Exhibit No. ___ (KH-4)
Docket TR-100572
Witness: Kathy Hunter

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

BENTON COUNTY, **Petitioner,** **v.** **BNSF RAILWAY COMPANY,** **Respondent.**	**DOCKET TR-100572**

EXHIBIT TO TESTIMONY OF

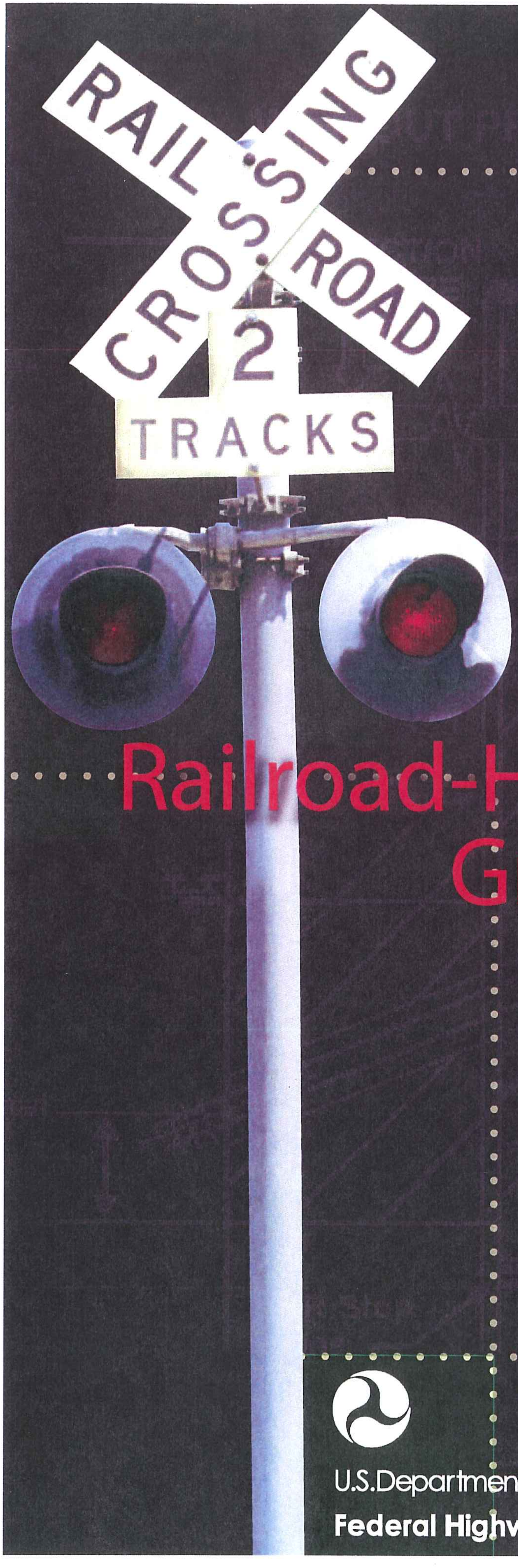
Kathy Hunter

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

U.S. DOT/FHWA
Railroad-Highway Grade Crossing Handbook, Aug. 2007 ed. (excerpts)

November 29, 2010

Exhibit No. (KH-4)
Docket TR-100572
Page 1 of 26



Railroad-Highway Grade Crossing Handbook

Revised Second Edition
August 2007

U.S.Department of Transportation
Federal Highway Administration

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Table 28. Factor Values for U.S. DOT Injury Accident Probability Formula

Injury Accident Probability Formula:

$$P(IA \mid A) = \frac{1 - P(FA \mid A)}{(1 + CI \times MS \times TK \times UR)}$$

where: P(FA|A) = Fatal accident probability, See Tables 25 and 27
CI = 4.280, formula constant
UR = 1.202, urban crossing
= 1.000, rural crossing, and

Maximum Timetable Train Speed	MS	Total Number Of Tracks	TK
1	1.000	0	1.000
5	0.687	1	1.125
10	0.584	2	1.265
15	0.531	3	1.423
20	0.497	5	1.800
25	0.472	6	2.025
30	0.452	7	2.278
40	0.423	8	2.562
50	0.401	9	2.882
60	0.385	10	3.241
70	0.371	15	5.836
80	0.360	20	10.507
90	0.350		
100	0.341		

Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

C. Engineering Study*

Federal requirements dictate that each state shall establish priorities for its crossing program based on:

- The potential reduction in collisions or collision severities.
- The project costs and available resources.
- The relative hazard of each crossing based on a hazard index formula.
- An on-site inspection of each candidate crossing.
- The potential danger to large numbers of people at crossings used on a regular basis by passenger trains or buses or by trains or motor vehicles carrying hazardous materials.
- Other criteria as deemed appropriate by each state.[57]

Engineering studies should be conducted of highway-rail crossings that have been selected from the priority list. The purpose of these studies is to:

- Review the crossing and its environment.
- Identify the nature of any problems.
- Recommend alternative improvements.

An engineering study consists of a review of site characteristics, the existing traffic control system, and highway and railroad operational characteristics. Based on a review of these conditions, an assessment of existing and potential hazards can be made. If safety deficiencies are identified, countermeasures can be recommended.

1. Diagnostic Team Study Method

The procedure recommended in earlier editions of this handbook, adopted in FHWA's *Highway Safety Engineering Study Procedural Guide*,[58] and adopted in concept by several states is the diagnostic team study approach. This term is used to describe a simple survey procedure utilizing experienced individuals from several sources. The procedure involves the diagnostic team's evaluation of the crossing as to its deficiencies and judgmental consensus as to the recommended improvements.

The primary factors to be considered when assigning people to the diagnostic team are that the team is interdisciplinary and representative of all groups having responsibility for the safe operation of crossings so that each of the vital factors relating to the operational and physical characteristics of the crossing may be properly identified. Individual team members are selected on the basis of their specific expertise and experience. The overall structure of the team is built upon three desired areas of responsibility:

- Local responsibility.
- Administrative responsibility.
- Advisory capability.

For the purpose of the diagnostic team, the operational and physical characteristics of crossings can be classified into three areas:

Traffic operations. This area includes both vehicular and train traffic operation. The responsibilities of highway traffic engineers and railroad operating personnel chosen for team membership include, among

* Includes previously unpublished materials provided by Ray Lewis, West Virginia Department of Transportation, 2006.

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[57] "Railroad Crossing Corridor Improvements." Washington, DC: U.S. Department of Transportation (U.S. DOT), Federal Highway Administration (FHWA), Demonstration Projects Division, June 1986.

[58] *Highway Safety Engineering Studies Procedural Guide*. Washington, DC: U.S. DOT, FHWA, November 1991.

other criteria, specific knowledge of highway and railroad safety, types of vehicles and trains, and their volumes and speeds.

Traffic control devices. Highway maintenance engineers, signal control engineers, and railroad signal engineers provide the best source for expertise in this area. Responsibilities of these team members include knowledge of active traffic control systems, interconnection with adjacent signalized highway intersections, traffic control devices for vehicle operations in general and at crossings, and crossing signs and pavement markings.

Administration. It is necessary to realize that many of the problems relating to crossing safety involve the apportionment of administrative and financial responsibility. This should be reflected in the membership of the diagnostic team. The primary responsibility of these members is to advise the team of specific policy and administrative rules applicable to the modification of crossing traffic control devices.

To ensure appropriate representation on the diagnostic team, it is suggested that the team comprise at least a traffic engineer with safety experience and a railroad signal engineer. Following are other disciplines that might be represented on the diagnostic team:

- Railroad administrative official.
- Highway administrative official.
- Human factors engineer.
- Law enforcement officer.
- Regulatory agency official.
- Railroad operating official.

The diagnostic team should study all available data and inspect the crossing and its surroundings with the objective of determining the conditions that affect safety and traffic operations. In conducting the study, a questionnaire is recommended to provide a structured account of the crossing characteristics and their effect on safety. Some states are now using automated diagnostic review forms to facilitate the collection, storage, and analysis of crossing data. Example forms developed and used by various states are reproduced in Appendix G. Figure 6 shows a sample questionnaire, which can be altered to fit individual agency needs. The questionnaire shown in Figure 6 is divided into four sections:

- Distant approach and advance warning.
- Immediate highway approach.
- Crossing proper.
- Summary and analysis.

To conduct the diagnostic team field study, traffic cones are placed on the approaches, as shown in Figure 7.

Crossing approach zone. Cone A is placed at the point where the driver first obtains information that there is a crossing ahead. This distance is also the beginning of the approach zone. Usually, this information comes from the advance warning sign, the pavement markings, or the crossing itself. The distance from the crossing is based on the decision sight distance, which is the distance required for a driver to detect a crossing and to formulate actions needed to avoid colliding with trains.

