Safety Criteria for Light Rail Pedestrian Crossings

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Light rail systems introduce certain risks that may not be effectively mitigated through vehicular traffic control conventions. Upon the opening of its Westside MAX light rail extension, TriMet experienced several significant incidents involving pedestrians at crossings. TriMet initiated a process aimed at identifying actions that would eliminate or mitigate causes of such incidents. The criteria and application steps that TriMet developed following review are described.

TriMet commissioned an independent review of its entire light rail system. It also established an internal committee involving engineering, maintenance, operations, safety, marketing and management to evaluate numerous recommendations and to determine an appropriate action plan. Recommendations were implemented, in some cases, on a trial basis. Effects on pedestrian behavior were monitored. The process resulted in TriMet developing "Light Rail Crossing Safety" design criteria for use in the planning, design, and construction of TriMet light rail facilities.

TriMet has applied the criteria to its subsequent light rail extension projects or improvements. Projects include the Airport MAX and Interstate MAX extensions, and improvements to the existing Westside and Banfield alignments. Improvements to the existing system are evaluated by TriMet's newly established "Rail Change Rail Control" committee. The criteria have raised the safety awareness level of those persons who plan, design, construct, and operate the system and resulted in a safer system.

INTRODUCTION

Upon the opening of the Westside MAX extension in 1998 in Portland, Oregon, TriMet experienced several serious incidents involving pedestrians and light rail vehicles (LRVs). The Westside extension added 18 mi to TriMet's system. Ridership nearly doubled to 63,000 daily boardings. The number of at-grade crossings increased approximately two-fold to 159, inclusive of intersections and stations.

The incidents involved risky behaviors including violation of well-marked "No Trespassing" signage in certain instances. While TriMet's system incorporated current standards in the transit industry for operating practices and track crossing designs, TriMet sought to reduce risky behavior around the tracks and particularly at crossings. Accordingly, TriMet initiated an independent review of its entire system for the purpose of identifying enhancements that might reduce risky behavior.

TriMet hired Korve Engineering Inc. to assist in its independent review. TriMet received recommendations based on Korve Engineering's North American light rail research, field evaluation of TriMet's system, and interviews with TriMet safety staff and LRV operators. In addition, TriMet established an internal safety committee to review and take action on

recommendations. TriMet's safety committee consisted of representatives from Operations, Maintenance of Way, Systems Engineering, Civil Engineering, and Systems Safety.

Track locations that presented different safety risks were identified for prototype installations of safety treatments. Locations, and the primary safety risks, included

- 28th Avenue in Hillsboro (restricted pedestrian-train line of sight at crossing);
- Baseline/173rd in Beaverton (non-perpendicular traffic crossing of tracks);
- Beaverton Transit Center (high volume train-bus transfer location); and
- 122nd/East Burnside (high volume vehicular and train traffic pedestrian crossing).

Safety treatments included additional signage, swing gates, channeling, detectable warnings, "Stop Here" markings, audible-visual warning devices, and automatic pedestrian gates. Risky behavior was monitored before and after installation of the safety treatments.

While difficult to measure, TriMet concluded that the treatments increased pedestrian safety awareness in certain applications. This led to the development by TriMet of "Light Rail Crossing Safety" criteria. The criteria standardize certain devices and treatments so that they are consistent within the TriMet light rail system. Additionally, the criteria serve as a guide for persons who plan, design, and manage TriMet projects. They supplement, and do not supersede, other applicable rules and regulations.

The primary purpose of this paper is to describe passive and active standards that TriMet has incorporated into its light rail criteria, and guidance in their application. It also identifies key management steps that TriMet has found effective in the mitigation of safety hazards and risks.

BACKGROUND

The TriMet light rail system has been very successful and continues to expand. Since Westside MAX, transit ridership has increased 160% in the corridor. Airport MAX opened in 2001. When Interstate MAX is completed in 2004, TriMet's light rail system will include 45 route miles of track, 64 stations, and 95 vehicles.

Each expansion introduces new elements into the community. The light rail-operating environment includes characteristics that differ from traffic control conventions for roadways and passenger or freight railroad crossings. These include

- LRVs are quiet. TriMet also takes specific measures to reduce LRV wheel-to-rail noise and to mitigate warning sounds at intersections, in response to community concerns.
- LRV crossings through intersections are frequent. The TriMet system accommodates 2- to 5-min headways in each direction.
- Light rail provides an alternative daily transit option and draws large numbers of people toward its stations. Stations are located to encourage transit usage and development.
- Light rail crossings occur in a wide variety of alignment configurations and operating environments. Typical railroad-style, gated crossings are not feasible in certain light rail environments.
- Pedestrian and vehicular incidents at light rail crossings tend to be severe. Incident severity increases as LRV speed increases.

Planning and Design Objectives

TriMet's general approach to planning and design is to eliminate hazards where possible, then mitigate or warn. More specifically, the approach is to

- Eliminate hazards: Hazards to the customers and public shall be identified, evaluated, and eliminated through planning and design where feasible. For example, the number of track crossings should be minimized. Line-of-sight obstructions to oncoming LRVs should be avoided.
- Mitigate unavoidable risks: Where planning and design does not allow for elimination of hazards or unacceptable safety risks, safety treatments that mitigate those risks shall be provided.
- Provide warning devices: Where neither planning, design, nor safety treatments effectively eliminate identified hazards or adequately reduce associated risks, warning devices shall be used to alert persons of the remaining risks and hazards. Warning devices may be passive or active.
- Acceptable level of risk: TriMet systems safety manager shall be consulted to confirm whether an identified risk or hazard that cannot be eliminated or mitigated is acceptable.

Safety Certification

TriMet utilizes a safety certification program to verify that identified safety requirements have been met prior to commencement of revenue service. Certifiable elements checklists are developed for each contract.

RCRC Review of Existing Light Rail Facilities Changes

TriMet has established a Rail Change Review Committee (RCRC) to review and approve all proposed revisions to rail transportation and maintenance policies, procedures, and existing rail system elements. The RCRC consists of members of Operations, Maintenance, Systems Safety, Systems Engineering, and Bus and Rail Transportation. Proposed revisions to the existing system should be supported with a behavior or incident analysis. It should address the risky behavior or incident that has led to the proposed revision, including how and why the proposed passive or active safety treatments will mitigate or eliminate the behavior or incident of concern.

Independent Safety Design Review and Hazard and Risk Analysis

TriMet has incorporated independent review of its designs for pedestrian and vehicular safety into its process for LRT extensions. Independent reviews may be provided by non-project personnel within the agency, by outside experts, or by peer groups. For example, as construction is being completed on Interstate MAX, TriMet is conducting a final, independent hazard and risk analysis. This is in addition to independent review by Korve Engineering during design development. TriMet's Interstate MAX safety committee has been established to discuss and review safety hazard and risk items, consider mitigation options, recommend resolution including changes to the existing design, and document process and follow-through on implementation.

TRIMET STANDARDS

TriMet has established standards for use to mitigate or warn of trackway crossing risks or hazards in the various light rail environments. Application depends upon analysis and review of each location. Standardized treatment is intended to promote the understanding of and compliance with the safety treatments by customers and the public at large.

Passive Safety Treatments

Passive treatments are not activated by approaching trains. A typical at-grade installation is depicted in Figure 1. Passive treatments are listed below.

"Stop Here" Pavement Markings

Figure 2 details Stop Here pavement marking for pedestrian warning. The purpose of this marking is to identify for pedestrians and bicyclists a safe stopping location that is outside the light rail vehicle dynamic envelope.

Generally, the Stop Here markings are not required in city environments because of the slower light rail vehicle operating speeds. Nor are they required at traffic-controlled intersections, at platforms, and at other locations where safe stopping locations are readily identifiable.

