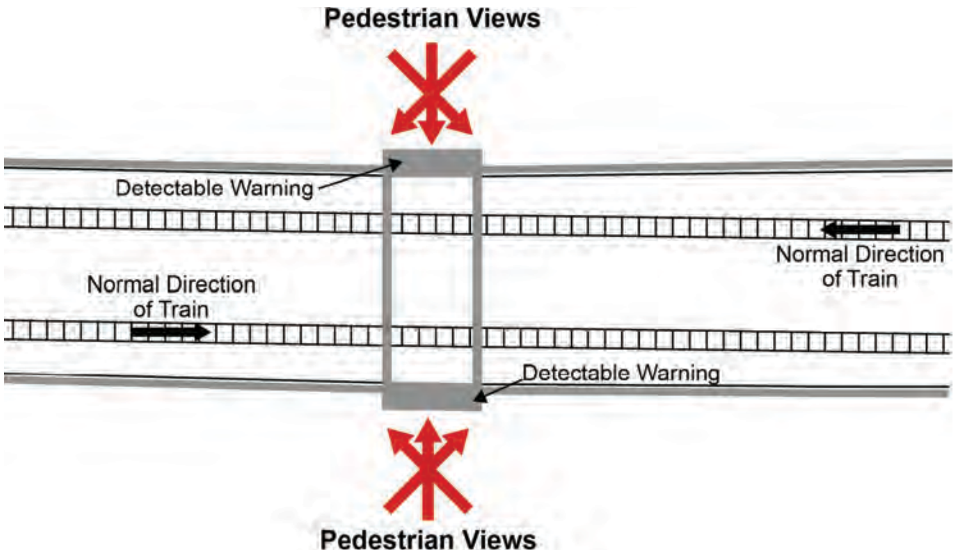
Figure 166. Gateway pedestrian channeling test using temporary barriers.

to force users to slow and face oncoming trains before entering tracks. In order to ensure designed elements would work as planned, Tri-Met instituted a pedestrian channeling test project, in which temporary barriers simulated the designed barriers. This allowed testing of the channeling to ensure positive impacts on pedestrian movements as designed without unforeseen negative impacts. A concern with the changed pedestrian flows was the ability to maintain ADA ramp grades. Figures 166 and 167 show images of the temporary barriers used during the channel test. Field test video footage proved the channelization performed appropriately and that installation could move forward as designed.

The primary focus at the crossings is to force users to slow and traverse the crossing in a controlled and predictable manner. This is largely done with barriers that control the pedestrian flow and, if possible, direct users to face the oncoming train direction. Figures 168 and 169

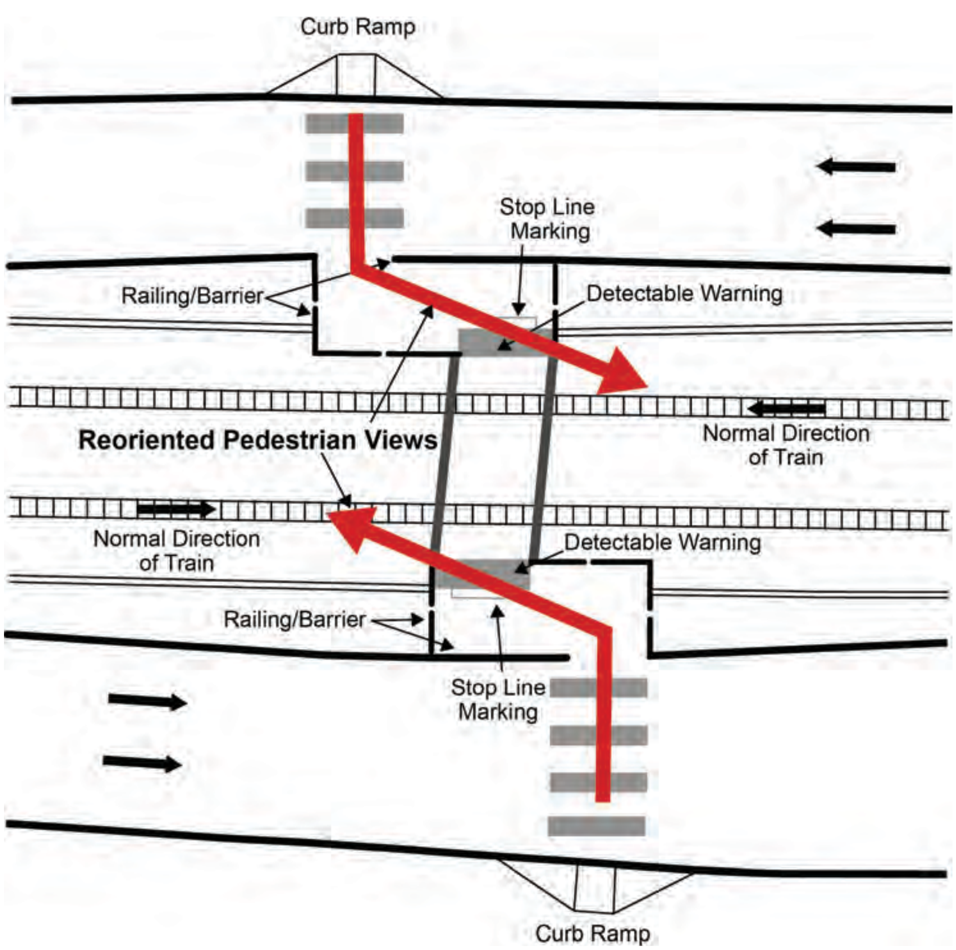
Source: Saporta, 2012 (*70*)