Tables 29 and 30 provide a range of distances from point A to the crossing stop line, dependent upon design vehicle speeds. The maximum distances are applicable to crossings with a high level of complexity and will generally be applicable on urban roads and streets. These distances correspond to the decision sight distances for stops on rural roads and for stops on urban roads in the American Association of State Highway and Transportation Officials (AASHTO) "Green Book." In calculating sight distances, the height of the driver's eye is considered 1.080 meter (3.5 feet) above the roadway surface for passenger vehicles; the target height is considered 0.6 meter (2.0 feet) above the roadway surface.[59]

Table 29. Distances in Meters to Establish Study Positions for Diagnostic Team Evaluation

Design vehicle speed (kilometers per hour)	Distance from stop line* to cone A (meters)	Distance from stop line* to cone B (meters)
50	155	70
60	195	95
70	235	115
80	280	140
90	325	170
100	370	200
110	420	235
120	470	265

** Note: The distance from the stop line is assumed to be 4.5 meters from nearest rail, or 2.4 meters from the gate if one is present.*

Source: From A Policy on Geometric Design of Highway and Streets, 2004, *by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

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[59] *A Policy on Geometric Design of Highways and Streets, 2004 Edition.* Washington, DC: American Association of State Highway and Transportation Officials, 2004.

Figure 6. Sample Questionnaire for Diagnostic Team Evaluation

LOCATIONAL DATA: Street Name: ______________________________ City: ______________________________
Railroad: ________________________________ Crossing Number: ____________________
VEHICLE DATA: No. of Approach Lanes: ___________ Approach Speed Limit: ___________ AADT: _________
Approach Curvature: _______________________ Approach Gradient: _______________________
TRAIN DATA: No. of Tracks: ____________ Train Speed Limit: ___________ Trains Per Day: _______________
Track Gradients: ____

SECTION I—Distance Approach and Advance Warning

1. Is advance warning of railroad crossing available?______ If so, what devices are used? ____________________
2. Do advance warning devices alert drivers to the presence of the crossing and allow time to react to approaching train traffic?
3. Do approach grades, roadway curvature, or obstructions limit the view of advance warning devices? ___ If so, how?
4. Are advance warning devices readable under night, rainy, snowy, or foggy conditions? ____________________

SECTION II—Immediate Highway Approach

1. What maximum safe approach speed will existing sight distance support? ______________________________
2. Is that speed equal to or above the speed limit on that part of the highway? ____________________________
3. If not, what has been done, or reasonably could be done, to bring this to the driver's attention? ______________
4. What restrictive obstructions to sight distance might be removed? _____________________________________
5. Do approach grades or roadway curvature restrict the driver's view of the crossing? _____________________
6. Are railroad crossing signals or other active warning devices operating properly and visible to adequately warn drivers of approaching trains? ____

SECTION III—Crossing Proper

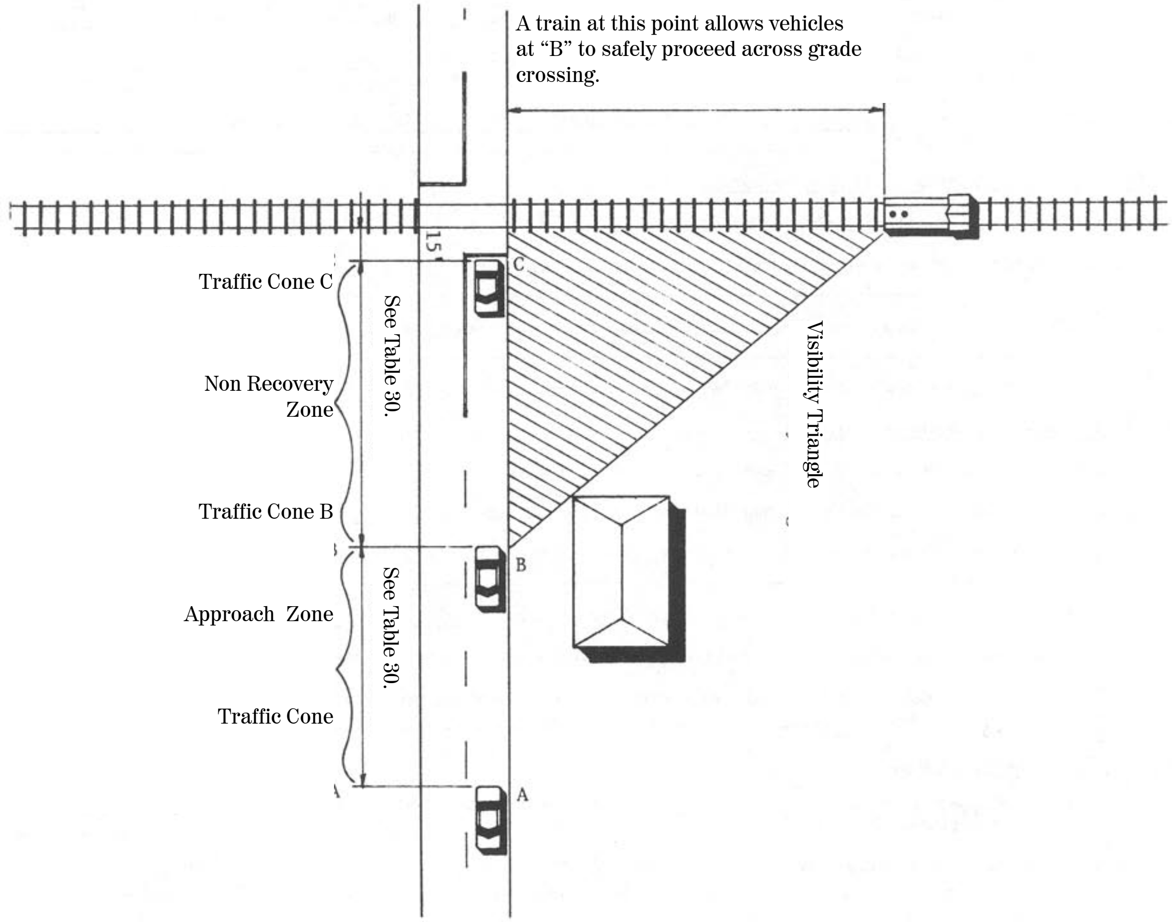
1. From a vehicle stopped at the crossing, is the sight distance down the track to an approaching train adequate for the driver to cross the tracks safely? ____
2. Are nearby intersection traffic signals or other control device affecting the crossing operation? If so, how? ____
3. Is the stopping area at the crossing adequately marked? ____
4. Do vehicles required by law to stop at all crossings present a hazard at the crossing? _____ Why? ___________
5. Do conditions at the crossing contribute to, or are they conducive to, a vehicle stalling at or on the crossing?
6. Are nearby signs, crossing signals, etc. adequately protected to minimize hazards to approaching traffic? _______
7. Is the crossing surface satisfactory? _____ If not, how and why? _________________________________
8. Is surface of highway approaches satisfactory? ____ If not, why?

SECTION IV—Summary and Analysis

1. List major attributes of the crossing which may contribute to safety.___________________________________
2. List features which reduce crossing safety. ____
3. Possible methods for improving safety at the crossing: _______________________________________
4. Overall evaluation of crossing: ____
5. Other comments: ____

Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Figure 7. Study Positions for Diagnostic Team



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Table 30. Distances in Feet to Establish Study Positions for Diagnostic Team Evaluation

Design vehicle speed (miles per hour)	Distance from stop line* to cone A (feet)	Distance from stop line* to cone B (feet)
30	490	220
40	690	330
50	910	465
55	1030	535
60	1150	610
70	1410	780

** Note: The distance from the stop line is assumed to be 15 feet from nearest rail, or 8 feet from the gate if one is present.*

Source: From A Policy on Geometric Design of Highway and Streets, 2004, *by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Safe stopping point. Cone B is placed at the point where the approaching driver must be able to see an approaching train so that a safe stop can be made if necessary. This point is located at the end of the approach zone and the end of the non-recovery zone. Distances to point B are based on the design vehicle speed and are also shown in Tables 29 and 30. These distances are stopping sight distances to the stop line and are in accordance with the upper end of the range of stopping sight distances in the AASHTO "Green Book."[60] In calculating these distances, a level approach is assumed. If this is not the case, an allowance must be made for the effects of positive or negative approach grades.

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[60] Ibid.

Stop line. Cone C is placed at the stop line, which is assumed to be 4.6 meters (15 feet) from the near rail of the crossing, or 8 feet from the gate if one is present.

The questions in Section I of the questionnaire (refer to Figure 6) are concerned with the following:

- Driver awareness of the crossing.
- Visibility of the crossing.
- Effectiveness of advance warning signs and signals.
- Geometric features of the highway.

When responding to questions in this section, the crossing should be observed from the beginning of the approach zone, at traffic cone A.