Stop Here markings should be considered where:

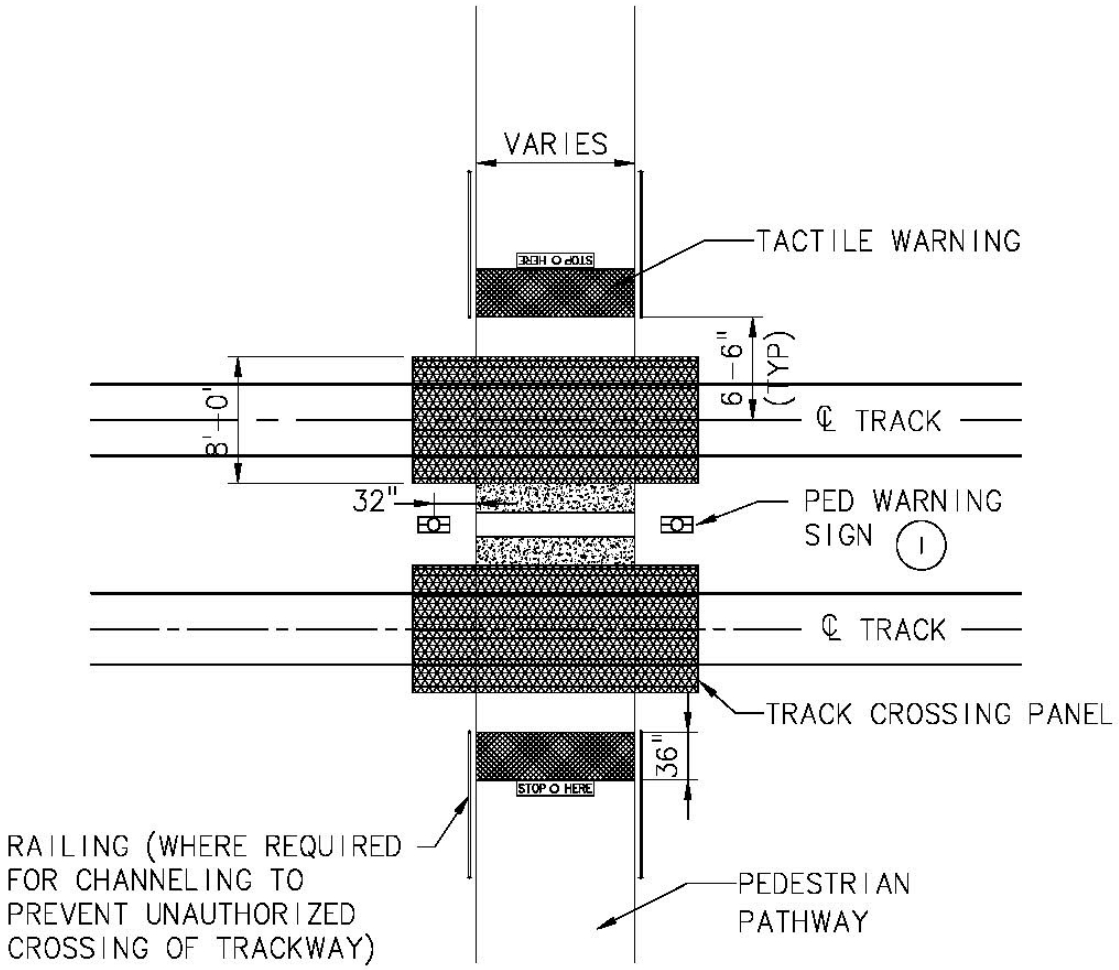
- LRV design speeds exceed 15 mph in non-city environments, and
- Safe pedestrian stopping location is unclear.

Tactile Warning

Figure 3 details pedestrian tactile warning treatment in pavement adjacent to a trackway crossing. The purpose of the tactile warning is to identify for pedestrians a safe stopping location and safe refuge area that is outside the LRV dynamic envelope.

This standard should be applied:

- In conjunction with "Stop Here" markings, or
- Where detectable warning is required at light rail station platforms and adjacent trackway crossings.



TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL TYPICAL AT-GRADE INSTALLATION	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 11/99
SCALE: NOT TO SCALE	FILE NAME: STD-13		CONTRACT NO:	SHEET NO: 15.06.5A

FIGURE 1 Typical at-grade installation.

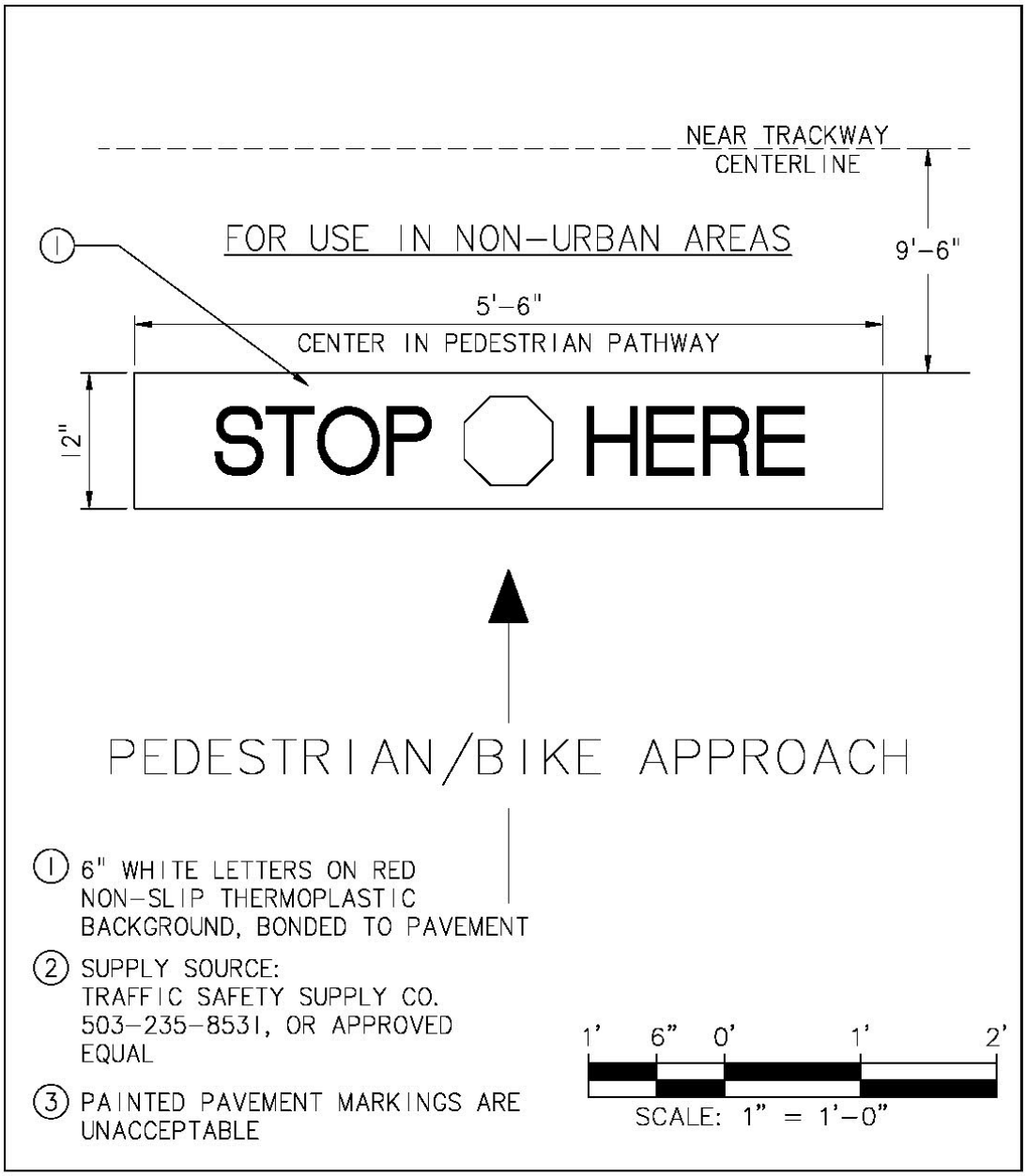
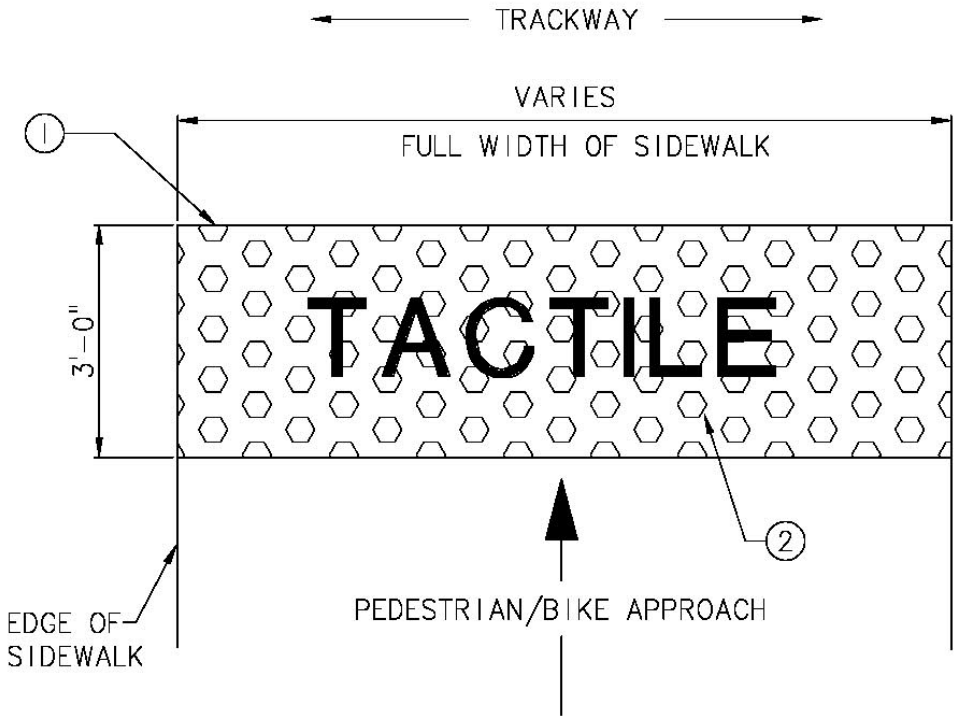


FIGURE 2 Pedestrian warning "Stop Here" marking.