Figure 167. Gateway pedestrian channeling test using temporary barriers (alternate view).



Source: Texas A&M Transportation Institute

Figure 168. Illustration of pedestrian flows before installation of barriers.



Source: Texas A&M Transportation Institute

Figure 169. Illustration of pedestrian flows after installation of barriers.

Source: Wilkinson

Figure 170. Before platform crossing improvements.

show how pedestrian flows changed with the addition of barriers at the crossing approach. As illustrated in Figure 168, the pedestrian may be looking away from the oncoming train. With the installation of the barriers (as shown in Figure 169), the pedestrian is initially reoriented toward the anticipated direction of the near train.

Results

The field test demonstrated that the designed treatments would positively direct pedestrians. Permanent changes at the Gateway Transit Center occurred in 2013, including at the platform crossings, at multi-use crossings, and along the approach paths. Figure 170 shows one of the platform rail crossings before the treatments, and Figure 171 shows the crossing after the treatments. Figure 172 shows the south multi-use path before the treatments, and Figure 173 shows the path after the treatments. Figure 174 demonstrates how pedestrians are no long able to dart directly across the track and must now follow the channeling, which ensures that they cross in a better position to see an oncoming train.

Source: Wilkinson

Figure 171. After platform crossing improvements.

Source: Wilkinson

Figure 172. ***Before south multi-use path crossing improvements.***

Source: Wilkinson

Figure 173. ***After south multi-use path crossing improvements.***

Source: Warner

Figure 174. ***Pedestrian channelization at a MAX platform crossing.***

References

1. Korve, H. W., J. I. Farran, D. M. Mansel, H. S. Levinson, T. Chira-Chavala, and D. R. Ragland (1996). *TCRP Report 17: Integration of Light Rail Transit into City Streets.* Transportation Research Board, National Research Council, Washington, D.C.
2. Korve, H. W., B. D. Ogden, J. T. Siques, D. M. Mansel, H. A. Richards, S. Gilbert, E. Boni, M. Butchko, J. C. Stutts, and R. G. Hughes (2001). *TCRP Report 69: Light Rail Service: Pedestrian and Vehicular Safety.* Transportation Research Board, National Research Council, Washington, D.C.
3. Korve Engineering, ATS Consulting, LLC, Fidell Associates, Center for Education and Research in Safety, and Bear Consulting (May 2007). *TCRP Research Results Digest 84: Audible Signals for Pedestrian Safety in LRT Environments.* Transportation Research Board of the National Academies, Washington, D.C.
4. Cleghorn, D., A. Clavelle, J. Boone, M. Masliah, and H. S. Levinson (2009). *TCRP Report 137: Improving Pedestrian and Motorist Safety along Light Rail Alignments.* Transportation Research Board of the National Academies, Washington, D.C.
5. Federal Railroad Administration (2008). *Compilation of Pedestrian Safety Devices in Use at Grade Crossings.* Accessed from http://www.fra.dot.gov/eLib/Details/L02732. Accessed on April 10, 2013.
6. Federal Railroad Administration (2012). *Guidance on Pedestrian Crossing Safety at or near Passenger Stations.* Washington, D.C.
7. Federal Highway Administration, Office of Safety (2008). *Pedestrian Safety Guide for Transit Agencies.* Report FHWA-SA-07-017, Washington, D.C.
8. Federal Highway Administration (2009). *Manual on Uniform Traffic Control Devices.* Washington, D.C.
9. American Public Transportation Association (October 2013). *2013 Public Transportation Fact Book, 64th Edition.* Washington, D.C. Accessed from http://www.apta.com/resources/statistics/Documents/FactBook/2013-APTA-Fact-Book.pdf. Accessed on October 10, 2014.
10. Federal Transit Administration (2013). National Transit Database Glossary. Accessed from http://www.ntdprogram.gov/ntdprogram/Glossary.htm. Accessed on March 5, 2013.
11. American Public Transportation Association (August 15, 2013). *2013 Public Transportation Fact Book Appendix A: Historical Tables.* Washington, D.C. Accessed from http://www.apta.com/resources/statistics/Documents/FactBook/2013-Fact-Book-Appendix-A.pdf. Accessed on October 10, 2014.
12. Federal Transit Administration (2014). National Transit Database. Accessed from http://www.ntdprogram.gov/ntdprogram/data.htm. Accessed on February 18, 2014.
13. Metrolink (2009). *SCRRA Highway-Rail Grade Crossings: Recommended Design Practices and Standards Manual.* Los Angeles, California. Accessed from http://www.metrolinktrains.com/pdfs/EngineeringConstruction/Grade_Cross_Stand_Guidelines_Manual_Jun29_09.pdf. Accessed on April 9, 2013.
14. Coffel, K., J. Parks, C. Semler, P. Ryus, D. Sampson, C. Kachadoorian, H. S. Levinson, and J. L. Schofer (2012). *TCRP Report 153: Guidelines for Providing Access to Public Transportation Stations.* Transportation Research Board of the National Academies, Washington, D.C.
15. Cervero, R., S. Murphy, C. Ferrell, N. Goguts, Y. Tsai, G. B. Arrington, J. Boroski, J. Smith-Heimer, R. Golem, P. Peninger, E. Nakajima, E. Chui, R. Dunphy, M. Myers, S. McKay, and N. Witenstein (2004). *TCRP Report 102: Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects.* Transportation Research Board of the National Academies, Washington, D.C.
16. State of New Jersey Department of Transportation (2013). Transit Village Initiative Overview. Accessed from http://www.state.nj.us/transportation/community/village/index.shtml. Accessed on April 8, 2013.
17. Dallas Area Rapid Transit (2013). Transit-Oriented Development Policy and Guidelines. Accessed from http://www.dart.org/about/todpolicy.asp. Accessed on April 8, 2013.
18. Valley Metro (2013). METRO TOD Policy. Accessed from http://www.valleymetro.org/metro_projects_planning/metro_tod_policy. Accessed on April 8, 2013.