The questions in Section II (refer to Figure 6) are concerned with whether the driver has sufficient information to detect an approaching train and make correct decisions about crossing safely. Observations for responding to questions in this section should be made from cone B. Factors considered by these questions include the following:

- Driver awareness of approaching trains.
- Driver dependence on crossing signals.
- Obstruction of view of train's approach.
- Roadway geometrics diverting driver attention.
- Potential location of standing railroad cars.
- Possibility of removal of sight obstructions.
- Availability of information for stop or go decision by the driver.

The questions in Section III (refer to Figure 6) apply to observations adjacent to the crossing, at cone C. Of particular concern, especially when the driver must stop, is the ability to see down the tracks for approaching trains. Intersecting streets and driveways should also be observed to determine whether intersecting traffic could affect the operation of highway vehicles over the crossing. Questions in this section relate to the following:

- Sight distance down the tracks.
- Pavement markings.
- Conditions conducive to vehicles becoming stalled or stopped on the crossing.
- Operation of vehicles required by law to stop at the crossing.
- Signs and signals as fixed object hazards.
- Opportunity for evasive action by the driver.

Corner sight distance.[61] Available sight distances help determine the safe speed at which a vehicle can approach a crossing. The following three sight distances should be considered:

- Distance ahead to the crossing.
- Distance to and along the tracks on which a train might be approaching the crossing from either direction.
- Sight distance along the tracks in either direction from a vehicle stopped at the crossing.

These sight distances are illustrated in Figure 8.

In the first case, the distance ahead to the crossing, the driver must determine whether a train is occupying the crossing or whether there is an active traffic control device indicating the approach or presence of a train. In such an event, the vehicle must be stopped short of the crossing, and the available sight distance may be a determining factor limiting the speed of an approaching vehicle.

The relationship between vehicle speed and this sight distance is set forth in the following formula:

$$d_H = AV_v t + \frac{BV_v^{\;2}}{a} + D + d_e \qquad (5)$$

where:

d_H = sight distance measured along the highway from the nearest rail to the driver of a vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area, feet
A = constant = 1.47
B = constant = 1.075
V_v = velocity of the vehicle, miles per hour (mph)
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 11.2 feet per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 15 feet
d_e = distance from the driver to the front of the vehicle, assumed to be 8 feet

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[61] Ibid.

This formula is also expressed in SI Metric terms, as follows:

$$d_H = AV_v t + \frac{BV_v^{\,2}}{a} + D + d_e \qquad (6)$$

where:

d_H = sight distance measured along the highway from the nearest rail to the driver of a vehicle, which allows the vehicle to be safely stopped without encroachment of the crossing area, feet
A = constant = 0.278
B = constant = 0.039
V_v = velocity of the vehicle, kilometers per hour (km/hr.)
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 3.4 meters per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 4.5 meters
d_e = distance from the driver to the front of the vehicle, assumed to be 2.4 meters

The minimum safe sight distances, d_H, along the highway for selected vehicle speeds are shown in the bottom line of Tables 31 and 32. As noted, these distances were calculated for certain assumed conditions and should be increased for less favorable conditions.

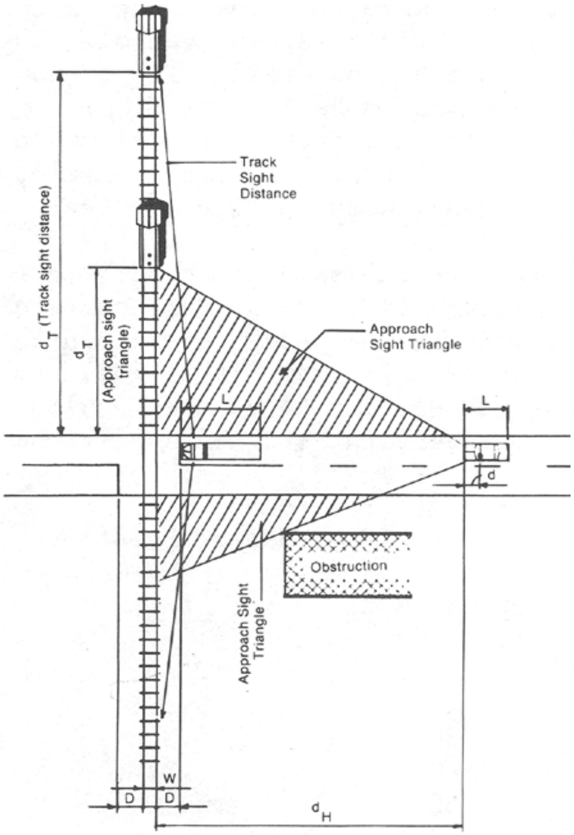
The second sight distance utilizes a so-called "sight triangle" in the quadrants on the vehicle approach side of the track. This triangle is formed by:

- The distance (d_H) of the vehicle driver from the track.
- The distance (d_t) of the train from the crossing.
- The unobstructed sight line from the driver to the front of the train.

This sight triangle is depicted in Figure 8. The relationships between vehicle speed, maximum timetable train speed, distance along the highway (d_H), and distance along the railroad are set forth in the following formula:

$$d_T = \frac{V_T}{V_v}(A)V_v t + \frac{BV_v^{\,2}}{a} + 2D + L + W \qquad (7)$$

Figure 8. Crossing Sight Distances



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

where:

d_T = sight distance along the railroad tracks to permit the vehicle to cross and be clear of the crossing upon arrival of the train
A = constant = 1.47
B = constant = 1.075
V_v = velocity of the vehicle, mph
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 11.2 feet per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 15 feet
L = length of vehicle, assumed to be 65 feet
W = distance between outer rails (for a single track, this value is 5 feet)

In SI Metric values, this formula becomes:

$$d_T = \frac{V_T}{V_v}(A)V_v t + \frac{BV_v^2}{a} + 2D + L + W \tag{8}$$

where:

d_T = sight distance along the railroad tracks to permit the vehicle to cross and be clear of the crossing upon arrival of the train
A = constant = 0.278
B = constant = 0.039
V_v = velocity of the vehicle, km/hr.
t = perception-reaction time, seconds, assumed to be 2.5 seconds
a = driver deceleration, assumed to be 3.4 meters per second^2
D = distance from the stop line or front of vehicle to the near rail, assumed to be 4.5 meters
L = length of vehicle, assumed to be 20 meters
W = distance between outer rails (for a single track, this value is 1.5 meters)

Distances d_h and d_T are shown in Tables 31 and 32 for several selected highway speeds and train speeds.

Clearing sight distance. In the case of a vehicle stopped at a crossing, the driver needs to see both ways along the track to determine whether a train is approaching and to estimate its speed. The driver needs to have a sight distance along the tracks that will permit sufficient time to accelerate and clear the crossing prior to the arrival of a train, even though the train might come into view as the vehicle is beginning its departure process.

Figure 9 illustrates the maneuver. These sight distances, for a range of train speeds, are given in the column for a vehicle speed of zero in Tables 31 and 32. These values are obtained from the following formula:

$$d_T = 1.47V_T\left(\frac{V_G}{a_1} + \frac{L + 2D + W - d}{V_G} + J\right) \tag{9}$$

where:

V_G = maximum speed of vehicle in selected starting gear, assumed to be 8.8 feet per second
a_1 = acceleration of vehicle in starting gear, assumed to be 1.47 feet per second per second
J = sum of the perception time and the time required to activate the clutch or an automatic shift, assumed to be 2 seconds
d_a = distance the vehicle travels while accelerating to maximum speed in first gear, or

$$d_a = \frac{V_G^2}{2a_1} \quad \text{or} \quad \frac{8.8^2}{(2)(1.47)} = 26.4 \text{ feet} \tag{10}$$

d_T, V_T, L, D, and W are defined as above.