1. DETECTABLE WARNING SURFACE, APPROVED BY TRI-MET, AS REQUIRED BY 49 CFR, PART 37, APPENDIX A, PARAGRAPH 4.29.5.
2. COLOR SHALL CONTRAST ADJACENT SURFACES, AS REQUIRED BY 49 CFR, PART 37, APP. A PARA. 4.29.2 & ADAAG APPENDIX R.
3. COORDINATE WITH JURISDICTION FOR APPLICATION IN JURISDICTION RIGHT-OF-WAY.
4. SUPPLY SOURCE: ARMOR TILE BY ENGINEERED PLASTICS, INC., OR STRONGWARN BY STRONGWALL INDUSTRIES, INC., OR APPROVED EQUAL
5. STRIATED OR MESHED CONCRETE IS NOT ACCEPTABLE

TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL PEDESTRIAN TACTILE WARNING	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 10/21/99
SCALE: 1/2" = 1'-0"	FILE NAME: STD-10		CONTRACT NO:	SHEET NO: 15.06.5C

FIGURE 3 Pedestrian tactile warning.

Channeling

Figure 4 details railing that may be used to channel pedestrians or bicyclists. The purpose of the channeling is to create a physical barrier that prevents or discourages persons from taking shortcuts or from crossing the trackway in a risky or unauthorized manner.

Application of channeling depends upon the particular conditions associated with the trackway crossing. It requires custom design for the particular location. Jurisdictional review of the proposed method may be required. In all cases, a channeling method that does not impair sight lines to an approaching train shall be selected.

Channeling should be considered where:

- A high likelihood exists that persons may cross the trackway in an unauthorized manner, particularly if in a hurry, and
- Other elements at the location will be effective in deterring unauthorized crossings.

"Look Both Ways" Signage

Figure 5 details "Look Both Ways" signage. The purpose of the signage is to remind pedestrians and bicyclists as they approach the trackway to look for approaching trains in both directions.

Generally, Look Both Ways signage is not required in city environments because of the slower LRV operating speeds. The signage should be installed at

- Non-city trackway crossing locations where LRV design speeds exceed 15 mph,
- Light rail platforms in ballasted trackway, or
- Mid-block pedestrian crossings.

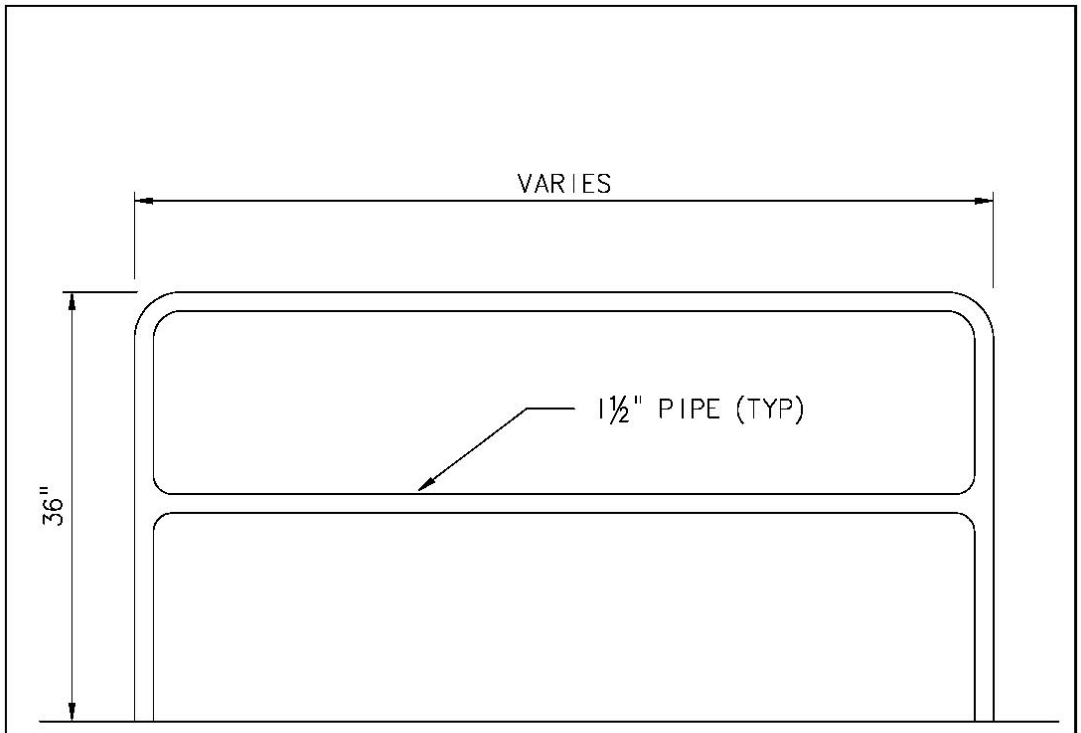
Swing Gates

Figure 6 details the installation of pedestrian crossing swing gates. The purpose of swing gates is to slow persons who hurriedly approach the trackway. Swing gate operation depends upon the individual. Gate operation is not electrically interconnected into approaching train or vehicular traffic signal systems.

Application of swing gates depends upon the particular conditions associated with the trackway crossing or light rail station. Generally, TriMet prefers barrier free access to its light rail stations.

Swing gates may be appropriate where:

- Pedestrian to train sight lines are restricted;
- A high likelihood exists that persons will hurriedly cross the trackway;
- Channeling or other barriers reasonably prevent persons from bypassing the swing gates; and
- Acceptable provisions for opening the gates by disabled persons can be provided.



NOTES:

1. DESIGN LOCATION AND LENGTH OF RAILING SO THAT CHANNELING REDUCES UNAUTHORIZED CROSSING OF TRACKWAY.
2. RAILING SHALL NOT INTRUDE INTO VEHICULAR DYNAMIC ENVELOPE
3. COORDINATE SET BACK FROM ROADWAY WITH JURISDICTION.
4. OTHER EFFECTIVE CHANNELING METHODS, SUCH AS THROUGH THE USE OF LANDSCAPING OR FENCING MAY ALSO BE APPROPRIATE IN CERTAIN SITUATIONS. RAILING WITH VERTICAL MAY ALSO BE ACCEPTABLE. OBTAIN TRI-MET APPROVAL.

TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL PEDESTRIAN CHANNELING TYPICAL RAILING	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 8-19-02
SCALE: 1" = 1'-0"	FILE NAME: STD-15		CONTRACT NO:	SHEET NO: 15.06.5B

FIGURE 4 Typical railing for pedestrian channeling.