19. Maryland Department of Transportation (2013). Transit-Oriented Development (TOD) Homepage. Accessed from http://www.mdot.maryland.gov/Office_of_Planning_and_Capital_Programming/TOD/TOD_Homepage.html. Accessed on April 8, 2013.
20. Massachusetts Bay Transportation Authority (2013). T-Projects and Transit Oriented Development. Accessed from http://www.mbta.com/about_the_mbta/t_projects/projects_tod/. Accessed on April 8, 2013.
21. Renne, J. L., K. Bartholomew, and P. Wontor (August 2011). *TCRP Legal Research Digest 36: Transit-Oriented and Joint Development: Case Studies and Legal Issues.* Transportation Research Board of the National Academies, Washington, D.C.
22. Environmental Protection Agency, Office of Sustainable Communities, Smart Growth Program (2013). *Infrastructure Financing Options for Transit-Oriented Development.* Washington, D.C.
23. Reconnecting America, Center for Transit-Oriented Development (2008). *Capturing the Value of Transit.* Federal Transit Administration, Office of Planning and Environment, Washington, D.C.
24. Evans, J. E., R. H. Pratt, A. Stryker, and J. R. Kuzmyak (2007). *TCRP Report 95: Traveler Response to System Changes*, "Chapter 17—Transit Oriented Development." Transportation Research Board of the National Academies, Washington, D.C.
25. Canepa, B. (2007). "Bursting the Bubble: Determining the Transit-Oriented Development's Walkable Limits." *Transportation Research Record: Journal of the Transportation Research Board*, *No. 1992*, Transportation Research Board of the National Academies, Washington, D.C., pp. 28–34.
26. Guerra, E., R. Cervero, and D. Tischler (2012). "Half-Mile Circle: Does It Best Represent Transit Station Catchments?" *Transportation Research Record: Journal of the Transportation Research Board*, *No. 2276*, Transportation Research Board of the National Academies, Washington, D.C., pp. 101–109.
27. O'Sullivan, S., and J. Morrall (1996). "Walking Distances to and from Light-Rail Transit Stations." *Transportation Research Record*, *No. 1538*, Transportation Research Board, National Research Council, Washington, D.C., pp. 19–26.
28. Transportation Research Board (2010). *Highway Capacity Manual.* Washington, D.C.
29. Cellular Telecommunications and Internet Association—The Wireless Association (2012). Wireless Quick Facts: Mid-Year Figures. Accessed from http://www.ctia.org/advocacy/research/index.cfm/aid/10323. Accessed on April 6, 2013.
30. Hatfield, J., and S. Murphy (2007). "The Effect of Mobile Phone Use on Pedestrian Crossing Behavior at Signalized and Unsignalized Intersections." *Accident Analysis and Prevention*, Vol. 39, pp. 197–205.