Expressing the formula again in SI Metric terms:

$$d_T = 0.28V_T\left(\frac{V_G}{a_1} + \frac{L + 2D + W - d_a}{V_G} + J\right) \tag{11}$$

where:

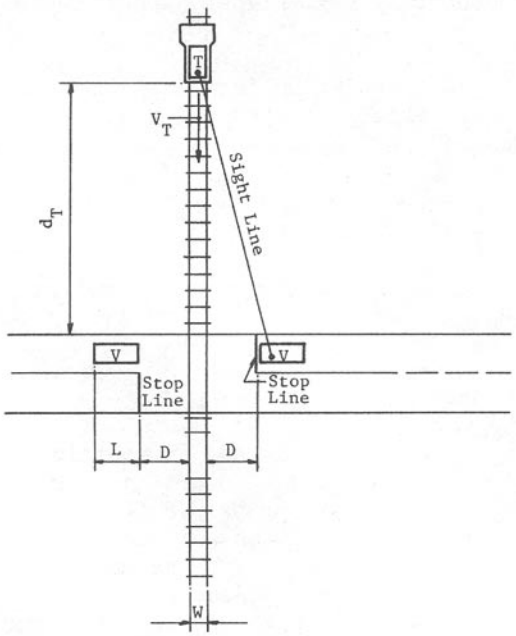
V_G = maximum speed of vehicle in selected starting gear, assumed to be 2.7 meters per second
a_1 = acceleration of vehicle in starting gear, assumed to be 0.45 meter per second per second
J = sum of the perception time and the time required to activate the clutch or an automatic shift, assumed to be 2 seconds
d_a = distance the vehicle travels while accelerating to maximum speed in first gear, or

$$d_a = \frac{V_G^2}{2a_1}$$

$$\frac{2.7^2}{(2)(0.45)} = 8.1\, meters$$

d_T, V_T, L, D, and W are defined as above.[62]

Figure 9. Sight Distance for a Vehicle Stopped at Crossing



Source: Railroad-Highway Grade Crossing Handbook, Second Edition. *Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.*

Table 31. Sight Distances for Combinations of Highway Vehicle and Train Speeds, Metric

	Case B: Departure from stop	Case A: Moving vehicle												
	Vehicle speed (km/hr.)													
Train speed (km/hr.)	0	10	20	30	40	50	60	70	80	90	100	110	120	130
	Distance along railroad from crossing, d_T (feet)													
10	45	39	24	21	19	19	19	19	20	21	21	22	23	24
20	91	77	49	41	38	38	38	39	40	41	43	45	47	48
30	136	116	73	62	57	56	57	58	60	62	64	67	70	73
40	181	154	98	82	77	75	76	77	80	83	86	89	93	97
50	227	193	122	103	96	94	95	97	100	103	107	112	116	121
60	272	232	147	123	115	113	113	116	120	124	129	134	140	145
70	317	270	171	144	134	131	132	135	140	145	150	156	163	169
80	362	309	196	164	153	150	151	155	160	165	172	179	186	194
90	408	347	220	185	172	169	170	174	179	186	193	201	209	218
100	453	386	245	206	192	188	189	193	199	207	215	223	233	242
110	498	425	269	226	211	207	208	213	219	227	236	246	256	266
120	544	463	294	247	230	225	227	232	239	248	258	268	279	290
130	589	502	318	267	249	244	246	251	259	269	279	290	302	315
140	634	540	343	288	268	263	265	271	279	289	301	313	326	339
	Distance along highway from crossing, d_H (feet)													
		15	25	38	53	70	90	112	136	162	191	222	255	291

Source: From A Policy on Geometric Design of Highway and Streets, 2004*, by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Table 32. Sight Distances for Combinations of Highway Vehicle and Train Speeds, U.S. Customary

	Case B: Departure from stop	Case A: Moving vehicle							
	Vehicle speed (mph)								
Train speed (mph)	0	10	20	30	40	50	60	70	80
	Distance along railroad from crossing, d_T (feet)								
10	240	146	106	99	100	105	111	118	126
20	480	293	212	198	200	209	222	236	252
30	721	439	318	297	300	314	333	355	378
40	961	585	424	396	401	419	444	473	504
50	1201	732	530	494	501	524	555	591	630
60	1441	878	636	593	601	628	666	709	756
70	1681	1024	742	692	701	733	777	828	882
80	1921	1171	848	791	801	833	888	946	1008
90	2162	1317	954	890	901	943	999	1064	1134
	Distance along highway from crossing, d_H (feet)								
		69	135	220	324	447	589	751	931

Source: From A Policy on Geometric Design of Highway and Streets, 2004*, by the American Association of State Highway and Transportation Officials, Washington, DC. Used by permission.*

Adjustments for longer vehicle lengths, slower acceleration capabilities, multiple tracks, skewed crossings, and other than flat highway grades are necessary. The formulas in this section may be used with proper adjustments to the appropriate dimensional values. It would be desirable that sight distances permit operation at the legal approach speed for highways. This is often impractical.

In Section IV of the questionnaire, the diagnostic team is given the opportunity to do the following:

- List major features that contribute to safety.
- List features that reduce crossing safety.
- Suggest methods for improving safety at the crossing.
- Give an overall evaluation of the crossing.
- Provide comments and suggestions relative to the questionnaire.

In addition to completing the questionnaire, team members should take photographs of the crossing from both the highway and the railroad approaches.

Current and projected vehicle and train operation data should be obtained from the team members. Information on the use of the crossing by buses, school buses, trucks transporting hazardous materials, and passenger trains should be provided. The evaluation of the crossing should include a thorough evaluation of collision frequency, collision types, and collision circumstances. Both train-vehicle collisions and vehicle-vehicle collisions should be examined.

Team members should drive each approach several times to become familiar with all conditions that exist at or near the crossing. All traffic control devices (signs, signals, markings, and train detection circuits) should be examined as part of this evaluation. If the crossing is equipped with signals, the railroad signal engineer should activate them so that their alignment and light intensity may be observed.

The *Manual on Uniform Traffic Control Devices* (MUTCD) should be a principal reference for this evaluation.[63] Also, *A User's Guide to Positive Guidance* provides information for conducting evaluations of traffic control devices.[64]

After the questionnaire has been completed, the team is reassembled for a short critique and discussion period. Each member should summarize his or her observations pertaining to safety and operations at the crossing. Possible improvements to the crossing may include the following:

- Closing of crossing—available alternate routes for highway traffic.
- Site improvements—removal of obstructions in the sight triangle, highway realignment, improved cross section, drainage, or illumination.
- Crossing surfaces—rehabilitation of the highway structure, the track structure, or both; installation of drainage and subgrade filter fabric; adjustments to highway approaches; and removal of retired tracks from the crossing.
- Traffic control devices—installation of passive or active control devices and improvement of train detection equipment.

The results and recommendations of the diagnostic team should be documented. Recommendations should be presented promptly to programming and implementation authorities.

Both government and railroad resources are becoming more limited. The *Highway Safety Engineering Studies Procedural Guide* suggests crossing evaluation by an individual, in lieu of the diagnostic team.[65] The guide suggests that this individual be a traffic engineer with experience in highway-rail crossing and traffic safety. A background in signal control and safety program administration would also be advantageous.

2. Traffic Conflict Technique

Highway traffic collisions are a statistically rare event. Typically, an engineer or analyst must assemble several years of collision data to have a large enough sample to identify a pattern of collisions and suggest countermeasures. The traffic conflict technique was developed during the early 1970s by Research Laboratories, General Motors Corporation, to be a measure of traffic collision potential.

A traffic conflict occurs when a driver takes evasive action, brakes, or weaves to avoid a collision. The conflict is evidenced by a brake-light indication or a lane change by the offended driver. Procedures have

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[63] *Manual on Uniform Traffic Control Devices, 2003 Edition*. Washington, DC: FHWA, 2003.

[64] *A User's Guide to Positive Guidance*. Washington, DC, U.S. DOT, FHWA, Office of Operations, June 1977.

[65] *Highway Safety Engineering Studies Procedural Guide*. Washington, DC: U.S. DOT, FHWA, November 1991.

should be notified of these intentions. The state highway agency might work out an agreement with the state regulatory commission that any information on railroad abandonments is automatically sent to the state highway agency. Additionally, the state highway agency should periodically call the state regulatory commission or STB to obtain the records on rail abandonments in the state. Railroad personnel responsible for crossing safety and operations should also seek the same information from their traffic and operating departments.

Once a rail line has been identified as abandoned or abandonment is planned, the crossings on that line should be identified. This can be determined from the state inventory of crossings or obtained from FRA, custodian of the U.S. DOT National Highway-Rail Crossing Inventory. A field inspection of these crossings should be made to determine if all crossings on that line, both public and private, are listed in the inventory and to verify the type of traffic control devices located at each crossing.

This field inspection provides an excellent opportunity to assess the safety and operations of each crossing on that line, as discussed in Chapter III. If the rail line is not abandoned, the necessary information has been gathered to improve each crossing by one of the alternatives described in following sections.

If rail service has been discontinued, pending resolution of the abandonment application and formal abandonment, immediate measures should be taken to inform the public. For example, “Exempt” signs, if authorized by state law or regulation, can be placed at the crossing to notify drivers of special vehicles that a stop at the crossing is not necessary. Gate arms should be removed, and flashing light signal heads should be hooded, turned, or removed. However, if these actions are taken, the traffic control devices must be restored to their original condition prior to operating any trains over the crossing. For any subsequent use of the crossing by rail traffic pending final abandonment, the railroad shall provide flagging, law enforcement, or other case-by-case manual control of the crossing. The railroad might flag the train over the crossing until such action can be taken.

If it appears that rail service has been permanently discontinued, and resolution of official abandonment appears certain, the track should be paved over and all traffic control devices removed. This action should be taken immediately following official abandonment if no possibility exists for resumption of rail service. This can be determined by examining the potential for industry or business to require rail service. For example, if the rail line was abandoned because the industry that required the service has moved and other plans for the land area have been made, it could be determined whether need for the rail service will continue. An agreement may be necessary between the public authority and the railroad to accomplish the physical removal of the tracks.