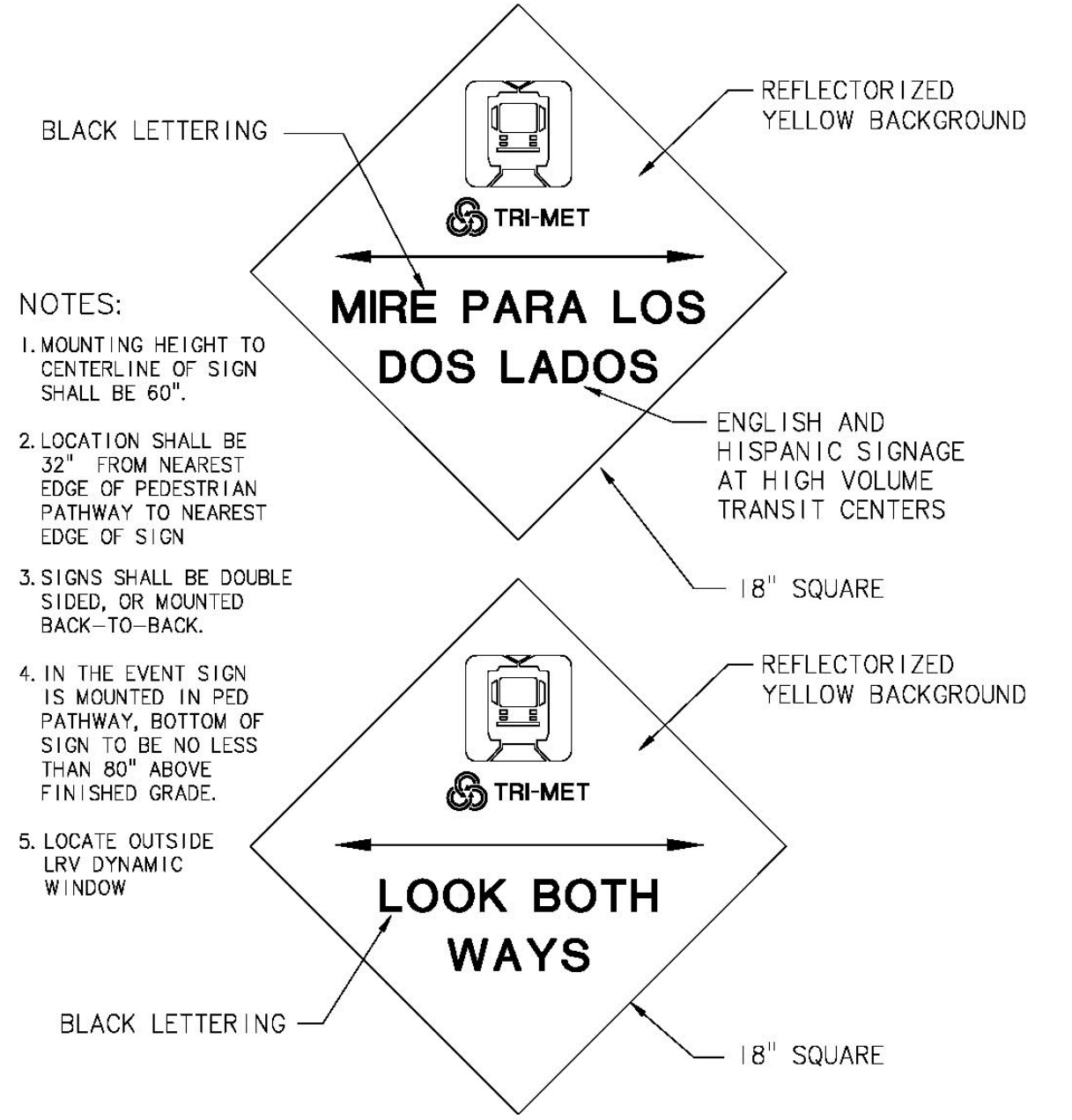
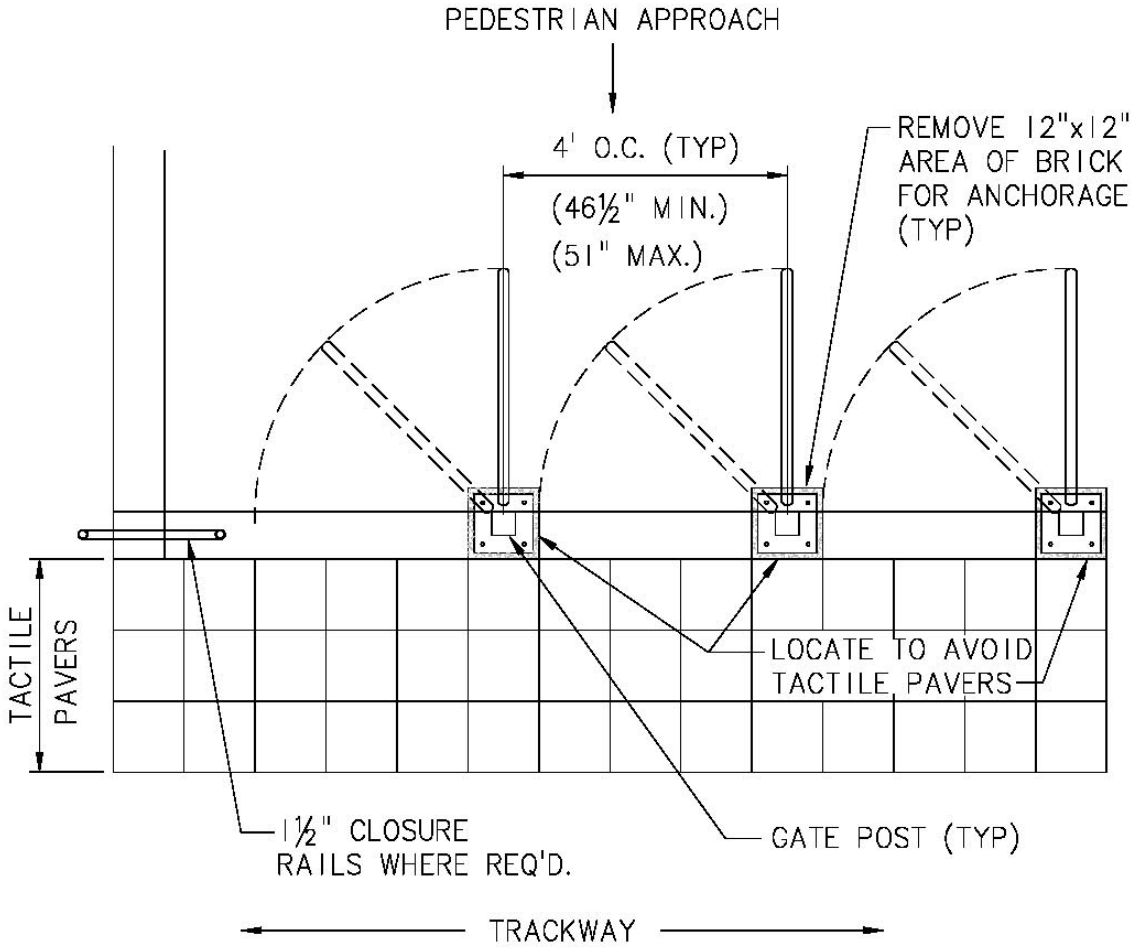


FIGURE 5 Typical crossing "Look Both Ways" sign.



1. GATES SHALL OPEN AWAY FROM TRACKWAY AND RETURN TO THEIR CLOSED POSITION THROUGH SPRING OR GRAVITY OPERATION.

2. AT STATION PLATFORMS, PROVISIONS SHALL BE MADE FOR ADA COMPLIANT PUSHBUTTON OPERATION OF ON SET OF GATES.

TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL PEDESTRIAN CROSSING SWING GATE INSTALLATION	
DRAWN BAL	DESIGN DI	CHECKED DI	APPROVED: DI	DATE: 11/12/02
SCALE: NOT TO SCALE	FILE NAME: STD-22		CONTRACT NO:	SHEET NO:

FIGURE 6 Pedestrian crossing swing gate installation.

The disadvantages of swing gates also should be considered prior to proposing their use. Generally, the swing gates have proven effective in slowing access across the trackway. However, swing gates require regular maintenance to ensure proper operation. Additionally, at light rail stations, TriMet requires provisions for push button operation of one set of gates that is compliant with the Americans with Disabilities Act (ADA).

Pedestrian Barriers

Figure 7 details pedestrian barriers. Similar to swing gates, these barriers are intended to slow persons who are hurriedly approaching the trackway. A major advantage of barriers is that there are no operating parts or systems to maintain.

Pedestrian barriers may be appropriate where:

- Pedestrian to train sight lines are restricted;
- A high likelihood exists that persons will hurriedly cross the trackway;
- Channeling or other barriers reasonably prevent persons from bypassing the barriers; or
- Adequate space is available to accommodate their installation.