31. Nasar, J., P. Hecht, and R. Wener (2008). "Mobile Telephones, Distracted Attention, and Pedestrian Safety." *Accident Analysis and Prevention*, Vol. 40, pp. 69–75.
32. Neider, M. B., J. S. McCarley, J. A. Crowell, H. Kaczmarski, and A. F. Kramer (2010). "Pedestrians, Vehicles, and Cell Phones." *Accident Analysis and Prevention*, Vol. 42, pp. 589–594.
33. Stavrinos, D. C., K. W. Byington, and D. C. Schwebel (2011). "Distracted Walking: Cell Phones Increase Injury Risk for College Pedestrians." *Journal of Safety Research*, Vol. 42, pp. 101–107.
34. Thompson, L. L., F. P. Rivara, R. C. Ayyagari, and B. E. Ebel (August 2013). "Impact of Social and Technological Distraction on Pedestrian Crossing Behaviour: An Observational Study." *Injury Prevention*, Vol. 19, No. 4, pp. 232–237.
35. Schwebel, D. C., D. C. Stavrinos, K. W. Byington, T. Davis, E. E. O'Neal, and D. de Jong (2012). "Distraction and Pedestrian Safety: How Talking on the Phone, Texting, and Listening to Music Impact Crossing the Street." *Accident Analysis and Prevention*, Vol. 45, pp. 266–271.
36. Byington, K. W., and D. C. Schwebel (2013). "Effects of Mobile Internet Use on College Student Pedestrian Injury Risk." *Accident Analysis and Prevention*, Vol. 51, pp. 78–83.
37. Ogden, B. (2007). "Pedestrian Safety: Best Practices from Recent Western Rail Transit Projects." Presented at the Eastern Rail Crossing Conference, Albany, New York, October 3. Accessed from https://www.dot.ny.gov/divisions/operating/osss/rail/grade-crossings/repository/Brent%20Ogden%20-%20Pedestrian%20Safety%20at%20Grade%20Crossings%20ERCC.pdf. Accessed on April 8, 2013.
38. Metaxatos, P., and P. S. Sriraj (April 2013). *Pedestrian/Bicyclist Warning Devices and Signs at Highway-Rail and Pathway-Rail Grade Crossings.* FHWA-ICT-13-013, Illinois Department of Transportation, Springfield, Illinois. Accessed from http://ict.illinois.edu/publications/report%20files/FHWA-ICT-13-013.pdf. Accessed on February 18, 2014.
39. Chase, S., S. Gabree, and M. DaSilva (December 2013). *Effect of Gate Skirts on Pedestrian Behavior at a Highway-Rail Grade Crossing.* DOT/FRA/ORD-13/51, U.S. Department of Transportation, John A. Volpe National Transportation Systems Center for the Federal Railroad Administration, Washington, D.C. Accessed from http://ntl.bts.gov/lib/50000/50900/50989/Effect_of_Gate_Skirts_20131227.pdf. Accessed on February 18, 2014.
40. Federal Transit Administration, Office of Safety and Security (2010). *2009 Rail Safety Statistics Report.* Washington, D.C. Accessed from http://www.fta.dot.gov/documents/Rail_Safety_Statistics_Report_2009-FINAL.pdf. Accessed on April 8, 2013.