G. New Crossings

Similar to crossing closure/consolidation, opening a new public highway-rail crossing should likewise consider public necessity, convenience, safety, and economics. Generally, new grade crossings, particularly on mainline tracks, should not be permitted unless no other viable alternatives exist and, even in those instances, consideration should be given to closing one or more existing crossings. If a new grade crossing is to provide access to any land development, the selection of traffic control devices to be installed at the proposed crossing should be based on the projected needs of the fully completed development.

Communities, developers, and highway transportation planners need to be mindful that once a highway-rail grade crossing is established, drivers can develop a low tolerance for the crossing being blocked by a train for an extended period of time. If a new access is proposed to cross a railroad where railroad operation requires temporarily holding trains, only grade separation should be considered.[85]

H. Passive Traffic Control Devices

Passive traffic control devices provide static messages of warning, guidance, and, in some instances, mandatory action for the driver. Their purpose is to identify and direct attention to the location of a crossing to permit drivers and pedestrians to take appropriate action. Passive traffic control devices consist of regulatory signs, warning signs, guide signs, and supplemental pavement markings. They are basic devices and are incorporated into the design of active traffic control devices.

Signs and pavement markings are to be in conformance with MUTCD, which is revised periodically as the need arises. If there are differences between this handbook and the current edition of MUTCD concerning both active and passive traffic control devices, MUTCD should be

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[85] Ibid.

the vehicle. The purpose is not to protect traffic control devices against collision or possible damage. The ring type guardrail placed around a signal mast may create the same type of hazard as the mast itself; that is, the guardrail may be a roadside obstacle. These guardrails do, however, serve to protect the signal mast. Because functioning devices are vital to safety, the ring type guardrail may be used at locations with heavy traffic, such as an industrial area, and low traffic speeds.

More information can be obtained from the *Roadside Design Guide*, published by AASHTO.

3. Illumination

Illumination at a crossing may be effective in reducing nighttime collisions. Illuminating most crossings is technically feasible because more than 90 percent of all crossings have commercial power available. Illumination may be effective under the following conditions:

- Nighttime train operations.
- Low train speeds.
- Blockage of crossings for long periods at night.
- Collision history indicating that motorists often fail to detect trains or traffic control devices at night.
- Horizontal and/or vertical alignment of highway approach such that vehicle headlight beam does not fall on the train until the vehicle has passed the safe stopping distance.
- Long dark trains, such as unit coal trains.
- Restricted sight or stopping distance in rural areas.
- Humped crossings where oncoming vehicle headlights are visible under trains.
- Low ambient light levels.
- A highly reliable source of power.

Luminaires may provide a low-cost alternative to active traffic control devices on industrial or mine tracks where switching operations are carried out at night.

Luminaire supports should be placed in accordance with the principles in the *Roadside Design Guide* and NCHRP Report 350.[117] If they are placed in the clear zone on a high-speed road, they should be breakaway.

4. Shielding Supports for Traffic Control Devices

The purpose of a traffic barrier, such as a guardrail or crash cushion, is to protect the motorist by redirecting or containing an errant vehicle. The purpose is not to protect a traffic control device against collision and possible damage. The use of a traffic barrier should be limited to situations in which hitting the object, such as a traffic control device, is more hazardous than hitting the traffic barrier and, possibly, redirecting the vehicle into a train.

A longitudinal guardrail should not be used for traffic control devices at crossings unless the guardrail is otherwise warranted, as for a steep embankment. The longitudinal guardrail might redirect a vehicle into a train.

On some crossings, it may be possible to use crash cushions to protect the motorist from striking a traffic control device. Some crash cushions are designed to capture rather than redirect a vehicle and may be appropriate for use at crossings to reduce the redirection of a vehicle into the path of a train.

The ring type guardrail placed around a signal mast may create the same type of hazard as the signal mast itself (the guardrail may be a roadside obstacle). It does, however, serve to protect the signal mast. Because functioning devices are vital to safety, the ring type guardrail may be used at locations with heavy industrial traffic, such as trucks, and low highway speeds.

When a barrier is used, it should be installed according to the requirements in the *Guide for Selecting, Locating and Designing Traffic Barriers*.

M. Crossing Surfaces

In negotiating a crossing, the degree of attention the driver can be expected to devote to the crossing surface is related to the condition of that surface. If the surface is uneven, the driver's attention may be devoted primarily to choosing the smoothest path over the crossing rather than determining if a train is approaching the crossing. This type of behavior may be conditioned; that is, if a driver is consistently exposed to uneven crossing surfaces, he or she may assume that all crossing surfaces are uneven whether or not they actually are. Conversely, if a driver encounters an uneven surface unexpectedly, he or she may lose control of the vehicle, resulting in a collision. Therefore, providing reasonably smooth crossing surfaces is viewed as one of several elements toward improving crossing safety and operations.

The AREMA *Manual of Railway Engineering*, Part 8, provides guidelines for the construction and reconstruction of highway-rail crossings. The first section of Part 8 provides information

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[117] Ibid.

Selection of Alternatives

V

This chapter discusses methods for selecting alternatives and the economic analysis techniques that may be utilized. Although procedures are provided for developing benefit-cost analyses of alternative treatments, more recent trends place emphasis on risk avoidance and best practices. As a result, benefit-cost studies may only be useful for evaluating alternatives that involve a major investment. Benefit-cost analysis requirements are contained in 23 CFR 924. In addition, the Rail-Highway Crossing Resource Allocation Procedure is presented and other low-cost solutions are discussed.

A. Technical Working Group Guidance on Traffic Control Devices—Selection Criteria and Procedure

The Technical Working Group (TWG) established by the U.S. Department of Transportation (U.S. DOT) is led by representatives from the Federal Highway Administration (FHWA), Federal Railroad Administration (FRA), Federal Transit Administration, and National Highway Traffic Safety Administration. This cooperation among the various representatives of TWG represents a landmark effort to enhance communication among highway agencies, railroad companies and authorities, and governmental agencies involved in developing and implementing policies, rules, and regulations.

The TWG document is intended to provide guidance to assist engineers in the selection of traffic control devices or other measures at highway-rail grade crossings.[118] It is not to be interpreted as policy or standards and is not mandatory. Any requirements that may be noted in the report are taken from the *Manual on Uniform Traffic Control Devices* (MUTCD) or another document identified by footnotes. A number of measures are included that may not have been supported by quantitative research but are being used by states and local agencies. These are included to inform practitioners of the array of tools being used or explored.

The introductory materials developed by the U.S. DOT TWG present an excellent perspective on the functioning of a highway-rail grade crossing. TWG notes that a highway-rail grade crossing differs from a highway-highway intersection in that the train always has the right of way. From this perspective, TWG indicates that the process for deciding what type of highway traffic control device is to be installed or even allowing that a highway-rail grade crossing should exist is essentially a two-step process, requiring consideration of what information the vehicle driver needs to be able to cross safely and whether the resulting driver response to a traffic control device is “compatible” with the intended system operating characteristics of the highway and railroad facility.

The TWG guidance outlines the technical considerations for satisfying motorist needs, including the role of stopping sight distance, approach (corner) sight distance, and clearing sight distance, and integrates this with highway system needs based upon the type and classification of the roadway as well as the allowable track speeds by class of track for the railway system. This handbook describes tools and analytical methodologies as well as treatments and criteria from a variety of sources for selecting treatments; the TWG document and its introduction should be consulted by persons involved with studies of grade crossing safety issues and improvements.

These treatments are provided for consideration at every public highway-rail grade crossing. Specific MUTCD signs and treatments are included for easy reference.

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[118] *Guidance on Traffic Control Devices at Highway-Rail Grade Crossings.* Washington, DC: Federal Highway Administration (FHWA), Highway/Rail Grade Crossing Technical Working Group, November 2002.

TECHNICAL WORKING GROUP GUIDANCE

1. Minimum Devices

All highway-rail grade crossings of railroads and public streets or highways should be equipped with approved passive devices. For street-running railroads/transit systems, refer to MUTCD Parts 8 and 10.

2. Minimum Widths

All highway-rail grade crossing surfaces should be a minimum of 1 foot beyond the edge of the roadway shoulder, measured perpendicular to the roadway centerline, and should provide for any existing pedestrian facilities.