Pedestrian Z-Crossings

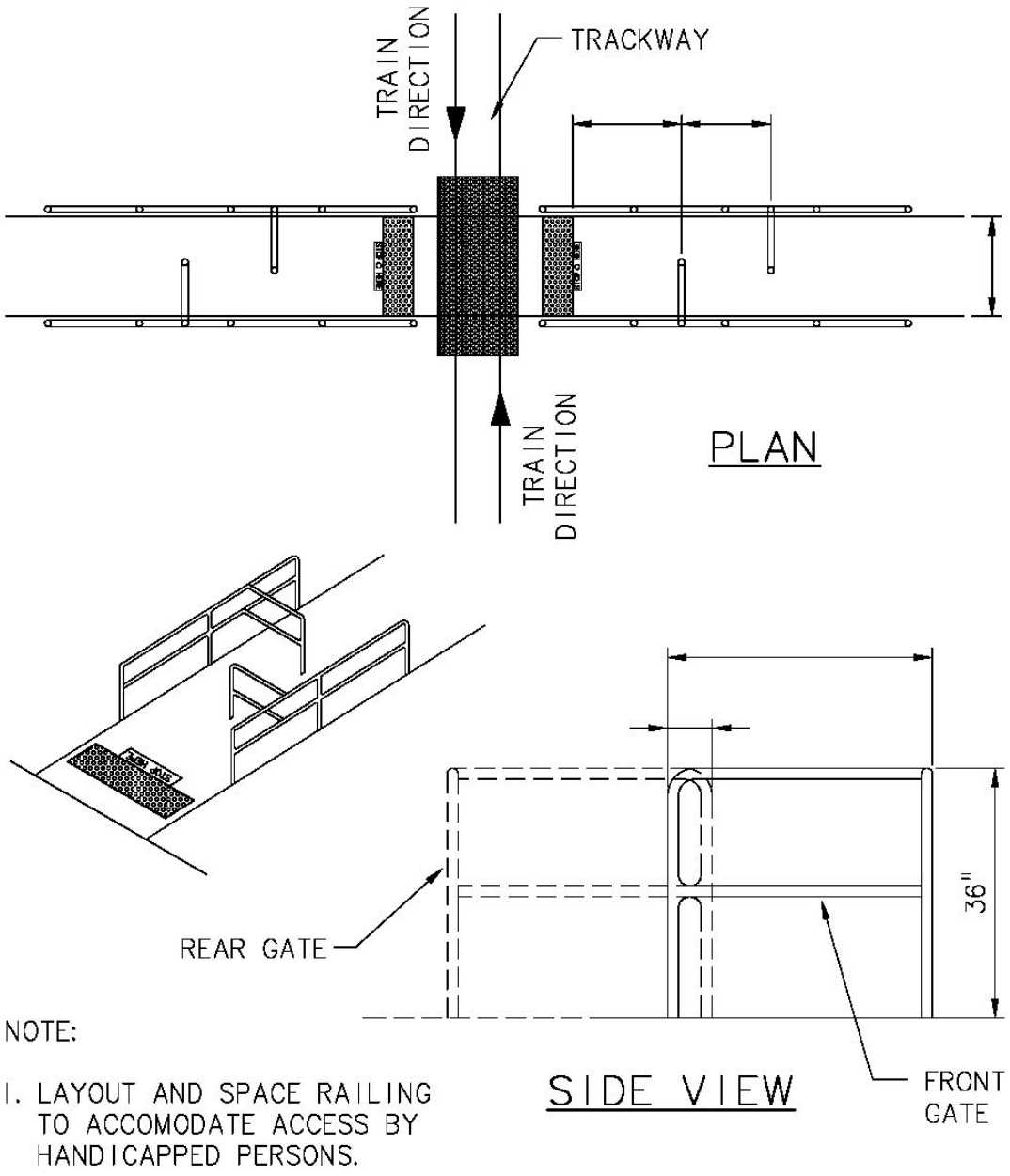
Figure 8 details a pedestrian Z-crossing installation. The purpose of this standard is to promote uniform application and safety features within the TriMet system.

In general, TriMet does not advocate the installation of pedestrian Z-crossings. Z-crossings occur at mid-block locations, rather than at vehicular intersections, and consequently are inherently less safe than traffic-controlled intersection crossings. Nevertheless, circumstances or community desires may result in incorporation of Z-crossings into the planning and design.

Pedestrian Z-crossings should cross the track as closely as possible to perpendicular, or with a slight angle so that a person is oriented facing the nearest, oncoming train direction. Care shall be taken to ensure compliance with ADA standards including path finding.
If a pedestrian Z-crossing is approved by TriMet and the jurisdiction having authority, consideration should be given to the incorporation of active audible or visual warning devices with it, in conjunction with the passive safety treatments. Audible or visual warning devices will require electrical interconnection with traffic signal or light rail signal systems in order to activate the devices. The installation requires careful engineering to ensure safe crossing clear-out time, given the LRV design speed and safe braking distance at each location.

"Do Not Cross Trackway" Signage

At station platforms in tie and ballast trackway, TriMet requires the placement of a warning notice on the vertical edge of the platform opposite customers who await oncoming trains. The warning notice shall read "Do Not Cross Trackway." Easily readable, painted black lettering over a white background may be used.



TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL PEDESTRIAN BARRIER (BEDSTED)	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 10/21/99
SCALE: 1" = 1'-0"	FILE NAME: STD-23		CONTRACT NO:	SHEET NO: 15.06.5H

FIGURE 7 Pedestrian barrier.

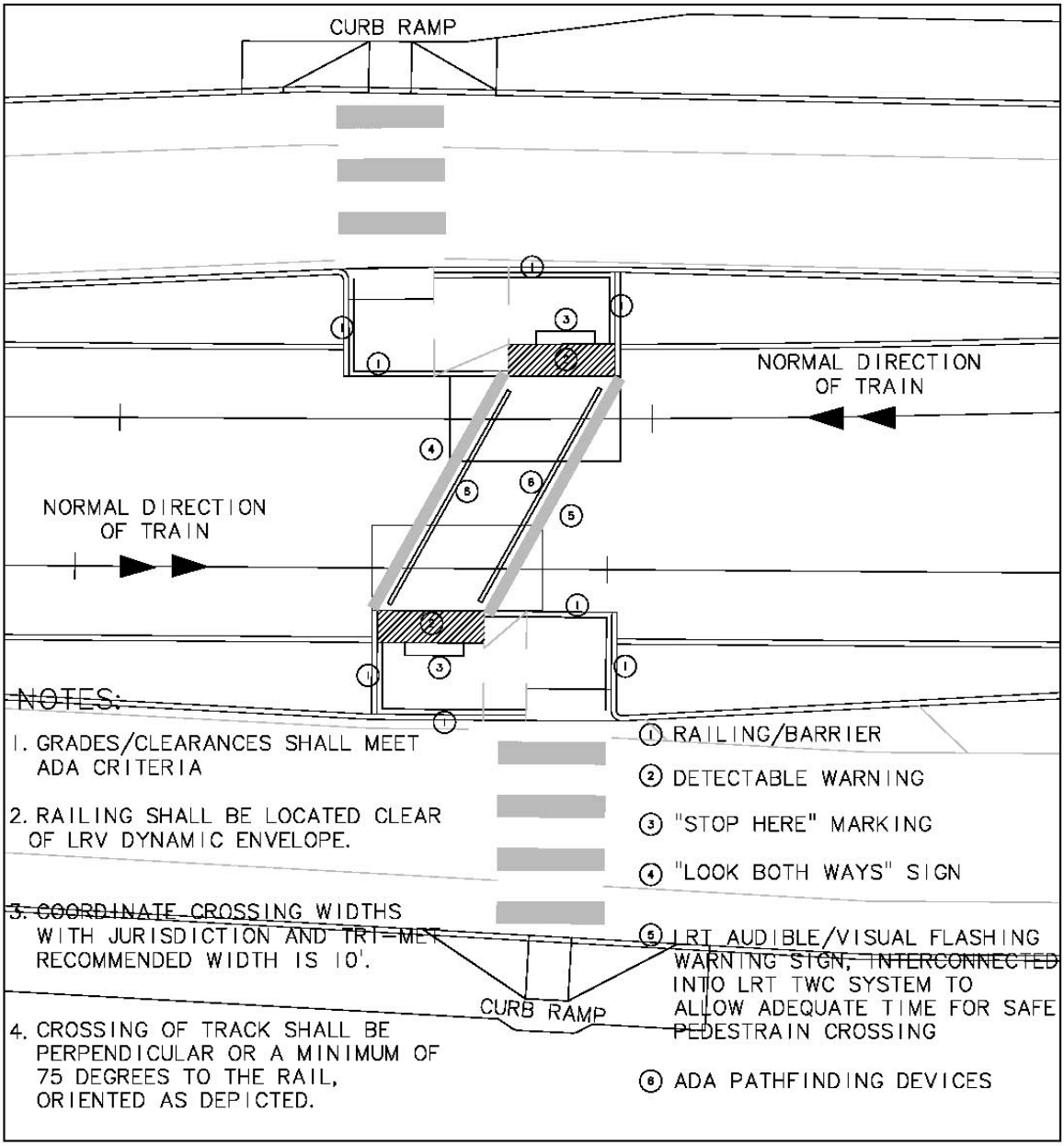


FIGURE 8 Standard detail of typical pedestrian Z-crossing.