41. Federal Railroad Administration, Office of Railroad Safety (May 23, 2011). *FRA Guide for Preparing Accident/Incident Reports.* DOT/FRA/RRS-22, Washington, D.C. Accessed from http://safetydata.fra.dot.gov/officeofsafety/ProcessFile.aspx?doc=FRAGuideforPreparingAccIncReportspubMay2011.pdf. Accessed on April 8, 2013.
42. Federal Railroad Administration, Office of Safety Analysis (2014). FRA Office of Safety Analysis Web Site. Accessed from http://safetydata.fra.dot.gov/OfficeofSafety/default.aspx. Accessed on February 18, 2014.
43. Federal Railroad Administration, Office of Safety Analysis (2014). 1.02—Operational Data Tables. Accessed from http://safetydata.fra.dot.gov/officeofsafety/publicsite/Query/rrstab.aspx. Accessed on February 18, 2014.
44. Synectics Transportation Consultants, Inc.; Center for Transportation Research and Education, Iowa State University; Pennsylvania State University; Kittelson and Associates, Inc.; and Science Applications International Corporation (2006). *FHWA Road Safety Audit Guidelines.* FHWA-SA-06-06, Federal Highway Administration, Washington, D.C.
45. AASHTO (2010). *Highway Safety Manual, 1st Edition.* Washington, D.C.
46. American Public Transportation Association (February 6, 2008). "3. Recommended Practice for Rail Transit System Highway Rail Grade Crossing Safety Assessment." *Volume 3—Rail Grade Crossings Rev 3*, APTA RT-RGC-RP-003-03, Washington, D.C. Accessed from http://www.apta.com/resources/standards/Documents/APTA-RT-RGC-RP-003-03.pdf. Accessed on February 18, 2014.
47. Utah Department of Transportation (July 2013). *UDOT Pedestrian Grade Crossing Manual.* Salt Lake City, Utah.
48. Utah Department of Transportation (July 2011). *UDOT Railroad Coordination Manual of Instruction.* Salt Lake City, Utah. Accessed from http://www.udot.utah.gov/main/uconowner.gf?n=8616921141581886. Accessed on April 8, 2013.
49. Clark, R. (2008). *Pedestrian-Rail Crossings in California.* California Public Utilities Commission, San Francisco, California.
50. Federal Highway Administration and Federal Transit Administration (2009). *Environmental Impact and Related Procedures.* 23 CFR 771, Effective April 23, 2009, Washington, D.C.
51. Federal Railroad Administration (May 26, 1999). "Procedures for Considering Environmental Impacts." *Federal Register*, Vol. 61, No. 101, pp. 28545–28556.
52. Federal Transit Administration, Office of Planning and Environment (2006). *Transit Noise and Vibration Impact Assessment.* Report FTA-VA-90-1003-06, Washington, D.C.
53. Federal Railroad Administration, Office of Railroad Policy and Development (2012). *High-Speed Ground Transportation Noise and Vibration Impact Assessment.* Report DOT/FRA/ORD-12/15, Washington, D.C.
54. Irwin, D. (2003). "Safety Criteria for Light Rail Pedestrian Crossings." *Transportation Research Circular E-C058: 9th National Light Rail Transit Conference*, Portland, Oregon, November 16–18. Transportation Research Board of the National Academies, Washington, D.C., pp. 266–288.
55. Americans with Disabilities Act of 1990. Accessed from http://www.ada.gov/pubs/adastatute08.pdf. Accessed on April 8, 2013.
56. Federal Highway Administration (2014). Questions and Answers about ADA/Section 504. Accessed from http://www.fhwa.dot.gov/civilrights/programs/ada_sect504qa.cfm. Accessed February 14, 2014.
57. U.S. Department of Transportation (2006). *Americans with Disabilities Act (ADA) Standards for Transportation Facilities.* Effective November 29, 2006, Washington, D.C. Accessed from http://www.access-board.gov/attachments/article/1417/ADAdotstandards.pdf. Accessed on February 12, 2014.
58. United States Access Board (2011). "Chapter R3: Technical Requirements." *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way.* Published in *Federal Register* on July 26, 2011. Accessed from http://www.access-board.gov/guidelines-and-standards/streets-sidewalks/public-rights-of-way/proposed-rights-of-way-guidelines/chapter-r3-technical-requirements. Accessed on April 9, 2013.
59. Railroad/Light Rail Transit Technical Committee of the National Committee on Uniform Traffic Control Devices (2013). *RRLRT No 2a (9-08-12) Pathway Sidewalks* (with January 10, 2013, edits by the committee).
60. Department of Justice (2010). *2010 ADA Standards for Accessible Design.* Washington, D.C.
61. United States Access Board (2002). ADA Accessibility Guidelines (ADAAG). As amended through September 2002. Access from http://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/background/adaag. Accessed on April 8, 2013.
62. Rail Accident Investigation Branch. (December 2006). *Rail Accident Report: Investigation into station pedestrian crossings (including pedestrian gates at highway level crossings); with reference to the fatal accident at Elsenham station on 3 December 2005.* Report 23/2006. Department for Transport. Derby, UK. Accessed from: http://www.raib.gov.uk/cms_resources.cfm?file=/061211_R232006_Elsenham.pdf. Accessed on August 26, 2014.
63. Cornell University Law School, Legal Information Institute. "49 CFR Part 209, Appendix A to Part 209—Statement of Agency Policy Concerning Enforcement of the Federal Railroad Safety Laws." Accessed from http://www.law.cornell.edu/cfr/text/49/part-209/appendix-A. Accessed on October 15, 2014.