3. Passive—Minimum Traffic Control Applications

a. A circular railroad advance warning (W10-1) sign shall be used on each roadway in advance of every highway-rail grade crossing except as described in MUTCD.
b. An emergency phone number should be posted at the crossing, including the U.S. DOT highway-rail grade crossing identification number, highway or street name or number, railroad milepost, and other pertinent information.
c. Where the roadway approaches to the crossing are paved, pavement markings are to be installed as described in MUTCD, subject to engineering evaluation.
d. Where applicable, the “Tracks Out Of Service” sign should be placed to notify drivers that track use has been discontinued.
e. One reflectorized crossbuck sign shall be used on each roadway approach to a highway-rail grade crossing.

    i. If there are two or more tracks, the number of tracks shall be indicated on a supplemental sign (R15-2) of inverted T shape mounted below the crossbuck.
    ii. Strips of retroreflective white material not less than 2 inches in width shall be used on the back of each blade of each crossbuck sign for the length of each blade, unless the crossbucks are mounted back to back.
    iii. A strip of retroreflective white material not less than 2 inches in width shall be used on the full length of the front and back of each support from the crossbuck sign to near ground level or just above the top breakaway hole on the post.

f. Supplemental passive traffic control applications (subject to engineering evaluation):

    i. Inadequate stopping sight distance:

        a. Improve the roadway geometry.
        b. Install appropriate warning signs (including consideration of active types).
        c. Reduce the posted roadway speed in advance of the crossing:

            i. Advisory signing as a minimum.
            ii. Regulatory posted limit if it can be effectively enforced.

  - d. Close the crossing.
  - e. Reconfigure/relocate the crossing.
  - f. Grade separate the crossing.

- ii. Inadequate approach (corner) sight distance (assuming adequate clearing sight distance):
  - a. Remove the sight distance obstruction.
  - b. Install appropriate warning signs.
  - c. Reduce the posted roadway speed in advance of the crossing:
    - i. Advisory signing as a minimum.
    - ii. Regulatory posted limit if it can be effectively enforced.
  - d. Install a YIELD (R1-2) sign, with advance warning sign (W3-2a) where warranted by MUTCD (restricted visibility reduces safe approach speed to 16–24 kilometers per hour (10–15 miles per hour)).
  - e. Install a STOP (R1-1) sign, with advance warning sign (W3-1a) where warranted by MUTCD (restricted visibility requires drivers to stop at the crossing).
  - f. Install active devices.
  - g. Close the crossing.
  - h. Reconfigure/relocate the crossing.
  - i. Grade separate the crossing.

- iii. Deficient clearing sight distances (for one or more classes of vehicles):
  - a. Remove the sight distance obstruction.
  - b. Permanently restrict use of the roadway by the class of vehicle not having sufficient clearing sight distance.
  - c. Install active devices with gates.
  - d. Close the crossing.
  - e. Reconfigure/relocate the crossing.
  - f. Grade separate the crossing.
  - g. Multiple railroad tracks and/or two or more highway approach lanes in the same direction should be evaluated with regard to possible sight obstruction from other trains (moving or standing on another track or siding) or highway vehicles.

- iv. Stopping and corner sight distance deficiencies may be treated immediately with warning or regulatory traffic control signs, such as a STOP sign, with appropriate advance warning signs. However, until such time as permanent corrective measures are implemented to correct deficient clearing sight distance, interim measures should be taken, which may include:
  - a. Temporarily close the crossing.
  - b. Temporarily restrict use of the roadway by the classes of vehicles.

Table 42. Guidelines for Active Devices

Class of track	Maximum allowable operating speed for freight trains—minimum active devices		Maximum allowable operating speed for passenger trains—minimum active devices	
Excepted track	10 mph	Flashers	N/A	N/A
Class 1 track	10 mph	Flashers	15 mph	Gates*
Class 2 track	25 mph	Flashers	30 mph	Gates*
Class 3 track	40 mph	Gates	60 mph**	Gates**
Class 4 track	60 mph	Gates	80 mph	Gates
Class 5 track	80 mph	Gates plus supplemental safety devices	90 mph	Gates plus supplemental safety devices
Class 6 track	110 mph with conditions	Gates plus supplemental safety devices	110 mph	Gates plus supplemental safety devices
Class 7 track	125 mph with conditions	Full barrier protection	125 mph	Full barrier protection
Class 8 track	160 mph with conditions	Grade separation	160 mph	Grade separation
Class 9 track	200 mph with conditions	Grade separation	200 mph	Grade separation

Note: 1 mile per hour (mph) = 1.61 kilometers per hour (km/hr.)
** Refer to the 2003 edition of MUTCD, Part 10, transit and light-rail trains in medians of city streets.*
*** Except 35 mph (56 km/hr.) for transit and light-rail trains.*

Source: Guidance on Traffic Control Devices at Highway-Rail Grade Crossings. *Washington, DC: Federal Highway Administration, Highway/Rail Grade Crossing Technical Working Group, November 2002.*

4. Active

If active devices are selected, the following devices should be considered:

a. Active devices with automatic gates should be considered at highway-rail grade crossings whenever an engineering study by a diagnostic team determines one or more of the following conditions exist:

  i. All crossings on the National Highway System, “U.S.” marked routes, or principal arterials not otherwise grade separated.
  ii. If inadequate clearing sight distance exists in one or more approach quadrants, AND it is determined ALL of the following apply:

    a. It is not physically or economically feasible to correct the sight distance deficiency.
    b. An acceptable alternate access does not exist.
    c. On a life-cycle cost basis, the cost of providing acceptable alternate access or grade separation would exceed the cost of installing active devices with gates.

  iii. Regularly scheduled passenger trains operate in close proximity to industrial facilities, such as stone quarries, log mills, cement plants, steel mills, oil refineries, chemical plants, and land fills.

- iv. In close proximity to schools, industrial plants, or commercial areas where there is substantially higher than normal usage by school buses, heavy trucks, or trucks carrying dangerous or hazardous materials.
- v. Based upon the number of passenger trains and/or the number and type of trucks, a diagnostic team determines a significantly higher than normal risk exists that a train-vehicle collision could result in death of or serious injury to rail passengers.
- vi. Multiple main or running tracks through the crossing.
- vii. The expected accident frequency for active devices without gates, as calculated by the U.S. DOT Accident Prediction Formula including five-year accident history, exceeds 0.1.
- viii. In close proximity to a highway intersection or other highway-rail crossings and the traffic control devices at the nearby intersection cause traffic to queue on or across the tracks (in such instances, if a nearby intersection has traffic signal control, it should be interconnected to provide preempted operation, and consider traffic signal control, if none).
- ix. As otherwise recommended by an engineering study or diagnostic team.

b. Active devices with automatic gates should be considered as an option at public highway-rail grade crossings whenever they can be economically justified based on fully allocated life-cycle costs and one or more of the following conditions exist:

- i. Multiple tracks exist at or in the immediate crossing vicinity where the presence of a moving or standing train on one track effectively reduces the clearing sight distance below the minimum relative to a train approaching the crossing on an adjacent track (absent some other acceptable means of warning drivers to be alert for the possibility of a second train).
- ii. An average of 20 or more trains per day.
- iii. Posted highway speed exceeds 64 km/hr. (40 mph) in urban areas or exceeds 88 km/hr. (55 mph) in rural areas.
- iv. Annual average daily traffic (AADT) exceeds 2,000 in urban areas or 500 in rural areas.
- v. Multiple lanes of traffic in the same direction of travel (usually this will include cantilevered signals).
- vi. The crossing exposure (the product of the number of trains per day and AADT) exceeds 5,000 in urban areas or 4,000 in rural areas.
- vii. The expected accident frequency as calculated by the U.S. DOT Accident Prediction formula, including five-year accident history, exceeds 0.075.
- viii. An engineering study indicates that the absence of active devices would result in the highway facility performing at a level of service below level C.
- ix. Any new project or installation of active devices to significantly replace or upgrade existing non-gated active devices. For purposes of this item, replacements or upgrades should be considered "significant" whenever the cost of the otherwise intended improvement (without gates) equals or exceeds one-half the cost of a comparable new installation, and should exclude maintenance replacement of individual system components and/or emergency replacement of damaged units.
- x. As otherwise recommended by an engineering study or diagnostic team.

c. Warning/barrier gate systems should be considered as supplemental safety devices at:

- i. Crossings with passenger trains;
- ii. Crossings with high-speed trains;
- iii. Crossings in quiet zones; or
- iv. As otherwise recommended by an engineering study or diagnostic team.

d. Enhancements for pedestrian treatments:

- i. Design to avoid stranding pedestrians between sets of tracks.
- ii. Add audible devices, based on an engineering study.

  - iii. Consider swing gates carefully; the operation of the swing gate should be consistent with the requirements of the Americans with Disabilities Act; the gate should be checked for pedestrian safety within the limits of its operation.
  - iv. Provide for crossing control at pedestrian crossings where a station is located within the proximity of a crossing or within the crossing approach track circuit for the highway-rail crossing.
  - v. Utilize a Train-to-Wayside Controller to reduce traffic delays in areas of stations.
  - vi. Delay the activation of the gates, flashers, and bells for a period of time at the highway-rail grade crossing in station areas, based on an engineering study.

5. Closure

Highway-rail grade crossings should be considered for closure and vacated across the railroad right of way whenever one or more of the following apply:

- a. An engineering study determines a nearby crossing otherwise required to be improved or grade separated already has acceptable alternate vehicular access, and pedestrian access can continue at the subject crossing, if existing.
- b. On a life-cycle cost basis, the cost of implementing the recommended improvement would exceed the cost of providing an acceptable alternate access.
- c. If an engineering study determines any of the following apply:

  - i. FRA Class 1, 2, or 3 track with daily train movements:

    - a. AADT less than 500 in urban areas, acceptable alternate access across the rail line exists within .4 km (one-quarter-mile), and the median trip length normally made over the subject crossing would not increase by more than .8 km (one-half-mile).
    - b. AADT less than 50 in rural areas, acceptable alternate access across the rail line exists within .8 km (one-half-mile), and the median trip length normally made over the subject crossing would not increase by more than 2.4 km (1.5 miles).

  - ii. FRA Class 4 or 5 track with active rail traffic:

    - a. AADT less than 1,000 in urban areas, acceptable alternate access across the rail line exists within .4 km (one-quarter-mile), and the median trip length normally made over the subject crossing would not increase by more than 1.2 km (three-quarters-mile).
    - b. AADT less than 100 in rural areas, acceptable alternate access across the rail line exists within 1.61 km (1 mile), and the median trip length normally made over the subject crossing would not increase by more than 4.8 km (3 miles).

  - iii. FRA Class 6 or higher track with active rail traffic, AADT less than 250 in rural areas, an acceptable alternate access across the rail line exists within 2.4 km (1.5 miles), and the median trip length normally made over the subject crossing would not increase by more than 6.4 km (4 miles).

- d. An engineering study determines the crossing should be closed to vehicular and pedestrian traffic when railroad operations will occupy or block the crossing for extended periods of time on a routine basis and it is determined that it is not physically or economically feasible to either construct a grade separation or shift the train operation to another location. Such locations would typically include:

  - i. Rail yards.
  - ii. Passing tracks primarily used for holding trains while waiting to meet or be passed by other trains.

- iii. locations where train crews are routinely required to stop their trains because of cross traffic on intersecting rail lines or to pick up or set out blocks of cars or switch local industries en route.
- iv. switching leads at the ends of classification yards.
- v. where trains are required to “double” in or out of yards and terminals.
- vi. in the proximity of stations where long distance passenger trains are required to make extended stops to transfer baggage, pick up, or set out equipment or be serviced en route.
- vii. locations where trains must stop or wait for crew changes.

6. Grade Separation

a. Highway-rail grade crossings should be considered for grade separation or otherwise eliminated across the railroad right of way whenever one or more of the following conditions exist:

- i. The highway is a part of the designated Interstate Highway System.
- ii. The highway is otherwise designed to have full controlled access.
- iii. The posted highway speed equals or exceeds 113 km/hr. (70 mph).
- iv. AADT exceeds 100,000 in urban areas or 50,000 in rural areas.
- v. Maximum authorized train speed exceeds 177 km/hr. (110 mph).
- vi. An average of 150 or more trains per day or 300 million gross tons per year.
- vii. An average of 75 or more passenger trains per day in urban areas or 30 or more passenger trains per day in rural areas.
- viii. Crossing exposure (the product of the number of trains per day and AADT) exceeds 1 million in urban areas or 250,000 in rural areas; or
- ix. Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 800,000 in urban areas or 200,000 in rural areas.
- x. The expected accident frequency for active devices with gates, as calculated by the U.S. DOT Accident Prediction Formula including five-year accident history, exceeds 0.5.
- xi. Vehicle delay exceeds 40 vehicle hours per day.[1]

b. Highway-rail grade crossings should be considered for grade separation across the railroad right of way whenever the cost of grade separation can be economically justified based on fully allocated life-cycle costs and one or more of the following conditions exist:

- i. The highway is a part of the designated National Highway System.
- ii. The highway is otherwise designed to have partial controlled access.
- iii. The posted highway speed exceeds 88 km/hr. (55 mph).
- iv. AADT exceeds 50,000 in urban areas or 25,000 in rural areas.
- v. Maximum authorized train speed exceeds 161 km/hr. (100 mph).
- vi. An average of 75 or more trains per day or 150 million gross tons per year.
- vii. An average of 50 or more passenger trains per day in urban areas or 12 or more passenger trains per day in rural areas.
- viii. Crossing exposure (the product of the number of trains per day and AADT) exceeds 500,000 in urban areas or 125,000 in rural areas; or
- ix. Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 400,000 in urban areas or 100,000 in rural areas.

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[1] *Guidance on Traffic Control Devices at Highway-Rail Grade Crossings*. Washington, DC: Federal Highway Administration (FHWA), Highway/Rail Grade Crossing Technical Working Group, November 2002.

x. The expected accident frequency for active devices with gates, as calculated by the U.S. DOT Accident Prediction Formula including five-year accident history, exceeds 0.2.
xi. Vehicle delay exceeds 30 vehicle hours per day.
xii. An engineering study indicates that the absence of a grade separation structure would result in the highway facility performing at a level of service below its intended minimum design level 10 percent or more of the time.

c. Whenever a new grade separation is constructed, whether replacing an existing highway-rail grade crossing or otherwise, consideration should be given to the possibility of closing one or more adjacent grade crossings.
d. Utilize Table 43 for LRT grade separation:

Table 43. LRT Grade Separation

Trains per hour	Peak-hour volume (vehicles per lane)
40	900
30	1000
20	1100
10	1180
5	1200

Source: *Light Rail Transit Grade Separation Guidelines, An Informational Report*. Washington, DC: Institute of Transportation Engineers, Technical Committee 6A-42, March 1992.

7. New Crossings

a. Should only be permitted to cross existing railroad tracks at grade when it can be demonstrated:

   i. For new public highways or streets where there is a clear and compelling public need (other than enhancing the value or development potential of the adjoining property);
   ii. Grade separation cannot be economically justified, i.e. benefit-to-cost ratio on a *fully allocated* cost basis is less than 1.0 (generally, when the crossing exposure exceeds 50,000 in urban areas or exceeds 25,000 in rural areas); and
   iii. There are no other viable alternatives.

b. If a crossing is permitted, the following conditions should apply:

   i. If it is a main track, the crossing will be equipped with active devices with gates.
   ii. The plans and specifications should be subject to the approval of the highway agency having jurisdiction over the roadway (if other than a state agency), the state department of transportation or other state agency vested with the authority to approve new crossings, and the operating railroad.
   iii. All costs associated with the construction of the new crossing should be borne by the party or parties requesting the new crossing, including providing financially for the ongoing maintenance of the crossing surface and traffic control devices where no crossing closures are included in the project.
   iv. Whenever new public highway-rail crossings are permitted, they should fully comply with all applicable provisions of this proposed recommended practice.
   v. Whenever a new highway-rail crossing is constructed, consideration should be given to closing one or more adjacent crossings.

8. Traffic Control Device Selection Procedure

Step 1—Minimum highway-rail grade crossing criteria (see report for full description):

a. Gather preliminary crossing data:

    i. Highway:

        a. Geometric (number of approach lanes, alignment, median).
        b. AADT.
        c. Speed (posted limit or operating).
        d. Functional classification.
        e. Desired level of service.
        f. Proximity of other intersections (note active device interconnection).
        g. Availability and proximity of alternate routes and/or crossings.

    ii. Railroad:

        a. Number of tracks (type: FRA classification, mainline, siding, spur).
        b. Number of trains (passenger, freight, other).
        c. Maximum train speed and variability.
        d. Proximity of rail yards, stations, and terminals.
        e. Crossing signal control circuitry.

    iii. Traffic control device:

        a. Passive or active.
        b. Advance.
        c. At crossing.
        d. Supplemental.

    iv. Prior collision history

b. Based on one or more of the above, determine whether any of the recommended thresholds for closure, installing active devices (if passive), or separation have been met based on highway or rail system operational requirements.
c. Consider crossing closure or consolidation:

    i. If acceptable alternate route(s) is/are available; or
    ii. If an adjacent crossing is improved, can this crossing be closed? or
    iii. If this crossing is improved, can an adjacent crossing be closed?

d. For all crossings, evaluate stopping and clearing sight distances. If the conditions are inadequate for the existing control device, correct or compensate for the condition (see Step 3 below).
e. If a passive crossing, evaluate corner sight distance. If less than the required for the posted or legal approach speed, correct or compensate for the condition (see Step 3 below).

Step 2—Evaluate highway traffic flow characteristics:

a. Consider the required motorist response to the existing (or proposed) type of traffic control device. At passive crossings, determine the degree to which traffic may need to slow or stop based on evaluation of available corner sight distances.

b. Determine whether the existing (or proposed) type of traffic control device and railroad operations will allow highway traffic to perform at an acceptable level of service for the functional classification of the highway.

Step 3—Possible revision to the highway-rail grade crossing:

a. If there is inadequate sight distance related to the type of control device, consider measures such as:

   i. Try to correct the sight distance limitation.
   ii. If stopping sight distance is less than "ideal" for the posted or operating vehicle approach speed and cannot be corrected, determine the safe approach speed and consider either posting an advisory speed plate at the advance warning sign or reduce the regulatory speed limit on the approach.
   iii. If corner sight distance is inadequate and cannot be corrected, determine the safe approach speed and consider posting an advisory speed plate at the advance warning sign, or reduce the regulatory speed limit on the approach, or install STOP or YIELD signs at the crossing.
   iv. If clearing sight distance is inadequate, upgrade a passive or flashing light-only traffic control device to active with gates, or close (consolidate) the crossing, or grade separate.

b. If highway and/or train volumes and/or speeds will not allow the highway to perform at an acceptable level of service, consider traffic control device upgrade to active (possibly with additional devices such as gates and medians), or closure (consolidation), or separation.
c. If crossing closure or consolidation is being considered, determine the feasibility and cost of providing of an acceptable alternate route and compare this to the feasibility and cost of improving the existing crossing.
d. If grade separation is being considered:

   i. Economic analysis should consider fully allocated life-cycle costs.
   ii. Consider highway classification and level of service.
   iii. Consider the possibility of closing one or more adjacent grade crossings.

Step 4—Interim measures and/or documentation:

a. If the above analysis indicates a change or improvement in the crossing or type of traffic control devices, determine what, if any, interim measures can or should be taken until such time as recommended improvement can be implemented.
b. If the above analysis indicates a change or improvement in the crossing or type of traffic control devices, but there are other compelling reasons or circumstances for not implementing them, document the reasons and circumstances for your decision.
c. If the above analysis indicates no change or improvement in the crossing or type of traffic control devices, document the fact that the crossing was evaluated and determined to be adequate.[2]

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[2] Ibid.

D. High-Speed Rail Corridors

Special consideration must be given to highway-rail grade crossings on high-speed passenger train routes. The potential for a catastrophic collision injuring many passengers demands special attention. This not only includes dedicated routes with speeds over 100 mph but also other passenger routes over which trains may operate at speeds higher than freight trains.

Variations in warning time may occur with high-speed passenger trains at crossings equipped with active traffic control devices. Because of the wide variation in train speeds (passenger trains versus freight trains), train detection circuitry should be designed to provide the appropriate advance warning for all trains.

High-speed passenger trains present additional problems at crossings with only passive traffic control devices. Safe sight distance along the track from a stopped position must be much greater for a faster train. The sight distance along the track from the highway approach must also be greater unless vehicle speed is reduced. In addition, it is difficult to judge the speed of an oncoming train.

Private crossings are a major concern for high-speed passenger trains. These crossings usually have only passive traffic control devices and often consist of narrow, unimproved, or gravel roads with limited visibility along the railroad tracks.

Special attention should be given to crossings on high-speed rail passenger routes. Some states utilize priority indices that include a factor for train speed or potential dangers to large numbers of people. In this manner, crossings with high-speed passenger trains are likely to rank higher than other crossings and, thus, be selected for crossing improvements.

Another method for improving crossings on high-speed passenger routes is to utilize the systems approach. As discussed in Chapter III, the systems approach involves the inspection and evaluation of safety and operations at crossings within a specified system, such as along a high-speed rail corridor.

It is desirable that all crossings located on high-speed rail corridors either be closed, grade separated, or equipped with automatic gates. The train detection circuitry should provide constant warning time. Where feasible, other site improvements may be necessary at these crossings. Sight distance should be improved by clearing all unnecessary signs, parking, and buildings from each quadrant. Vegetation should be periodically cut back or removed. Improvements in the geometries of the crossing should be made to provide the best braking and acceleration distances for vehicles.

Education of the public is an important element for the improvement of safety and operations at crossings on high-speed rail corridors. This can be accomplished with publicity campaigns and public service announcements, as described in the next chapter. Public education might also alleviate some fears of high-speed trains and provide for better railroad-community relations. State agencies and railroads should cooperatively undertake this.

Special signing might also be employed at these crossings to remind the public that the crossings are used by high-speed trains. No national standard exists for such signing; however, the signing should be in conformance with the guidelines provided in MUTCD.

E. Special Vehicles, Pedestrians, Motorcycles, and Bicycles

Highway-rail grade crossings are designed and controlled to accommodate the vehicles that use them. The vast majority of these vehicles consist of automobiles, buses, and all types of trucks. Generally speaking, improvements to a crossing with these users in mind will be adequate for any other special users, such as trucks carrying hazardous materials, long-length trucks, school buses, motorcycles, bicycles, and pedestrians. However, these users have unique characteristics and special needs that should be considered. Chapter II discussed some of these characteristics. This chapter will present some design and control considerations.

1. Trucks with Hazardous Material Cargo

Collisions involving trucks with hazardous material cargo are potentially the most dangerous because they can have deleterious effects over a wide area. Consequently, all crossings used by these vehicles should be considered for improvements and, in turn, these improvements should consider the special needs of these vehicles.

Drawing on the National Transportation Safety Board's study of train collisions involving these vehicles and their subsequent recommendations, several suggestions are provided to address this concern:

- Trucks carrying bulk hazardous material should use routes that have grade separations or active control devices. Where routes that have crossings with only passive control devices are near terminals, the crossings should be considered for upgrading to active control.
- Ensure that active warning devices are activated with enough "warning time" (activation in advance of the arrival of a train) so that trucks have the available distance required for stopping. Also, for vehicles stopped at the crossing when signals are not operating, adequate warning time should be provided for clearance of tracks by loaded trucks before the arrival of a train.
- If feasible, where there is an intersection in close proximity to the crossing, increase the storage space (defined as the "clear storage distance" in MUTCD) between the tracks and the intersecting highway. If on a direct route to a truck terminal, also consider giving right of way to the critical movement through control measures.
- Promote a program of education and enforcement to reduce the frequency of hazardous driving and alert the driver of potential danger. Driver training and education programs such as Operation Lifesaver should be expanded to include a specific program that addresses the problems.

At crossings where a significant volume of trucks is required to stop, consideration should be given to providing a pull-out lane. These auxiliary lanes allow trucks to come to a stop and then to cross and clear the tracks without conflicting with other traffic. Hence, they minimize the likelihood of rear-end collisions or other vehicle-vehicle collisions. They would be appropriate for two-lane highways or for high-speed multilane highways.

2. Long and Heavily Laden Trucks

As discussed in Chapter II, large trucks have particular problems at crossings because of their length and performance characteristics. Longer clearance times are required for longer vehicles and those slow to accelerate. Also, longer braking distances become necessary when trucks are heavily laden, thus reducing their effective braking capability.

As truck sizes, configurations, and weights have increased over time, it is critical to address currently allowable large vehicles (such as the interstate semitrailer truck—WB-62 or WB-65), where such vehicles may be expected to utilize a highway-rail grade crossing on a regular basis. Consequently, when considering improvements, the designer should be aware of and design for the amount and type of current and expected truck traffic. Areas that should be focused upon include:

- Longer sight distances.
- Placement of advance warning signs.
- Warning time for signals.
- Approach and departure grades.
- Storage area between tracks and nearby highway intersection.

3. Buses

Because buses carry many passengers and have performance characteristics similar to large trucks, these vehicles also need special consideration. Many of the measures suggested for trucks with hazardous material apply to buses. Railroad-highway grade crossings should be taken into consideration when planning school bus routes.

Potentially hazardous crossings, such as those with limited sight distance or horizontal or vertical alignment issues, should be avoided if possible. Crossings along school bus routes should be evaluated by the appropriate highway and railroad personnel to identify potentially dangerous crossings and the need for improvements. Drivers should be instructed on safe crossing procedures and should be made aware of expected railroad operations, such as the speed and frequency of train movements.

4. Motorcycles and Bicycles

Although motorcycles and bicycles typically travel at different speeds, these two-wheeled vehicles can experience the same problem at crossings. Depending on the angle and type of crossing, a cyclist may lose control of the vehicle if the wheel becomes trapped in the flangeway. The surface materials and the flangeway width and depth must be evaluated. The more the crossing deviates from the ideal 90-degree crossing, the greater the potential for a cycle wheel to be trapped in the flangeway. If the crossing angle is less than 45 degrees, consideration should be given to widening the bikeway to allow sufficient width to cross the tracks at a safer angle.

Other than smooth surface treatments, there are no special controls for these special vehicles. However, if a bicycle trail crosses tracks at grade, the bicyclist should be warned of this with suitable markings and signs, such as those shown in Figure 81.