Active Safety Treatments

An approaching train automatically activates these devices. These systems may consist of automatic gates, flashing light signals, traffic control signals, warning signs, audible signals, and other active warning devices.

LED Flashing Train Warning Signs

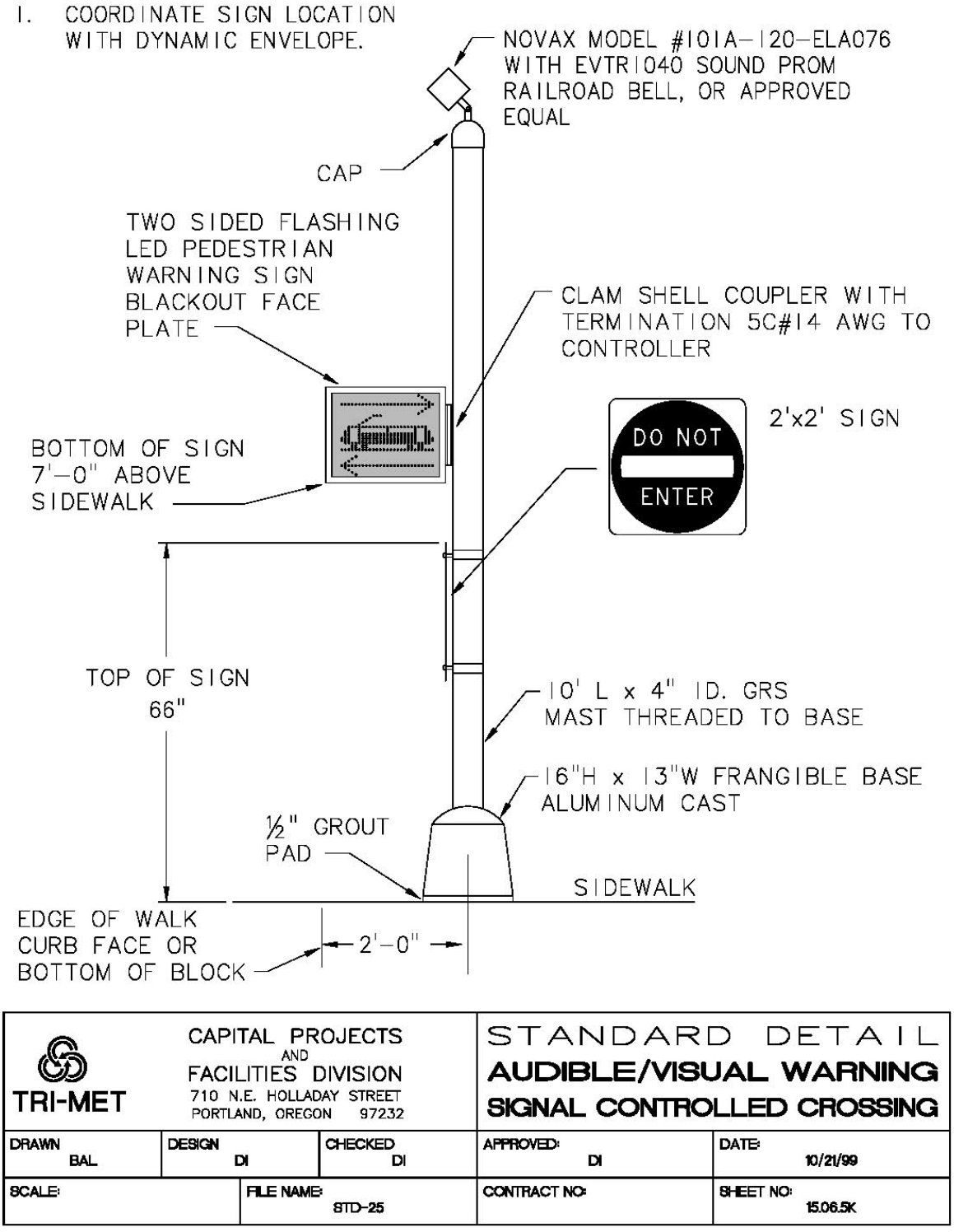
TriMet light rail operations has found that flashing train signs are an effective warning device for both pedestrians and motorists. Figure 9 depicts such a device in a pedestrian application.

To warn motorists of an approaching train at traffic signal controlled intersections, consideration should be given to incorporation of LED flashing train signs on traffic signal mast arms or poles in the following situations:

- Left turns by motorists are permitted across the trackway,
- Cross traffic motorist volumes are high,
- Line of sight obstructions limit motorist ability to see oncoming trains, or
- There is a high volume of slow moving or turning truck traffic across tracks.

TriMet has installed LED flashing signs overhead at several locations for motorists. Examples are 10th and Washington in Hillsboro, 18th and Salmon in downtown Portland, and 82nd and Airport Way. On Interstate MAX, which is currently under construction, the signs have been incorporated into the design at all left turns across the trackway, at cross streets with high volumes of traffic, and at certain obstructed crossings.

At pedestrian crossings at intersections equipped with traffic control signals, pedestrians cross the light rail tracks in response to standard “Walk” and “Don’t Walk” signal indications. Generally, a pedestrian LED flashing sign and audible warning device is not required in the traffic signal controlled environment.



TRI-MET CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232			STANDARD DETAIL AUDIBLE/VISUAL WARNING SIGNAL CONTROLLED CROSSING	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 10/21/99
SCALE:	FILE NAME: STD-25		CONTRACT NO:	SHEET NO: 15.06.5K

FIGURE 9 Audible or visual warning signal controlled crossing.

The device may be appropriate where:

- LRV design speed at the location exceeds 15 mph,
- The LRV operates in the median of city streets,
- Motor vehicle traffic is discouraged within the trackway and does not normally share the use of the light rail trackway, and
- The pedestrian crossing is an unsignalized mid-block crossing or is at a traffic signal controlled intersection adjacent to a platform.

Pedestrian Flashing Lights and Audible Warning Device in Gated Crossing Controlled Environments

Figure 10 depicts the Pedestrian Flashing Lights and Audible Warning Device that operates when a LRV is approaching in a train signal controlled environment. The purpose of this device is to warn pedestrians against crossing the trackway as trains approach.

This device is used where automatic crossing gates, lights, and bells are provided to warn of an approaching train. This standard should be considered where:

- LRV design speed at the location exceeds 25 mph,
- The LRV operates in a semi-exclusive right-of-way, and
- Sight distance considerations or heavy pedestrian or bicycle activity warrant its use, and
- Oregon Department of Transportation (ODOT) Rail crossing order permits its use.

Automatic Pedestrian Gates

Figure 11 depicts an Automatic Pedestrian Gate installation. The purpose of this device is to prevent or discourage a pedestrian or bicyclist from crossing the trackway when a train is approaching. These gates are electrically interconnected into and activated by the train signal system.

Automatic pedestrian gates should be used only when severe safety hazards or risks, that cannot otherwise be eliminated, exist in the train control signal environment. The circumstances for application of this standard include the following:

- Train speeds exceed 35 mph,
- LRVs are operating in a semi-exclusive right of way,
- Pedestrian-to-train sight distance or visibility is severely limited,
- A safe refuge area between the gates and LRV dynamic envelope can be provided, and ODOT Rail approves use

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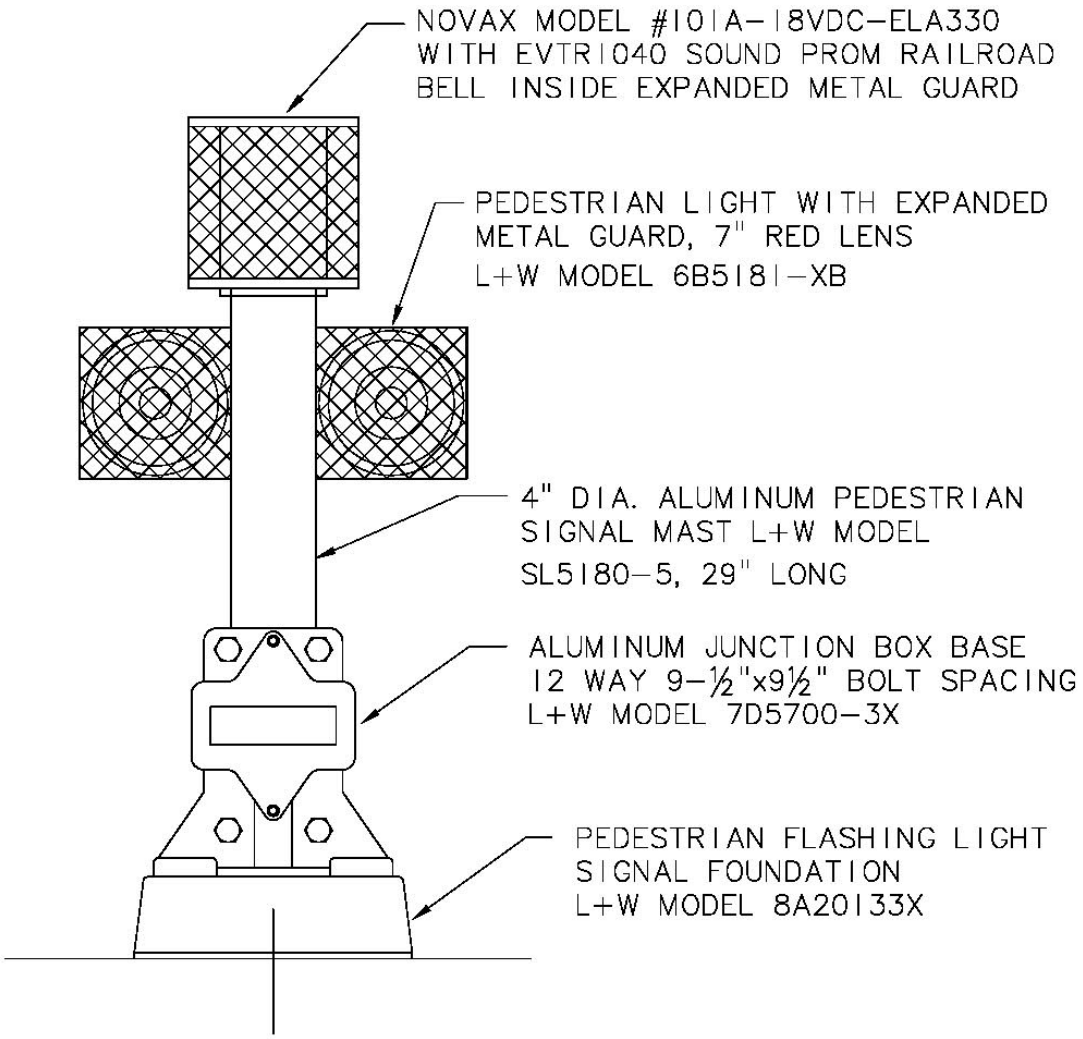
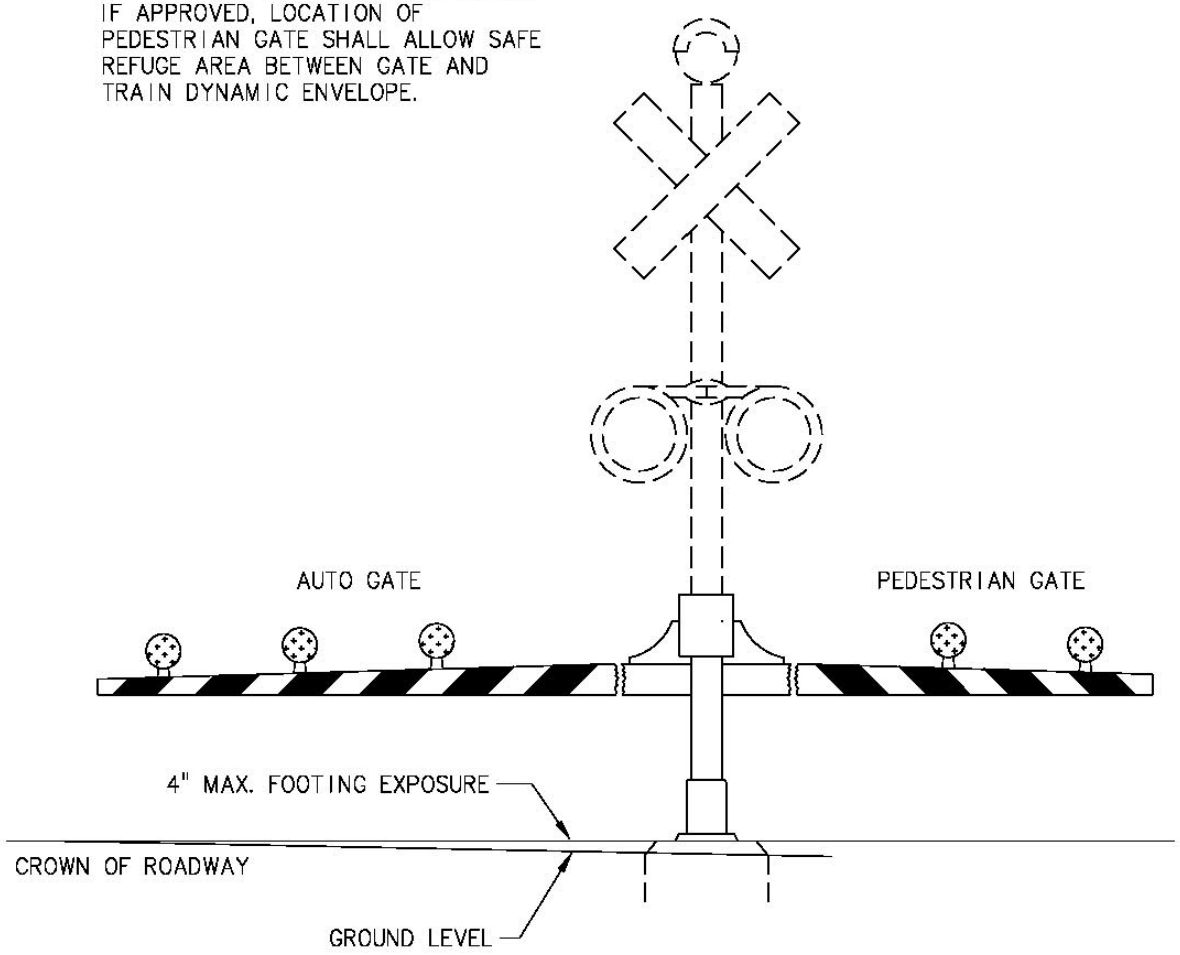


TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL AUDIBLE/VISUAL WARNING GATED CROSSING	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 10/21/99
SCALE:	FILE NAME: STD-26		CONTRACT NO:	SHEET NO: 15.06.5L

FIGURE 10 Audible or visual warning gated crossing.

1. ODOT RAIL APPROVED AND CROSSING ORDER REQUIRED FOR ALL GATES.

2. IN GENERAL, ODOT RAIL DOES NOT APPROVE USE OF PEDESTRIAN GATES. IF APPROVED, LOCATION OF PEDESTRIAN GATE SHALL ALLOW SAFE REFUGE AREA BETWEEN GATE AND TRAIN DYNAMIC ENVELOPE.



TRI-MET	CAPITAL PROJECTS AND FACILITIES DIVISION 710 N.E. HOLLADAY STREET PORTLAND, OREGON 97232		STANDARD DETAIL AUTOMATIC AUTO/PED GATE	
DRAWN: BAL	DESIGN: DI	CHECKED: DI	APPROVED: DI	DATE: 08/06/01
SCALE:	FILE NAME: STD-28		CONTRACT NO:	SHEET NO: 15.06.5M

FIGURE 11 Automatic automobile or pedestrian gate.

In general, ODOT Rail disapproves of the use of automatic pedestrian gates. An exception may be approved only when extreme circumstances exist and when no other treatments are feasible. TriMet only has one automatic pedestrian gate installation. Its location is at 28th Avenue in Hillsboro. Severely restricted sight distance coupled with train speeds exceeding 35 mph were major considerations in this application. Layout and placement must consider ADA requirements, ensure safe refuge between the gate and train envelope, and comply with the ODOT Rail crossing order.

APPLICATION OF CRITERIA AND STANDARDS

Application of the criteria is dependent upon the operating environment. The exclusivity of use, LRV design speed, line of sight, and other conditions must be considered.

Exclusivity of Use

A semi-exclusive use, light rail-operating environment is a light rail alignment in a separate right of way, or along a street or railroad right of way, where motorists, pedestrians, and bicyclists cross at designated crossings only. An example is Interstate MAX where light rail operates in the median of Interstate Avenue. Along the alignment, traffic signals and crosswalk pavement markings permit pedestrians to cross Interstate Avenue and to access station platforms located in the median.

A mixed-use, light rail-operating environment is a light rail alignment in mixed traffic with motorists, pedestrians, and bicyclists. An example is MAX light rail service in downtown Portland between the Steel Bridge and Jefferson Street, and in downtown Hillsboro between 1st and 10th Avenues.

An exclusive use, light rail-operating environment is a light rail alignment that is grade-separated or by a barrier that prevents intrusion by motorists, pedestrians, and bicyclists. Examples are the Washington Park tunnel, Interstate Max light rail-only structure from Argyle to Delta Park/Vanport station, and segments of Airport MAX. TriMet light rail crossing safety treatments generally are inapplicable, because motor vehicles, pedestrians, and bicycles are prohibited within exclusive right of way.

LRV Design Speed

Application of safety treatments requires consideration of numerous conditions. TriMet's safety committee considered numerous flow charts and approaches in trying to decide how to organize the application of the treatments. TriMet decided to organize application of the criteria around LRV design speed for three primary reasons. First, the committee desired an easily understood starting point so that staff and consultants would apply the criteria as intended. Secondly, TriMet's existing light rail system is easily categorized by design speed and the selected break points. Third, TriMet's experience is that the severity of safety hazards and risks increases with LRV speed.

Table 1 categorizes application treatments based upon the LRV design speed. Design speeds with possible treatments are grouped as follows: 1) 15 mph and less; 2) 35mph and less, but greater than 15 mph; and 3) greater than 35 mph.

TABLE 1 Pedestrian Crossing Application Chart

	LRV DESIGN SPEED		
CROSSING CONDITION	**15 MPH AND LESS**	**16 TO 35 MPH[a]**	**GREATER THAN 35 MPH**
Ordinary, no special conditions	Detectable Warning only	Basic treatment.	Basic treatment; AT
Special Conditions: Treatments listed below are in addition to those above			
Moderate Sight Restriction[b]	----	Channeling; AT; PT gates/barriers	Channeling; AT; PT gates/barriers
Severe Sight Restriction**	----	Channeling; AT; Automatic ped gates	Channeling; AT; Automatic ped gates
High Pedestrian Activity	----	Channeling	Channeling
Extreme pedestrian surges, high pedestrian non-attention or hurried behavior; school zone; transit centers	Basic treatment; Channeling	Channeling; AT; PT gates/barriers	Channeling; AT; PT gates/barriers
Angled crossing or odd geometry; mid-block pedestrian Z-crossings	Basic treatment; Channeling; PT gates/barriers	Channeling; PT gates/barriers; AT	Channeling; PT gates/barriers; AT

NOTES: Basic Treatment: "Stop Here" pavement marking; Detectable warning; "Look Both Ways" signage. Other Passive Treatments: Channeling; PT Swing gates or Pedestrian barriers. Active Treatments (AT): Pedestrian flashing signs/lights and audible warning devices. Other Active Treatments: Automatic pedestrian gates
This chart is intended as a guide only, and not a mandate, as to what treatments should be applied. Perform safety analysis for each location. Apply treatments in a manner consistent with all TriMet design criteria and other governing code and regulatory requirements.
[a]Crossings immediately adjacent to light rail platforms fall into this category.
[b]Eliminate sight restrictions if feasible. Comply with train-person line-of-sight criteria.

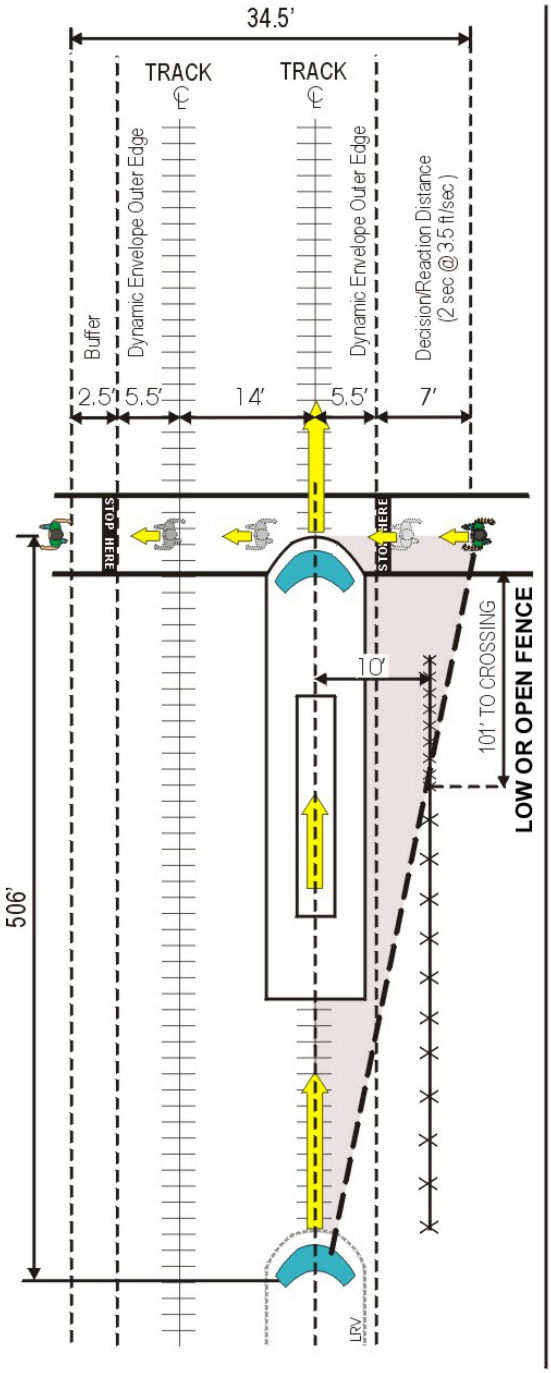
Line-of-Sight Between Persons and Trains

Clear sight lines between persons about to cross the trackway and approaching or leaving trains are important at all locations. TriMet, working with Korve Engineering, developed a pedestrian sight triangle to assist in planning and design. A pedestrian sight triangle may be applied as demonstrated in Figure 12.

On Westside, TriMet encountered several specific line-of-sight obstructions. As a result, TriMet recommends the following:

- Avoid landscaping other than low-growing ground cover in and adjacent to trackway,
- Where sound walls are required for noise mitigation, ensure height does not violate the line-of-sight criteria, and

Figure 4. PEDESTRIAN SIGHT TRIANGLE



CASE: LRV Approaching Crossing at 35 mph

Figure 4 illustrates sight distance required for pedestrian to safely cross two tracks, covering a distance of 34.5 feet.

Assumptions:

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

Minimum Crossing Distance, 34.5 feet, where:

- 7.0 ft is the distance traveled at 3.5 feet per 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 Braking Distances for Unanticipated Stops

LRV Speed (mph)	LRV Traveled Distance (ft) in 9.86 sec.	Full Service Braking Distance (ft)	Emergency Braking Distance (ft)	Distance of Low or Open Fence
15	217	110	81	43
25	362	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' covered in 9.86 seconds and 7' reaction time, fence height should not obstruct view 101' from crossing.

Figure NOT TO SCALE

Korve Engineering, Inc. March 6, 2000

FIGURE 12 Pedestrian sight triangle illustration.

- Avoid placement of buildings or large cabinets on or immediately adjacent to platforms and crossings.

Other Conditions

In addition to exclusivity of use, LRV design speed and line-of-sight between persons and trains, other special considerations may exist. These include

- Degree of sight restriction
- Volume and frequency of pedestrian activity
- Likelihood of pedestrian inattention or hurried behavior
- School zone proximity
- Alignment geometry such as terrain or angled crossing paths.

CONCLUSION

Since Westside MAX, TriMet has applied the criteria to its light rail extension and improvement projects. Projects include Airport MAX and Interstate MAX extensions, and various improvements to the existing Westside and Banfield alignments. The criteria have raised the safety awareness level of those persons who plan, design, construct, and operate the system. Management processes, involving RCRC and project specific safety hazard and risk review teams, encourage independent review and application of the criteria as conditions warrant. The result is a system that is planned, designed, and operated as safely as possible.