64. Cornell University Law School, Legal Information Institute. "49 CFR Part 211, Appendix A to Part 211—Statement of Agency Policy Concerning Waivers Related to Shared Use of Trackage or Rights-of-Way by Light Rail and Conventional Operations." Accessed from http://www.law.cornell.edu/cfr/text/49/part-211/appendix-A. Accessed on October 15, 2014.
65. California Department of Transportation (2013). *2012 Contract Cost Data: A Summary of Cost by Items for Highway Construction Projects.* Accessed from http://www.dot.ca.gov/hq/esc/oe/awards/2012CCDB/2012ccdb.pdf. Accessed on September 12, 2013.
66. Texas Department of Transportation (2013). Statewide Construction Average Low Bid Unit Price. Accessed from http://www.txdot.gov/business/letting-bids/average-low-bid-unit-prices.html. Accessed on October 2, 2013.
67. Korve, H. W., J. I. Farran, and D. M. Mansel (1995). "Pedestrian Control Systems for Light Rail Transit." *1995 Compendium of Technical Papers*, pp. 499–503.
68. Bushell, M. A., B. W. Poole, C. V. Zegeer, and D. A. Rodriguez (2013). *Costs for Pedestrian and Bicyclist Infrastructure Improvements.* Federal Highway Administration, Washington, D.C.
69. Sriraj, P. S., and P. Metaxatos (April 2013). *Pedestrian/Bicycle Warning Devices and Signs at Highway-Rail and Pathway-Rail Grade Crossings.* FHWA-ICT-13-013, Federal Highway Administration, Washington, D.C., p. A-18.
70. Saporta, H. (2012). "Pedestrian Crossing Upgrades." Presented at the American Public Transportation Association 2012 Rail Conference, Dallas, Texas, June 3–6, 2012. Available from http://www.apta.com/mc/rail/previous/2012/presentations/Presentations/Saporta-H-Pedestrian-Crossing-Upgrades.pdf. Accessed on April 8, 2013.
71. Currie, G., and P. Smith (2006). "An Innovative Design for Safe and Accessible Light Rail/Tram Stops Suitable for Streetcar Style Conditions." *Transportation Research Board 85th Annual Meeting, 2006, CD-ROM*, pp. 1–15.
72. Mathieu, R. (2007). "Metrolink Pedestrian Railroad Crossings Lessons Learned." Presented at the Eastern Rail Crossing Conference, Albany, New York, October 3, 2007. Available from https://www.dot.ny.gov/divisions/operating/osss/rail/grade-crossings/repository/Ron%20Mathieu%20-%20Pedestrian%20Treatments%20at%20Crossings%20ERCC.pdf. Accessed on April 8, 2013.
73. Kirschbaum, J. B., P. W. Axelson, P. E. Longmuir, K. M. Mispagel, J. A. Stein, and D. A. Yamada (2001). *Designing Sidewalks and Trails for Access: Part II, Best Practices Design Guide.* Federal Highway Administration, Washington, D.C.
74. Public Utilities Commission of the State of California (2006). "General Order No. 75-D." Accessed from http://docs.cpuc.ca.gov/word_pdf/GENERAL_ORDER/60157.pdf. Accessed on April 1, 2014.
75. Federal Railroad Administration, Office of Research and Development, Signal, Train Control, and Communication Division (2012). "Grade Crossing Safety and Trespass Prevention Research Program." Presentation made at the New Jersey TransAction Conference.
76. PB Farradyne (2002). *Final Report for the Second Train Warning Sign Demonstration Project on the Los Angeles Metro Blue Line.* FTA-CA-26-7017-01, Federal Transit Administration, Washington, D.C.
77. Sabra, Wang, and Associates, Inc., and PB Farradyne (2002). *TCRP Research Results Digest 51: Second Train Coming Warning Sign Demonstration Projects.* Transportation Research Board of the National Academies, Washington, D.C.
78. Carson, J. L., J. Tydlacka, L. S. Gray, and A. P. Voigt (2008). *NCHRP Synthesis 380: Applications of Illuminated, Active, In-Pavement Marker Systems.* Transportation Research Board of the National Academies, Washington, D.C.
79. Fitzpatrick, K., M. A. Brewer, and R. Avelar (2014). "Driver Yielding at Traffic Control Signals, Pedestrian Hybrid Beacons, and Rectangular Rapid Flashing Beacons in Texas." Paper accepted for publication in *Transportation Research Record*, Transportation Research Board of the National Academies, Washington, D.C.
80. Kovacs, J. (April 8, 2014). Deputy General Manager, Rail Safety and Training Department, New Jersey Transit. Email Correspondence.
81. Von Fay, P. (2013). "RTD Denver West Rail Line." Presentation at the 2013 National Highway-Rail Grade Crossing Safety Training Conference, November 4, 2013. Accessed from http://static.tti.tamu.edu/conferences/rail13/presentations/bo2-light-rail/vonfay.pdf. Accessed on February 18, 2014.
82. Murphy, A. (2013). "Renew the Blue Moving Forward along Eastside MAX Blue Line." *TriMet News*, November 13, 2013. Available from http://news.trimet.org/2013/11/renew-the-blue-moving-forward-along-eastside-max-blue-line/. Accessed on February 21, 2014.

Abbreviations, Acronyms, and Initialisms

ADAAG	Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities
ANSI	American National Standards Institute
APS	Accessible pedestrian signal
CE	Categorical Exclusion
CPUC	California Public Utilities Commission
DART	Dallas Area Rapid Transit
EA	Environmental Assessment
EIS	Environmental Impact Statement
FONSI	Finding of No Significant Impact
fps	Feet per second
IPM	In-pavement markings
LED	Light-emitting diode
LRT	Light-rail transit
LRV	Light-rail vehicle
MUTCD	*Manual on Uniform Traffic Control Devices*
NCUTCD	National Committee on Uniform Traffic Control Devices
NEPA	National Environmental Policy Act
NTD	National Transit Database
ROD	Record of Decision
ROW	Right-of-way
RTD	Regional Transportation District (Denver)
SCRRA	Southern California Regional Rail Authority
TOD	Transit-oriented development
UDOT	Utah Department of Transportation
UK	United Kingdom
UPRR	Union Pacific Railroad

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation