

GUIDANCE ON TRAFFIC CONTROL DEVICES AT HIGHWAY-RAIL GRADE CROSSINGS

**U.S. DEPARTMENT OF
TRANSPORTATION**

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HIGHWAY/RAIL GRADE CROSSING TECHNICAL WORKING GROUP (TWG)

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U.S. Department of Transportation
Highway-Railroad Grade Crossing Technical Working Group

Guidance on Traffic Control at Highway-Rail Grade Crossings

EXECUTIVE SUMMARY

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

The report is intended to provide guidance to assist engineers in selection of traffic control devices or other measures at highway-rail grade crossings. It is not to be interpreted as policy or standards. Any requirements that may be noted in this guidance are taken from the Manual on Uniform Traffic Control Devices (MUTCD) or other document identified by footnotes. These authorities should be followed. This guide merely tries to incorporate some of the requirements found in those documents. A number of measures are included which may not have been supported by quantitative research, but are being used by States and local agencies. These are included to inform practitioners of an array of tools used or being explored.

The goal is to provide a guidance document for users who understand general engineering and operational concepts of highway-rail grade crossings. The Guide serves as a reference to aid in decisions to install traffic control devices or otherwise improve such crossings. Additional references are provided as resource for further information.

The Guide discusses a number of existing laws, regulations and policies of the FHWA and FRA concerning highway-rail grade crossings and railroad operations, driver needs concerning various sight distance, and highway and rail system operational requirements and functional classification. There is an extensive description of passive and active traffic control devices, including supplemental devices used in conjunction with active controls. Traffic control devices in the 2000 edition of the MUTCD are listed, together with a few experimental devices. An appendix provides limited discussion on the complex topic of interconnection and preemption of traffic signals near highway-rail grade crossings. There is also discussion concerning closure, grade separation and consideration for installing new grade crossings. A glossary defines a few less familiar and technical terms. (Please note that the term grade crossings is synonymous with both the terms “highway-rail grade crossings” and “highway-rail intersections” in this document.)

A traffic control device selection procedure and extensive list of quantitative guidance are the specific products of this document. However, due to the unique characteristics of each individual crossing, these procedures and practices should not be considered as warrants or standards. Therefore, selection decisions must be made based on engineering studies.

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INTRODUCTION

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The report is intended to provide guidance to assist engineers in selection of traffic control devices or other measures at highway-rail grade crossings. 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)¹ or other document identified by footnotes. A number of measures are included which may not have been supported by quantitative research, but are being used by States and local agencies. These are included to inform practitioners of an array of tools used or being explored.

The goal is to provide a guidance document for users who understand general engineering and operational concepts of public highway-rail grade crossings. The document will serve as a reference to aid in decisions to install traffic control devices or otherwise improve such crossings, and also provide information on additional references.

The report includes discussion of a number of existing laws, regulations and policies of the FHWA and FRA concerning highway-rail grade crossings and railroad operations, driver needs concerning various sight distance, and highway and rail system operational requirements and functional classification. There is extensive description of passive and active traffic control devices, including supplemental devices used in conjunction with active controls. Traffic control devices in the 2000 edition of the MUTCD are listed, together with a few experimental devices. An appendix provides limited discussion on the complex topic of interconnection and preemption of traffic signals near highway-rail grade crossings. There is also discussion concerning closure, grade separation and consideration for installing new grade crossings. Finally, an extensive list of quantitative recommend guidance is provided. (Please note that the term grade crossings is synonymous with highway-rail grade crossings in this document.)

EXISTING LAWS, RULES, REGULATIONS AND POLICIES

Several documents provided by the Federal Highway Administration, the Federal Railroad Administration, and other organizations, provide some guidelines for selecting traffic control devices. For example, the MUTCD, published by the Federal Highway Administration, contains detailed guidance on the design and placement of traffic control devices. The MUTCD is a Federal standard under title 23, United States Code 109(d) and is incorporated by reference into the Code of Federal Regulations (CFR). If a particular device is selected for use, the MUTCD will indicate what the size, color, and placement of that device should be. Considered by the FHWA as a national standard, the MUTCD has the force of law.

¹ MUTCD is available at the following URL: <http://mutcd.fhwa.dot.gov>

Another document frequently used to assist in determining the need for certain traffic control devices is the *Railroad-Highway Grade Crossing Handbook - Second Edition, (RHGCH)*², also published by the FHWA. The handbook draws on a number of different sources (including the MUTCD and the AASHTO *A Policy on Geometric Design of Highways and Streets*³ [Greenbook]) to provide an overview of highway-rail grade crossing legal and jurisdictional considerations. Included is a brief discussion of grade crossing design issues involving the physical and geometric characteristics of the crossing, and risk assessment formulas. The *RHGCH* provides guidelines for the identification and selection of active control devices. Also included are discussions of issues surrounding shortline railroads, high-speed rail corridors, and special vehicles such as trucks carrying hazardous materials and trucks having low-ground clearance.

These source documents provide limited guidance, mostly in the form of lists of factors “to be considered” for installing either flashing-lights or flashing-lights and gates; however, they lack specific guidance on how to determine the most appropriate type of highway traffic control at a given highway-rail crossing. For example, the *RHGCH* cites “high speed trains” as a factor, but does not define the conditions under which a train is considered “high speed.” In another instance, the presence of school buses or vehicles carrying hazardous materials is cited as a factor, but every public crossing has the potential to carry both of these types of traffic. “Past collision history” is also frequently cited as a rationale for upgrading passive grade crossings to active control, or adding gates to “flasher only” grade crossings, but no specific guidance is provided.

Several previous attempts have been made to quantify the relative emphasis these factors should have in evaluating the need to improve a crossing. The *RHGCH* contains several examples of formulae that have been developed to help determine the likelihood of a collision occurring at a particular crossing. Use of these formulae, however, is far from universal. Some States use either exposure factors or a minimum expected accident frequency (EAF) to determine whether a given crossing “qualifies” for public funding for improved traffic control devices. Illinois, for example, uses a modified New Hampshire formula to “qualify” crossings for improvement or upgrade whenever the EAF exceeds 0.02; Iowa gives “priority” to those crossings having a USDOT Accident Predictor Model EAF of 0.075 or higher. A number of States have established their own criteria for determining when or where active devices are deployed, but their rationale for establishing such criteria is not commonly known nor is there much consistency from State to State.

Current FHWA regulations specifically prohibit at-grade intersections on highways with full access control. The FRA’s rail safety regulations require that crossings be separated or closed where trains operate at speeds above 125 mph (49 CFR 213.347(a)). Additionally, if train operation is projected at FRA track class 7 (111 – 125mph) an application must be made to the FRA for approval of the type of warning/barrier system. The regulation does not specify the type of system, but allows the petitioner to propose a suitable system for FRA review.

² Railroad-Highway Grade Crossing Handbook - Second Edition is available at the following URL:
<http://www.fhwa.dot.gov/tfhr/safety/pubs/86215/intro.htm>

³ A Policy on Geometric Design of Highways and Streets is available at the following URL:
<http://www.ite.org/bookstore/lp323b.html>

In 1998, the FRA issued an Order of Particular Applicability for high-speed rail service on the Northeast Corridor. In the Order, the FRA set a maximum operating speed of 80 mph over any highway-rail crossing where only conventional warning systems are in place and a maximum operating speed of 95 mph where 4-quadrant gates and presence detection are provided and tied into the signal system. Grade crossings are prohibited on the Northeast Corridor if maximum operating speeds exceed 95 mph. Current statutory, regulatory and Federal policy requirements are summarized in Table 1.

TABLE 1
FEDERAL LAWS, RULES, REGULATION & POLICIES

	Active	Warning/Barrier W/FRA Approval	Grade Separate or Close
Controlled Access Highways	Not allowed	Not allowed	Required
High Speed Rail	> 79 MPH	111-125 MPH	> 125 MPH

Note: 1 mph = 1.61 km/h

HIGHWAY-RAIL GRADE CROSSING PERSPECTIVE

A highway-rail grade crossing differs from a highway/highway intersection in that the train always has the right of way. From this perspective, the process for deciding what type of highway traffic control device is to be installed, or to even allow that a highway-rail grade crossing should exist is essentially a two-step process: 1) What information does the vehicle driver need to be able to cross safely? and, 2) Is the resulting driver response to a traffic control device “compatible” with the intended system operating characteristics of the highway and railroad facility?

MOTOR VEHICLE DRIVER NEEDS ON THE APPROACH

The first step involves three essential elements required for “safe” passage through the crossing, which are the same elements a driver needs for crossing a highway-highway intersection:

ADVANCE NOTICE - STOPPING SIGHT DISTANCE

The first element pertains to “stopping” or “braking” sight distance, which is the ability to see a train and/or the traffic control device at the crossing ahead sufficiently in advance so that a driver can bring the vehicle to a safe, controlled stop at least 4.5 m (15 ft) short of the near rail, if necessary. This applies to either a passive or active controlled crossing. Stopping sight distance is measured along the roadway and is a function of the distance required for the “design” vehicle, traveling at the posted speed limit to safely stop⁴. Insufficient stopping sight distance is often due to poor roadway geometry and/or surrounding topography.

TRAFFIC CONTROL DEVICE COMPREHENSION

⁴ A Policy on Geometric Design of Highways and Streets. American Association of State Highway Transportation Officials (AASHTO). 2001 Edition. P. 449, available at www.ite.org, or 202-289-0222 and www.aashto.org

The second element is a function of the type of traffic control device at the highway-rail crossing. There are typically three types of control devices, each requiring a distinct compliance response per the Uniform Vehicle Code⁵, various Model Traffic Ordinances and State regulations.

1. A crossbuck is a type of YIELD sign: the driver should be prepared to stop at least 4.5 m (15 ft) before the near rail if necessary, unless and until the driver can make a reasonable decision that there are no trains in hazardous proximity to the crossing, and it is safe to cross.
2. Operating flashing lights have the same function as a STOP sign: a vehicle is required to stop completely at least 4.5 m (15 ft) short of the near rail. Then, even though the flashing lights may still be operating, the driver is allowed to proceed after stopping (subject to State or local laws), when safe to do so.
3. Flashing lights with lowered gates are equivalent to a red vehicular traffic signal indication: a vehicle is required to stop short of the gate and remain stopped until the gates go up.

Motorist comprehension and compliance with each of these devices is mainly a function of education and enforcement. The traffic engineer should make full use of the various traffic control devices as prescribed in the MUTCD to convey a clear, concise and easily understood message to the driver, which should facilitate education and enforcement.

DECIDING TO PROCEED

The third element concerns the driver's decision to safely proceed through the grade crossing. It involves sight distance available both on the approach and at the crossing itself.

Approach (Corner) Sight Distance

On the approach to the crossing with no train activated traffic control devices (or STOP sign) present, in order to proceed at the posted speed limit, a driver would need to be able to see an approaching train, from either the left or right, in sufficient time to stop safely 4.5 m (15 ft) before the near rail. This would require an unobstructed field of vision along the approach sight triangle, the extent of which is dependent upon train and vehicle speed. These sight distances are available in the RHGCH. However, view obstructions often exist within the sight triangle, typically caused by structures, topography, crops or other vegetation (continually or seasonal), movable objects or weather (fog, snow, etc.). Where lesser sight distances exist, the motorist should reduce speed and be prepared to stop not less than 4.5 m (15 ft) before the near rail unless and until they are able to determine, based upon the available sight distance, that there is no train approaching and it is safe to proceed. Wherever possible, sight line deficiencies should be improved by removing structures or vegetation within the affected area, regrading an embankment, or realigning the highway approach.

Many conditions however cannot be corrected because the obstruction is on private property, or it is economically infeasible to correct the sight line deficiency. If available corner sight distance is less than what is required for the legal speed limit on the highway approach, supplemental traffic control devices such as enhanced advance warning signs, STOP or YIELD signs, or reduced speed limits (advisory or regulatory) should be evaluated. If it is desirable from traffic mobility criteria to allow vehicles to travel at the legal speed limit on the highway approach, active control devices should be considered.

⁵ Uniform Vehicle Code is available at the following URL : <http://mutcd.fhwa.dot.gov/>

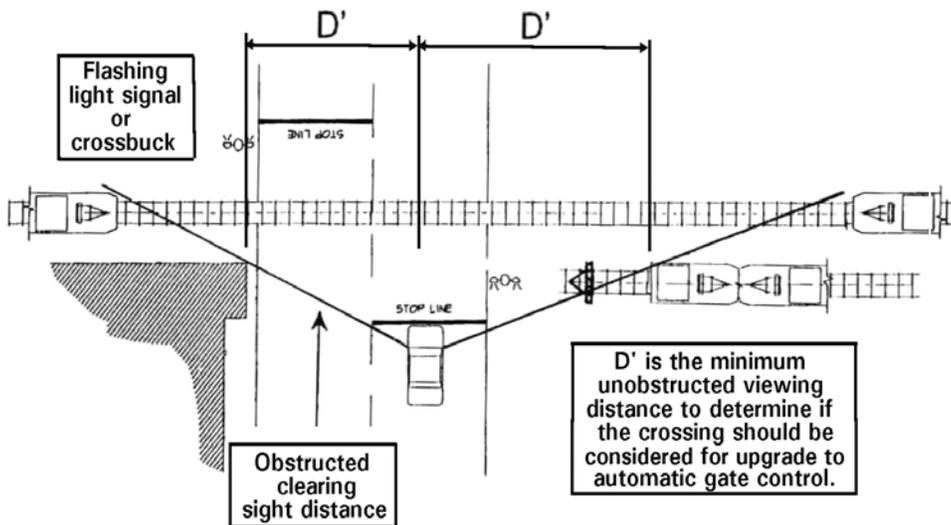


FIGURE 1

Clearing Sight Distance

At all crossings, except those with gates, a driver stopped 4.5 m (15 ft) short of the near rail must be able to see far enough down the track, in both directions, to determine if sufficient time exists for moving their vehicle safely across the tracks to a point 4.5 m (15 ft) past the far rail, prior to the arrival of a train. Required clearing sight distance along both directions of the track, from the stopped position of

the vehicle, is dependent upon the maximum train speed and the acceleration characteristics of the “design” vehicle.

At multiple track highway-rail grade crossings of two or more in-service railroad tracks through the roadway, and where two or more trains can operate simultaneously over or in close proximity to the crossing, the presence of a train on one track can restrict or obscure a driver’s view of a second train approaching on an adjacent track. Such crossings must be treated the same as any other crossing having insufficient clearing sight distance. Even where there is only one track through the crossing, but additional tracks (such as a siding) are located adjacent to, but terminate before reaching the crossing, the sight distance to the limit of where railroad cars or equipment could be stored should be evaluated. Figure 1 is a diagram designed to illustrate some unusual conditions that would merit special consideration at a single-track highway-rail grade crossing.

Figure 1

This figure shows an aerial view of a highway-rail grade crossing. A single-rail track stretches across the width of the figure. A locomotive is located on both the right and left-ends of the track. There is a second track on right side of the crossing with a locomotive on it. This track ends before the roadway. An automobile is stopped behind a “stop line” in the middle of the figure. On both sides of the intersection there is a symbol for a flashing light signal. In the lower left quadrant, a building is shown that restricts sight the sight of a locomotive approaching from the left. There is a 45-degree line between the automobile and the locomotive on the left end of the track that demonstrates the obstructed clearing sight distance caused by the building. Another 45-degree line stretches from the automobile to the locomotive on the right end of the track that demonstrates the obstructed clearing sight distance caused by the locomotive on the second track. There is a box between the automobile and locomotive that says, “D is the minimum unobstructed viewing distance to determine if the crossing should be considered for upgrade to automatic gate control.”

Table 2, prepared by members of the TWG, relates the typical minimal clearing sight distances for various train speeds and vehicle types. (It should be noted the column for 65 foot double trucks generally corresponds to the distances listed in table 36 on page 133 of the *RHGCH*, under the column for vehicle speed of “0 MPH.” Vehicle acceleration data has been interpreted from the *Traffic Engineering Handbook*.⁶) The person or agency evaluating the crossing should determine the specific design vehicle, pedestrian, bicyclist, or other non-motorized conveyance and compute clearing sight distance if it is not represented in the table. Also note the table values are for a level, 90-degree crossing of a single track. If other circumstances are encountered, the values must be re-computed.

TABLE 2
CLEARING SIGHT DISTANCE (in feet) *

Train Speed	Car	Single Unit-Truck	Bus	WB-50 Semi-Truck	65-ft Double Truck	Pedestrian **
10	105	185	200	225	240	180
20	205	365	400	450	485	355
25	255	455	500	560	605	440
30	310	550	600	675	725	530
40	410	730	795	895	965	705
50	515	910	995	1120	1205	880
60	615	1095	1195	1345	1445	1060
70	715	1275	1395	1570	1680	1235
80	820	1460	1590	1790	1925	1410
90	920	1640	1790	2015	2165	1585

* A single track, 90-degree, level crossing.

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

Note: 1 meter = 0.3048 feet.

Figure 2: Pedestrian Sight Triangle

A highway-rail grade crossing is displayed depicting a pattern for the pedestrian sight triangle. The distance the pedestrian travels from one side of the crossing to the other is 42 feet. There are two tracks in the crossing. The distance is broken up into the following respective categories:

- 7 ft. Decision/Reaction Distance of 2 seconds @3.5 feet per second;
- 10 ft. Clearance Area just before a rail track;
- 15 ft. between two rail tracks;
- 10 ft. from last rail track to clearance area.

A locomotive is approaching from the south in the diagram. The pedestrian is on the immediate right of the crossing starting at the Decision/Reaction Distance category-space. The figure of the pedestrian is shown several times to represent the movement over the crossing. There is a “STOP HERE” label on both sides of the crossing immediately prior to the beginning of the clearance area. There is a dotted line reaching from the pedestrian’s figure to the first track that demonstrates the sight distance to an approaching locomotive. The area inside the triangle is shaded. The sight triangle demonstrates that the pedestrian is 17 ft. from the center of the first track.

⁶ *Traffic Engineering Handbook - Fourth Edition*. Institute of Transportation Engineers. Washington D.C.: 1990. available at www.ite.org, or 202-289-0222

If there is insufficient clearing sight distance, and the driver is unable to make a safe determination to proceed, the clearing sight distance needs to be improved to safe conditions, or flashing light signals with gates, or closure, or grade separation should be considered. (See Recommendation, “3.F.3”.)

SYSTEMS OPERATING REQUIREMENTS AND OBJECTIVES

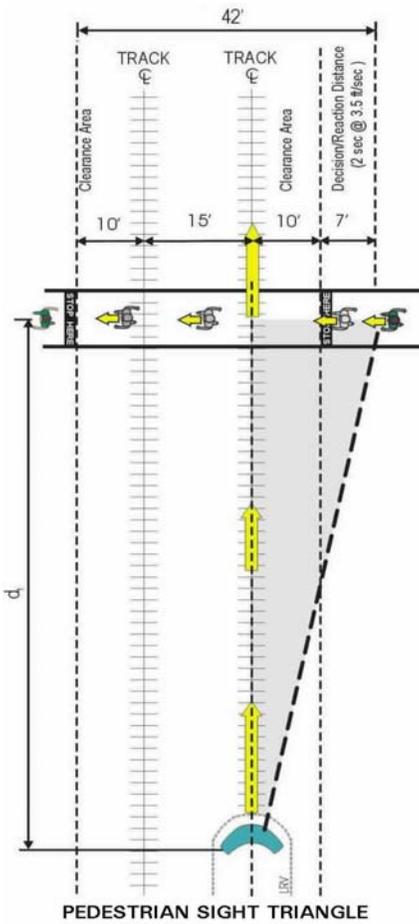


FIGURE 2

The second step involves a traffic control device selection process considering respective highway and rail system operational requirements. From a highway perspective, concerns for roadway capacity and drivers' expectations may mandate the type of traffic control present. There are circumstances when train interference can be so disruptive to highway operations that a highway-rail grade crossing is incompatible with system objectives. From the rail perspective, there can also be circumstances when the potential for highway traffic interference can be sufficiently disruptive, or potentially so catastrophic, that closure, grade separation, or activated control would be considered. It is within these contexts where operation and safety variables should be considered, such as:

- a) Highway - AADT (Annual Average Daily Traffic), legal and/or operating speed;
- b) Railroad - train frequency, speed and type (passenger, freight, other);
- c) Highway - Functional classification and/or design level of service;
- d) Railroad - FRA Class of Track and/or High Speed Rail corridors;
- e) Proximity to other intersections;
- f) Proximity to schools, industrial plants and commercial areas;
- g) Proximity to rail yards, terminals, passing tracks and switching operations;
- h) Available clearing and corner sight distance;
- i) Prior accident history and predicted accident frequency;
- j) Proximity and availability of alternate routes and/or crossings; and
- k) Other geometric conditions.

Special consideration should also be given to situations where highway-rail crossings are sufficiently close to other highway intersections that traffic waiting to clear the adjacent highway intersection can queue on or across the tracks. Additionally, special consideration is required when there are two or more sets of tracks sufficiently close to each other that traffic stopped on one set could result in a queue of traffic across the other.

HIGHWAY SYSTEM OBJECTIVES

Roads and streets which are planned, designed, constructed, maintained and operated by public agencies serve two important but conflicting functions: land access and mobility. Overriding these interests should be a concern for safety.

An example of a facility constructed primarily for mobility is the Interstate highway. Access is only by interchanges, with ramps and acceleration/deceleration lanes. These allow vehicles to enter and leave the highway with minimal effect on the through traffic stream. Interstate highways do not have direct driveway access to adjacent properties, grade level intersections, transit stops, pedestrian and bicycle facilities or highway-rail grade crossings, all of which interfere with the free flow of traffic.

A local street is at the other end of the spectrum. It provides direct access to adjacent land, with driveways to parking facilities and provision of services such as on-street deliveries and trash pickup. The

low-type design of local streets, including presence of parked vehicles, pedestrians and bicycles, makes travel at any significant speed undesirable.

Many roads and highways fall in the spectrum between Interstate highways and local roads, and fulfill their purpose with varying degrees of success. Mobility is affected by providing adequate access to adjacent development in an environment complicated by driveways and street intersections, and other modes of transportation such as transit, bicycles, pedestrians and railroads. The concept is illustrated in Figure 3.⁷

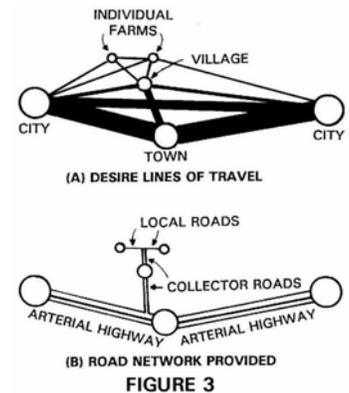


Figure 3:

A) Desired Lines of Travel

The figure depicts the desired lines of travel between several points and is depicted in the form of an irregular pentagon. A circle, representing “City”, “Town”, and “City”, respectively is shown on each of the three southern points of the figure. On the left and right points of the irregular pentagon, there is a label that reads “City.” The far-south point of the pentagon reads “Town.” In the center of the pentagon there is a circle with an arrow pointing to it labeled “Village.” Above “Village” are two smaller circles that are labeled “Individual Farms”. Twelve lines connect the various circles of the pentagon indicating the desired lines of travel between the various points. There are thick black lines leading from each “City” to the “Town”.

B) Road Network Provided

The figure shows the same pattern of circles as Figure A that are labeled the same as in A). There are five lines connecting the points indicating the roadway network. “Arterial Highway” is written for the segments connecting both “City” circles to the “Town”. To the left of the “Town” is a vertical line labeled “Collector Roads” which runs to the “Village” circle and extends slightly beyond the village. Horizontally placed atop the “Collector Roads” is a small “local roads” line with the two “Individual Farms” circles on each endpoint. Each line represents travel between the various points.

A highway-rail grade crossing can impede highway traffic flow based on several factors. The most obvious is, of course, blockages by trains. The geometry of the crossing and approaches, and the condition of the surface can present additional impediments.

LEVELS OF SERVICE

The performance of a road or street is normally described in terms of “Level of Service.”⁸ The Level of Service is a concept that describes the operational characteristics of the traffic stream and how they are perceived by drivers and passengers. Speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience are factors that characterize levels of service. Traffic flow characteristics are described by letter designations; “A” the best, corresponding to a free flow condition, and “F” the worst, corresponding to a breakdown of flow or “stop and go” condition. Table 3 provides guidance for selecting Level of Service for particular locations.

⁷ *A Policy on Geometric Design of Highways and Streets.* American Association of State Highway Transportation Officials (AASHTO). 2001 Edition. pages 4 and 5, available at www.ite.org, or 202-289-0222 and www.aashto.org.

⁸ *Highway Capacity Manual, Special Report 209, 3rd Edition.* Transportation Research Board. Washington, D.C.: 1994, available at www.ite.org or 202-289-0222 or www.trb.org.

TABLE 3
GUIDE FOR SELECTION OF DESIGN LEVELS OF SERVICE

Highway Type	Type of Area and Appropriate Level of Service			
	Rural Level	Rural Rolling	Rural Mountainous	Urban and Suburban
Freeway	B	B	C	C
Arterial	B	B	C	C
Collector	C	C	D	D
Local	D	D	D	D

Note: General operating conditions for levels of service:

- A - free flow, with low volumes and high speeds.
- B - reasonably free flow, but speeds beginning to be restricted by traffic conditions.
- C - in a stable flow zone, but most drivers restricted in freedom to select their own speed.
- D - approaching unstable flow, drivers have little freedom to maneuver.
- E - unstable flow, may be short stoppages.
- F - forced flow, congested stop-and-go operation.

(Source: A Policy on Geometric Design of Highways and Streets. AASHTO. 2001. Page 90)

The nominal level of service normally considered acceptable during the planning and design of a new or reconstructed roadway is “C” which is within the range of stable flow. The presence of a highway-rail grade crossing can drop the level of service below “C”.

SAFE APPROACH SPEED

Passive crossings with a restricted sight distance require an engineering study to determine the safe approach speed based upon available stopping and/or corner sight distance. As a minimum, an advisory speed posting may be appropriate, or a reduced regulatory speed limit might be warranted (if it can be effectively enforced). (See Guidance Section of this Report, “3.F.2c.”) Active devices improve highway capacity and level of service in the vicinity of a crossing, particularly where corner sight distances are restricted. When flashing lights are active however, a driver is required to stop and look for a train.

The effects of such delay increases as volume increase. Queues become longer and vehicle delay increases proportionally. These delays are observed by the driver as a reduction in the facility’s level of service. The type of control installed at highway-rail crossings needs to be evaluated in the context of the highway system classification and level of service.

RAILROAD SYSTEMS - FUNCTIONAL CLASSIFICATION

A commonly used means of classifying freight and “heavy rail” passenger rail routes is by their respective FRA designations for class of track. This Federal designation establishes the maximum authorized speed for freight and passenger trains, and places requirements on the track maintenance criteria, vehicle standards, and train control signal systems. In some respects, the FRA Class of Track may be viewed as a surrogate for rail traffic volume. In general, railroads are not likely to make the additional investment required to maintain tracks to a higher standard absent sufficient traffic volume to justify the added expense. Table 4 indicates maximum permissible train speeds for various classes of track.

TABLE 4

MAXIMUM TRAIN SPEEDS BY CLASS OF TRACK *

Class of Track	Freight	Passenger
Class 1	10 MPH	15 MPH
Class 2	25 MPH	30 MPH
Class 3	40 MPH	60 MPH
Class 4	60 MPH	80 MPH
Class 5	80 MPH	90 MPH
Class 6	110 MPH	110 MPH
Class 7	125 MPH	125 MPH
Class 8	160 MPH	160 MPH
Class 9	200 MPH	200 MPH

* If train operations exceed 177 km/h (110 mph) for a track segment that will include highway-rail grade crossings, FRA approval of a complete description of the proposed warning/barrier system to address the protection of highway traffic and high speed trains must be obtained in advance. All elements of the warning/barrier system must be functioning.

Source: 49 CFR 213

Note: 1 mph = 1.61 km/h

Not unlike the system specification that all highway-rail crossings on full control access highways be grade separated, it is only logical that certain rail systems should have similar status. In 1994, the FRA defined a core railroad system of approximately 128,800 km (80,000 mi) known as the Principal Railroad Lines (PRLs). These lines have one or more of the following attributes: Amtrak service; defense essential; or, annual freight volume exceeding 20 million gross tons. This core network was described in the Department of Transportation's 1994 Action Plan to improve highway-rail grade crossing safety. The Action Plan set forth a long-term goal of eliminating (grade separating or realigning) intersections of PRLs and highway routes on the National Highway System (NHS - defined as "an interconnected system of principal arterial routes to serve major population centers, intermodal transportation facilities and other major travel destinations; meet national defense requirements; and serve interstate and interregional travel").

FUNCTION, GEOMETRIC DESIGN AND TRAFFIC CONTROL

Functional classification is important to both the highway agency and railroad operator. Even though geometric criteria can be determined without reference to the functional classification, the designer should consider the function that the highway is expected to serve. The functional classification of the highway defines the geometric criteria to be used in its planning, design and construction. Where the highway intersects a railroad, the crossing, whether grade separated or at-grade, should be designed consistently with the functional classification of the highway or street. These design considerations can also extend to traffic control.

Drivers form expectancies based on their training and experience; that is, situations which occur in similar environments and in similar ways are incorporated into the driver's knowledge base, along with successful responses to the situations. Drivers on a US or state-numbered route, or on a facility having a higher functional classification, have higher expectancies for operating characteristics, level of service and traffic control than do those same drivers on local roads and streets. These higher classed roads and streets also tend to serve a more diverse cross-section of vehicles and loading, including transit buses, intercity buses and haz-mat carriers. For these reasons, functional classification of the road or street should be considered in the decision-making process concerning geometric design and traffic control devices.

TRAFFIC CONTROL DEVICES

GENERAL DISCUSSION

The purpose of traffic control at highway-rail grade crossings is to permit safe and efficient operation of rail and highway traffic over such crossings. Highway vehicles approaching a highway-rail grade crossing should be *prepared to yield and stop if necessary* if a train is at or approaching the crossing.

PASSIVE DEVICES

A passive highway-rail grade crossing is described as follows:

All highway-rail grade crossings having signs and pavement markings (if appropriate to the roadway surface) as traffic control devices that are not activated by trains.

The following tables describe a variety of devices that can be used at a passive controlled highway-rail grade crossing, or supplement active devices. Table 5A are devices currently referenced in the 2000 MUTCD edition. Table 5B lists devices that are not currently proposed in the MUTCD, and any jurisdiction wishing to use these devices to experiment must request permission from the FHWA.

TABLE 5A - CURRENT MUTCD DEVICES

MUTCD	Traffic Control Device	Application or Indication of Need
R15-1	CROSSBUCK sign	Required device
R15-2	“Multiple Tracks” sign	Standard device, with 2 or more tracks; optional with gate.
W10-1	Advance warning sign	Required device, with MUTCD exceptions
	RR Pavement Markings	All paved roads, with MUTCD exceptions
R1-1	STOP sign	As indicated in MUTCD reference 1993 memorandum.
W3-1, 1a	STOP AHEAD sign	Where STOP sign is present at crossing.
R1-2	YIELD sign	As indicated in MUTCD reference 1993 memorandum.
W3-2, 2a	YIELD AHEAD sign	Where YIELD sign is present at crossing.
R3-1, -2	Turn Restriction sign * (An “active” sign)	Use with interconnected, preempted traffic signals. Install on the nearby parallel highway to control turns toward the tracks.
R3-4	U-Turn Prohibition sign	Use in median of divided highways at highway-rail grade crossings to inhibit turning vehicles from using the track zone for illegal movement as necessary.
R4-1, W14-3	DO NOT PASS sign	Where passing near the tracks is observed.
R8-8	DO NOT STOP ON TRACKS sign	Where queuing occurs, or where storage space is limited between a nearby highway intersection and the tracks. May be supplemented with a flashing light activated by queuing traffic in the exit lane(s) from the crossing. (See discussion on Queue Cutters Signals.)
R8-9	TRACKS OUT OF SERVICE sign	Applicable when there is some physical disconnection along the railroad tracks to prevent train using those tracks.
R10-5	STOP HERE ON RED sign	Use with pre-signal and/or Stop Line pavement markings to discourage vehicle queues onto the track.
R10-11	NO TURN ON RED sign	Use with pre-signal and/or where storage space is limited between a nearby-interconnected traffic signal controlled intersection.
R15-3, W10-1	EXEMPT sign	School buses and those commercial vehicles that are usually required to stop at crossings are not required to do so where authorized by ordinance.
R15-4	Light Rail Transit Only Lane sign series	For multilane operations where roadway users might need additional guidance on lane use and/or restrictions.
R15-5, 5a	DO NOT PASS Light	Where vehicles are not allowed to pass LRT vehicles loading or unloading

	Rail Transit signs	passengers where no raised platform physically separates the lanes.
R15-6, 6a	No Vehicles on Tracks signs	Used where there are adjacent vehicle lanes separated from the LRT lane by a curb or pavement markings.
R15 -7, 7a	DIVIDED HIGHWAY sign	Use with appropriate geometric conditions.
R15-8	LOOK, Supplementary sign	<ul style="list-style-type: none"> ➤ Multiple tracks ➤ Collision experience ➤ Pedestrian presence
W10-2, 3, 4	Advance Warning Signs Series	Based upon specific situations with a nearby parallel highway.
W10-5	LOW GROUND CLEARANCE CROSSING sign	As indicated by MUTCD guidelines, incident history or local knowledge.
W10-8, 8a	TRAINS MAY EXCEED 80 MPH (130 KM/H) sign	Where train speed is 80 mph (130 km/h) or faster
W10-9	NO TRAIN HORN sign	Shall be used only for crossings in FRA-authorized quiet zones.
W10-10	NO SIGNAL sign	May be used at passive controlled crossings.
W10-11, 11a	Storage Space signs	Where the parallel highway is close to crossing, particularly with limited storage space between the highway intersection and tracks.
W13-1	Advisory Speed plate	<ul style="list-style-type: none"> ➤ May be used with any advance warning sign where appropriate, e.g. advance warning, humped crossing, rough crossing, super-elevated track or other condition where a speed lower than the posted speed limit is advised.
I-12	Light Rail Station sign	Used to direct road users to a light rail station or boarding location.
I-13, 13a	Emergency Notification sign	Post at all crossings to provide for emergency notification.
	Dynamic Envelope Delineation, pavement markings	Where there is queuing or limited storage space for highway vehicles at a nearby highway intersection..
	Signs on both sides of highway	<ul style="list-style-type: none"> ➤ For extra emphasis ➤ Multi lane ➤ One-way roads ➤ Curved approaches
	Increased retroreflectivity on highway signs	<ul style="list-style-type: none"> ➤ Nighttime train operations.
	Roadway delineators, post-mounted on shoulders	<ul style="list-style-type: none"> ➤ Frequent inclement weather ➤ Crossing narrower than approach pavement ➤ Isolated crossings ➤ May be used as an alternative to illumination
	Flashing lights on signs and lighted signs	<ul style="list-style-type: none"> ➤ Presence of competing stimuli, “visual clutter” ➤ Restricted sight distance to the crossing ➤ High speed highway traffic approach ➤ Isolated crossing ➤ Heavy volume or queued traffic in advance of the crossing
	Overhead signs	<ul style="list-style-type: none"> ➤ Multi-lane approach ➤ High speed highway approach ➤ If a sign cannot be placed on the roadside ➤ May be used as an alternative to the double signs
	Crossing illumination:	<ul style="list-style-type: none"> ➤ Nighttime train operations ➤ Crossings are blocked for long periods ➤ Train speeds are low ➤ Nighttime collision experience ➤ Curved approach (vertical and horizontal curves) ➤ Frequent occurrence of fog or smoke.

	Stop and flag	<ul style="list-style-type: none"> ➤ Railroad option, but may be considered by traffic engineer. ➤ Combination of low train frequency, short trains, high-volume highway traffic, multilane highway
TABLE 5B - NOT CURRENTLY PROPOSED IN THE MUTCD - <i>EXPERIMENTAL DEVICES</i>		
	SECOND TRAIN and other supplemental signs	<ul style="list-style-type: none"> ➤ Multiple tracks ➤ Collision experience ➤ Pedestrian presence
	Buckeye CROSSBUCK	Among a number of special signs under current research.

HIGHWAY-RAIL GRADE CROSSING (CROSSBUCK) SIGNS

The MUTCD states, “The Highway-Rail Grade Crossing (R15-1) sign, commonly identified as the Crossbuck Sign, shall be retroreflectorized white with the words RAILROAD CROSSING in black lettering. As a minimum, one Crossbuck sign shall be used on each highway approach to every highway-rail grade crossing, alone or in combination with other traffic control devices. If automatic gates are not present and if there are two or more tracks at the highway-rail grade crossing, the number of tracks shall be indicated on a supplemental Number of Tracks (R15-2) sign of inverted T shape mounted below the Crossbuck sign in the manner and at the height indicated in the MUTCD.”

STOP and YIELD SIGNS

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) (Public Law 102-240; 105 Stat 1914; December 18, 1991) required that the FHWA revise the MUTCD to enable State or local governments to install STOP or YIELD signs at any passive highway-rail grade crossing where two or more trains operated daily. In response, the FHWA published a final rule in the Federal Register (57 FR 53029), which incorporated the new standards into the MUTCD. This final rule, published in March 1992, was effective immediately.

The FHWA and the FRA published a memorandum containing guidelines for when the use of STOP or YIELD signs is appropriate. According to the jointly-developed document, “it is recommended that the following considerations be met in every case where a STOP sign is installed:”⁹

1. Local and/or State police and judicial officials commit to a program of enforcement no less vigorous than would apply at a highway intersection equipped with STOP signs.
2. Installation of a STOP sign would not occasion a more dangerous situation (taking into consideration both the likelihood and severity of highway-rail collisions and other highway traffic risks) than would exist with a YIELD sign.

According to this memorandum, any of the following conditions indicate that the use of a STOP sign

⁹ U.S. Department of Transportation; Federal Highway Administration; Federal Railroad Administration. 1993. Recommended Guidance for Stop and Yield Sign at Highway-rail Grade Crossings. Washington, DC. 3 p. [Attachment 2 to a July 8, 1993 memorandum from the Associate Administrator for Safety and Systems Applications, FHWA, and the Associate Administrator for Safety, FRA, to the FHWA Regional Administrators and the FRA Regional Directors of Railroad Safety.]

might reduce risk at a crossing:

1. Maximum train speeds equal, or exceed, 48 km/h (30 mph).
2. Highway traffic mix includes buses, hazardous materials carriers and/or large (trash or earth moving) equipment.
3. Train movements are 10 or more per day, five or more days per week.
4. The rail line is used by passenger trains.
5. The rail line is regularly used to transport a significant quantity of hazardous materials.
6. The highway crosses two or more tracks, particularly where both tracks are main tracks or one track is a passing siding that is frequently used.
7. The angle of approach to the crossing is skewed.
8. The line of sight from an approaching highway vehicle to an approaching train is restricted such that approaching traffic is required to substantially reduce speed.

The memorandum also states, however, that the above conditions should be weighed against the possible existence of the following factors:

1. The highway is other than secondary in character. Recommended maximum of 400 ADT in rural areas, and 1,500 ADT in urban areas.
2. The roadway is a steep ascending grade to or through the crossing, sight distance in both directions is unrestricted in relation to maximum closing speed, and heavy vehicles use the crossing.

A footnote in this joint document also states that “a crossing where there is insufficient time for any vehicle, proceeding from a complete stop, to safely traverse the crossing within the time allowed by maximum train speed, is an inherently unsafe crossing that should be closed.”

ACTIVE DEVICES

An active highway-rail grade crossing is described as follows:

All highway-rail grade crossings equipped with warning and/or traffic control devices that gives warning of the approach or presence of a train.

Due to the variables which should be considered, an engineering and traffic investigation is required to determine the specific application of active devices at any given highway-rail grade crossing. Guidance is provided in the following sections for the application of the many active traffic control system devices available for grade crossing design, in addition to various median treatments that can supplement these devices. The following is a list of active devices that can be considered for use at a highway-rail grade crossing. The first four commonly found at many grade crossings are designated as “standard devices.”

STANDARD ACTIVE DEVICES

Flashing-Light Signal

A standard flashing-light signal consists of two red lights in a horizontal line flashing alternately at approaching highway traffic. At a crossing with highway traffic approaching in both directions, flashing-lights are installed facing oncoming traffic in a back-to-back configuration in accordance with the MUTCD. The support used for the lights should also include a standard crossbuck sign and, where there is more than one track, an auxiliary “multiple tracks” R15-2 sign. Back lights may be eliminated with one-way highway traffic, based on engineering judgment. An audible control device may be included.

Cantilever Flashing-Light Signal

This device supplements the standard flashing-light signal. Cantilever flashing-lights consist of an additional one or two sets of lights mounted over the roadway on a cantilever arm and directed at approaching highway traffic. Cantilevered lights provide better visibility to approaching highway traffic, particularly on multi-lane approaches. This device is also useful on high-speed two-lane highways, where there is a high percentage of trucks, or where obstacles by the side of the highway could obstruct visibility of standard mast mounted flashing-lights. An example is where the terrain or topography of the approaching highway is such that the sight of a roadside mounted signal light could not be readily seen by an approaching driver due to vertical or horizontal curves.

Cantilever flashing-light signals may be mounted back-to-back and should also have an additional crossbuck added to the overhead structure, based on site conditions and engineering judgment.

Automatic Gate

The automatic gate provides supplemental visual display when used with both road side mounted flashing-lights and cantilever flashing-light signals. The device consists of a drive unit and a gate arm. The drive mechanism can be mounted on flashing-light posts or cantilever pole supports, or on a stand-alone support. The gate arm is fully reflectorized on both sides with 45 degree diagonal red and white stripes and has at least three lights; the tip light is continuously lit and the others alternately flash when the gate is activated and lowered. When lowered, the gate should extend across approaching highway traffic lanes. Special consideration should be given to clearances for movement of the counter weight arm portion of the gate drive unit in a median and adjacent to sidewalk locations with pedestrians, particularly with the requirements of the Americans with Disabilities Act (ADA) of 1990.

Additional Flashing-Light Signals

Additional approaches to active highway-rail grade crossings require additional flashing-light signals be directed at the approaching traffic. These lights can be mounted on existing flashing-light masts, extension arms, additional traffic signal masts, cantilever supports, in medians or other locations on the left side of the roadway.

SUPPLEMENTAL ACTIVE DEVICES

Active Advance Warning Signs with Flashers

A train activated advance warning sign (utilizing the W-10 sign) should be considered at locations where sight distance is restricted on the approach to a crossing, and the flashing-light signals cannot be seen until an approaching driver has passed the decision point (the distance to the track from which a safe stop can be made).¹⁰ Two yellow lights can be placed on the sign to warn drivers in advance of a crossing

¹⁰ *Manual on Uniform Traffic Control Devices For Streets and Highways* - 2000 Edition. FHWA. Sections 2C.26 and 4K.01. Official website is <http://mutcd.fhwa.dot.gov> or 202-289-0222

where the control devices are activated. The continuously flashing yellow “caution” lights can influence driver speed and/or provide warning for stopped vehicles ahead. An Advisory Speed Plate sign indicating the safe approach speed also should be posted with the sign.

If the advance flashers are connected to the railroad control circuitry, and only flash upon the approach of a train, they should be activated prior to the control devices at the crossing so that a driver would not pass a dark flasher and then encounter an activated flashing-light at the crossing. (Track circuits may need to be revised to handle this.) A few States use a supplementary message such as TRAIN WHEN FLASHING. In order to allow the traffic queue at the crossing time to dissipate safely, the advance flashers should continue to operate for a period of time after the active control devices at the crossing deactivate, as determined by an engineering study.

If such an advance device fails, the driver would not be alerted to the activated crossing controls. If there is concern for such failure, some agencies use a passive, RAILROAD SIGNAL AHEAD sign to provide a full time warning message. The location of this supplemental advance warning sign is dependant on vehicle speed and geometric conditions of the roadway.

Active Turn Restriction Signs

An active turn restriction sign (blank-out sign with internal illumination) displaying “No Right Turn” or “No Left Turn” (or appropriate international symbol) should be used in the following instances; on a parallel street within 15 m (50 ft) of the tracks where a turning vehicle from that parallel street could proceed around lowered gates; at a signalized highway intersection, where traffic signals at a nearby highway intersection are interconnected and preempted by the approach of the train, and all existing turn movements toward the grade crossing should be prohibited. These signs shall be visible only when the restriction is in effect.

MEDIAN SEPARATION

Despite the dangers of crossing in front of oncoming trains, drivers continue to risk lives and property by driving around crossing gates. At many crossings a driver is able to cross the center line pavement marking and drive around a gate with little difficulty. The numbers of crossing gate violations can be reduced by restricting driver access to the opposing lanes. Highway authorities have implemented various median separation devices, which have shown a significant reduction in the number of vehicle violations at crossing gates.

There are limitations common to the use of any form of traffic separation at highway-rail grade crossings. These include restricting access to intersecting streets, alleys and driveways within the limits of the median and possible adverse safety effects. The median should be designed to allow vehicles to make left turns or U-turns through the median where appropriate, based on engineering judgment and evaluation.

BARRIER WALLS SYSTEMS

Concrete barrier walls and guardrails generally prevent drivers from crossing into opposing lanes throughout the length of the installation. In this sense they are the most effective deterrent to crossing gate violations. But, the road must be wide enough to accept the width of the barrier and the appropriate end treatment.¹¹ Sight restrictions for vehicles with low driver eye heights and any special need for emergency

¹¹ *Roadside Design Guide*. American Association of State Highway and Transportation Officials (AASHTO). Washington D.C.; 1996, www.aashto.org, 202-624-5801

vehicles to make a U-turn maneuver should be considered (but not for the purpose of circumventing the traffic control devices at the crossing). Installation lengths can be more effective if they extend beyond a minimum length of 46 m (150 ft).

WIDE RAISED MEDIANS

Curbed medians generally range in width from 1.2 to more than 30 m (4 - 100 ft). While not presenting a true barrier, wide medians can be nearly as effective since a driver would have significant difficulty attempting to drive across to the opposing lanes. The impediment becomes more formidable as the width of the median increases. A wide median, if attractively landscaped, is often the most aesthetically pleasing separation method.

Drawbacks to implementing wide raised medians include availability of sufficient right-of-way, and maintenance of surface and/or landscape. Additions such as trees, flowers and other vegetation higher than .9 m (3 ft) above the roadway can restrict the drivers' view of approaching trains. Maintenance can be expensive depending on the treatment of the median. Limitation of access can cause property owner complaints, particularly for businesses. Non-mountable curbs can increase total crash rate and severity of accidents when struck by higher speed vehicles (>64 km/h [40 mph]).¹²

NON-MOUNTABLE CURB ISLANDS

Non-mountable curb islands are typically six to nine inches in height and at least .6m (2 ft) wide, and may have reboundable, reflectorized vertical markers. Drivers have significant difficulty attempting to violate these types of islands because the six to nine inch heights cannot be easily mounted and crossed.

There are some disadvantages to be considered. The road must be wide enough to accommodate a two foot median. The increased crash potential should be evaluated. AASHTO recommends special attention be given to high visibility if such a narrow device is used in higher speed (>64 km/h [40 mph]) environments.¹³ Care should be taken to assure that an errant vehicle cannot bottom-out and protrude into the oncoming traffic lane. Sight restrictions for low driver eye heights should be considered if vertical markers are installed. Access requirements should be fully evaluated, particularly allowing emergency vehicles to cross opposing lanes (but not for the purpose of circumventing the traffic control devices at the crossing). Paint and reflective beads should be applied to the curb for night visibility.

MOUNTABLE RAISED CURB SYSTEMS

Mountable raised curb systems with reboundable vertical markers present drivers with a visual impediment to crossing to the opposing traffic lane. The curbs are no more than six inches in height, less

¹² Ibid.

¹³ *A Policy on Geometric Design of Highways and Streets*. American Association of State Highway Transportation Officials (AASHTO). 2001 Edition., available at www.ite.org, or 202-289-0222 or www.aashto.org, 202-624-5801

than twelve inches in width, and built with a rounded design to create minimal deflection upon impact. When used together, the mountable raised median and vertical delineators discourage passage. These systems are designed to allow emergency vehicles to cross-opposing lanes (but not for the purpose of circumventing the traffic control devices at the crossing). Usually such a system can be placed on existing roads without the need to widen them.

Because mountable curbs are made to allow emergency vehicles to cross, and are designed to deflect errant vehicles, they also are the easiest of all the barriers and separators to violate. Large, formidable vertical markers will inhibit most drivers. Care should be taken to assure that the system maintains its stability on the roadway with design traffic conditions, and that retro-reflective devices or glass beads on the top and sides of the curb are maintained for night visibility. Curb colors should be consistent with location and direction of traffic adjacent to the device.

OTHER BARRIER DEVICES

FOUR-QUADRANT TRAFFIC GATE SYSTEMS

Four-quadrant gate systems consist of a series of automatic flashing-light signals and gates where the gates extend across both the approach and departure side of roadway lanes. Unlike two-quadrant gate systems, four-quadrant gates provide additional visual constraint and inhibit nearly all traffic movements over the crossing after the gates have been lowered. At this time, only a small number of four-quadrant gate systems have been installed in the U.S., and incorporate different types of designs to prevent vehicles from being trapped between the gates.

VEHICLE ARRESTING BARRIER SYSTEM - BARRIER GATE

A moveable barrier system is designed to prevent the intrusion of vehicles onto the railroad tracks at highway-rail grade crossings. The barrier devices should at least meet the evaluation criteria for a NCHRP Report 350 (Test Level 2) attenuator;¹⁴ stopping an empty: 4500-pound pickup truck traveling at 70 km/h (43 mph). However, it could injure occupants of small vehicles during higher speed impacts, and may not be effective for heavy vehicles at lower speeds.

Two types of barrier devices have been tested and used in the U.S.; vehicle arresting barriers and safety barrier gates.

The vehicle arresting barrier (VAB) is raised and lowered by a tower lifting mechanism. The VAB in the down position consists of a flexible netting across the highway approaches that is attached to an energy absorption system. When the netting is struck, the energy absorption system dissipates the vehicle's kinetic energy and allows it to come to a gradual stop. This device was tested at three locations in the high-speed rail corridor between Chicago, IL and St. Louis, MO.

The safety barrier gate is a movable gate designed to close a roadway temporarily at a highway-rail crossing. A housing contains electro-mechanical components that lower and raise the gate arm. The gate arm consists of three steel cables, the top and bottom of which are enclosed aluminum tubes. When the gate is in the down position the end of the gate fits into a locking assembly that is bolted to a concrete foundation. This device has been tested to safely stop a pickup truck traveling at 72 km/h

¹⁴ National Cooperative Highway Research Program NCHRP Report 350. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. Transportation Research Board. National Research Council. Washington, DC: 1993, contact TRB at www.trb.org.

(45 mph) and has been installed in Madison, WI and Santa Clara County, CA.

A barrier gate could also be applied in those situations requiring a positive barrier e.g., in a down position, closing off road traffic and opening only on demand.

TRAIN DETECTION SYSTEMS

WARNING TIME AND SYSTEM CREDIBILITY

Reasonable and consistent warning times re-enforce system credibility. Unreasonable or inconsistent warning times may encourage undesirable driver behavior. Research has shown when warning times exceed 40-50 seconds, drivers will accept shorter clearance times at flashing lights, and a significant number will attempt to drive around gates.¹⁵ Although mandated maximum warning times do not yet exist, efforts should be made to ensure traffic interruptions are reasonable and consistent without compromising the intended safety function of an active control device system's design. Excessive warning times are generally associated with a permanent reduction in the class of track and/or train speeds without a concomitant change in the track circuitry and without constant warning time equipment. When not using constant warning train detection systems, track approach circuits should be adjusted accordingly when train speeds are permanently reduced. Another frequent cause of excessive warning times at crossings without constant warning time equipment is variable speed trains, e.g., inter-city passenger trains or fast commuter trains interspersed with slower freight trains.

A major factor affecting system credibility is an unusual number of false activations at active crossings. Every effort should be made to minimize false activations through improvements in track circuitry, train detection equipment, and maintenance practices. A timely response to a system malfunction coupled with repairs made without undue delay can reduce credibility issues. Remote monitoring devices are an important tool.

Joint study and evaluation is needed between the highway agency and railroad to make a proper selection of the appropriate train detection system.

Train detection systems are designed to provide the minimum warning time for a crossing. In general, the MUTCD states that the system should provide for a minimum of 20 seconds warning time. When determining if the minimum 20 seconds warning time should be increased, the following factors should be considered:

- track clearance distances due to multiple tracks and/or angled crossings; (add one second for each 3 m [10 ft] of added crossing length in excess of 10.7 m [35 ft]);
- the crossing is located within close proximity of a highway intersection controlled by STOP signs where vehicles have a tendency of stopping on the crossing;
- the crossing is regularly used by long tractor-trailer vehicles;
- the crossing is regularly used by vehicles required to make mandatory stops before proceeding over the crossing (e.g. school buses and hazardous materials vehicles);
- the crossing's active traffic control devices are interconnected with other highway traffic signal systems;

¹⁵ *Warning Time Requirements at Railroad-Highway Grade Crossings with Active Traffic Control*. Report No. FHWA SA-91-007, Federal Highway Administration. Washington, DC: February 1991, www.fhwa.dot.gov.

- provide at least 5 seconds between the time the approach lane gates to the crossing are fully lowered and when the train reaches the crossing, per 49 CFR Part 234;
- the crossing is regularly used by pedestrians and non-motorized components;
- where the crossing and approaches are not level and ;
- where additional warning time is needed to accommodate a four-quadrant gate system.

INTERFERENCE / INTEGRITY OF ACTIVE TRAFFIC CONTROL DEVICE SYSTEMS

Interference with normal functioning of an active control device system diminishes the driver's perception of the integrity of the system. Interference can result from, but is not limited to, trains, locomotives or other railroad equipment standing within the system's approach circuit, and testing or performing work on the control device systems or on track and other railroad systems or structures. The integrity of the control device system may be adversely affected if proper measures are not taken to provide for safety of highway traffic when such work is underway. It is important that Railroad employees are familiar with Federal regulations and railroad procedures which detail measures to be taken prior to commencing activities, which might interfere with track circuitry.

TYPE OF DETECTION SYSTEM

DC, AC-DC or AFO Grade Crossing Island and Approach Circuits:

These basic train detection circuits use a battery or transmitter at one end of a section of track and a relay, receiver or diode at the other end. A train on the section of the affected track will shunt the circuit and de-energize the relay. This type of system will continue to operate until the train leaves the circuit.

Motion Sensitive Devices (MS)

A type of train detection (control) system for automatic traffic control devices that has the capability of detecting the presence and movement of a train within the approach circuit of a crossing. MS devices will activate the traffic control devices at the crossing for all trains located within the approach circuit that are moving toward the crossing, regardless of train speed. If a train stops within the approach circuit before reaching the crossing, the traffic control devices will deactivate until the train resumes motion toward the crossing, but will remain deactivated if the train retreats beyond the detection circuit.

Constant Warning Time (CWT) Systems

A constant warning time system has the capability of sensing a train as it approaches a crossing, measuring its speed and distance from the crossing, and activating the traffic control devices to provide the desired warning time. Traffic control systems equipped with CWT provide relatively uniform warning times where train speeds vary and trains do not accelerate or decelerate within the approach circuits once the devices have activated. Trains may perform low speed switching operations beyond 213 m (700 ft) from a crossing without causing the crossing devices to unnecessarily activate. This reduces or eliminates excess gate operation that in turn, causes unnecessary delays to highway traffic. Like motion sensitive systems, if a train stops within the approach circuit before reaching the crossing the traffic control devices will deactivate.

RAILROAD TRAIN DETECTION TIME AND APPROACH LENGTH CALCULATIONS

It should be noted that even when "constant warning devices" are used, the calculated arrival time of the train at the crossing is based on the instantaneous speed of the train as it enters the crossing circuit. Once the calculation is made, changes in train speed will change train arrival time at the crossing and correspondingly reduce (or increase) the elapsed warning time at the crossing. This factor must be considered at a crossing interconnected to a nearby highway traffic signal utilizing either a simultaneous or advance preemption sequence.

Design information about railroad interconnection circuits and approach length calculations can be found in the American Railway Engineering and Maintenance-of-Way Association (AREMA) Signal Manual¹⁶, Manual Part 3.1.10, *Recommended Functional/Operating Guidelines for Interconnection Between Highway Traffic Signals and Highway - Rail Grade Crossing Warning Systems*; and Manual Part 3.3.10, *Recommended Instructions for Determining Warning Time and Calculating Minimum Approach Distance for Highway-Rail Grade Crossing Warning Systems*.

PREEMPTION/INTERCONNECTION:

WHEN TO INTERCONNECT

The guidance in the MUTCD states: “When a highway-rail grade is equipped with a flashing-light signal system and is located within 60 m (200 ft) of an intersection or mid-block location controlled by a traffic control signal, the traffic control signal should be provided with preemption in accordance with Section 4D.13.” Recent studies indicate that when designing for the installation of a new traffic control signal substantially beyond 60 m (200 ft) (possibly 152-305m [500-1000 ft]) of a highway-rail grade crossing, an estimate of the expected queue length should be performed. For estimation purposes, a 95% probability level should be used. If the resulting expected queue length is equal to or greater than the available storage distance, consideration should be given to interconnecting the traffic control signal with the active control system of the railroad crossing and providing a preemption sequence. Guidance on estimating queue length is available in the article, “Design Guidelines for Railroad Preemption at Signalized Intersections,” *ITE Journal*, February 1997. Guidance on the design of preemption operation is available in *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices*, #RP-025A, Institute of Transportation Engineers, 1997 www.ite.org or 202-289-0222; and the *Implementation Report of the USDOT Grade Crossing Safety Task Force, June 1, 1997, U.S. Department of Transportation*, www.fhwa.dot.gov. The *Implementation Report* is an excellent source of definitions.

FACTORS TO CONSIDER

Joint Agency Coordination

Close coordination between the highway agency and the railroad company is required when interconnecting a traffic signal with active railroad traffic control devices. In order to properly design the highway-rail preemption system, both the railroad company and the highway agency should understand how each system operates. An engineering study should be conducted at each interconnected location to determine the minimum preemption warning time necessary to adequately clear traffic from the crossing in the event of an approaching train. Factors that need to be considered when calculating this time are equipment response and programmed delay times, minimum traffic signal green times, traffic signal vehicular and pedestrian clearances, queue clearance times and train/vehicle separation time.

Extended Advance Warning Times

Whenever it becomes necessary at gated crossings to provide design advance warning times in excess of 45 seconds, whether for traffic signal preemption or other purposes, consideration should be given to including supplemental median treatments to discourage drivers from attempting to circumvent the gates.

Second Train Circuitry at Multiple Track Crossings

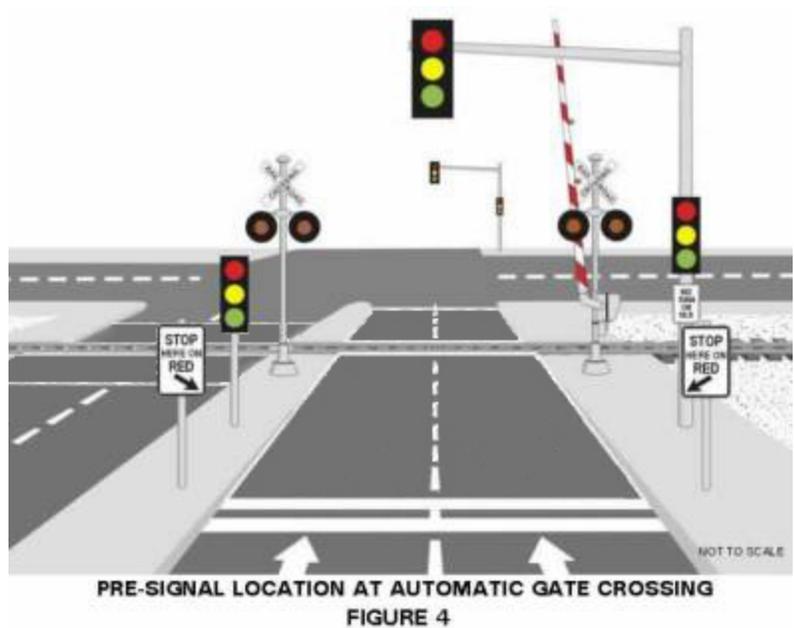
At multiple track crossings, “second train” circuitry can be considered as part of the control network.

16 American Railway Engineering and Maintenance-of-Way Association (AREMA) Signal Manual, Manual Part 3.1.10 is available at the following URL: <http://www.arema.org/pubs/pubs.htm>

This circuitry is intended to detect a second train approaching the crossing, but outside the normal warning time approach circuit. For instance, the normal approach circuit may provide 25 seconds warning but the second-train circuit may look an additional 10 seconds. If a train activates a train activates the traffic control devices AND a second train is detected within the 35-second circuit, the gates will be held down for the second train and the traffic signals remain preempted. (Also see Traffic Signal Controller Re-Service Considerations in the Preemption/Interconnection Appendix.)

Diagonal Railroad Crossing Both Highway Approaches to the Intersection

Where the railroads run diagonally to the direction of the highway, it is probable that the railroad may cross two highway approaches to an interconnected intersection. When this situation occurs, it is normally necessary to clear out traffic on both roadways prior to the arrival of the train, requiring approximately twice the preemption time computed for one approach. It is also normally required to have both railroad active traffic control device systems designed to operate concurrently. This is needed to prevent the interconnected traffic signals and railroad active control devices from falling out of coordination with each other which otherwise can occur under certain types of train movements or when one of the two crossings experiences a false signal activation prior to an actual train movement. When the railroad control devices activate, traffic leaving the intersection and approaching either crossing may queue back into the intersection and block traffic if there is not adequate storage for those vehicles between the crossing and the intersection. Traffic turning at the intersection toward the other crossing may also be unable to proceed due to stopped traffic.



When this occurs, utilization of advance preemption together with a hybrid design may help alleviate this problem. The hybrid design could consist of delaying the activation of the railroad devices facing vehicles leaving the intersection and approaching both crossings to help vehicles clear out of the intersection during the preemption sequence.

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Pre-Signals

Pre-signals control traffic approaching the highway-rail grade crossing toward the nearby highway intersection, and are operated as part of the highway intersection traffic signal system. Their displays are integrated into the railroad preemption program. A diagram of a pre-signal is shown as Figure 4.

Figure 4

This figure depicts the location of a pre-signal at an automatic gate crossing. In the foreground of the figure is the away-going side of a divided highway. The road crosses a railroad track and a little further, intersects another road. At the intersection of the two roads, there is a traffic-control signal. The crossing is equipped with lights and an automated crossarm. Prior to the railroad crossing is another traffic-control signal and a double white line where vehicles are to stop. The signal and lines are designed to prevent a line of vehicles forming at the highway-highway intersection that would back

up onto the railroad tracks. On either side of the road at the double white line is a sign that reads “STOP HERE ON RED,” with an arrow pointing to the double white line.

An engineering study should be made to evaluate the various elements involved in a pre-signal. These are summarized as follows.

Where the highway intersection is less than 15m (50 ft) from the highway-rail crossing (23m [75 ft] for a roadway regularly used by multi-unit vehicles), pre-signals should be considered. Where the clear storage distance is greater than 23 m (75 ft), pre-signals could be used, subject to an engineering study determining that the queue extends into the track area.

Without pre-signals at highway-rail grade crossings, drivers may focus on the downstream highway traffic signal indications rather than the flashing-light signals located at the grade crossing. This type of driver behavior is especially undesirable during the beginning of the preemption sequence when the downstream traffic signals are typically green (in order to clear queued vehicles off the tracks) and the flashing-light signals are activated.

Driver behavior at crossings equipped with pre-signals is modified because the driver stops at the railroad stop line even when a train is not approaching. By providing a consistent stopping location, with or without the presence of a train, the driver will not become confused as to a safe location to stop when a train is approaching.

Where geometric considerations in advance of the crossing complicate the installation of a pre-signal on a separate support in front of the railroad signal, the placement of railroad flashing-light signals and traffic signals on the same support should be considered to reduce visual clutter and to increase driver visibility of the pre-signals. A written agreement between the highway agency and railroad may be required.

The pre-signal phase sequencing should be progressively timed with an offset adequate to clear vehicles from the track area and downstream intersection. Vehicles that are required to make a mandatory stop (e.g., school buses, vehicles hauling hazardous materials, etc.) should be considered when determining the amount of time for the offset to ensure that they will not be forced to stop in the clear storage area.

For highway-rail grade crossings equipped with a pre-signal and clear storage distance less than 15 m (50 ft), (23 m [75 ft] for a roadway regularly used by multi-unit vehicles), a clear zone between the crossing and the downstream intersection may be diagonally striped to delineate the clear storage area.

The downstream traffic signal at the highway intersection controlling the same approach as the pre-signal should be equipped with programmable visibility indications or louvers. The downstream heads should only be visible from within the downstream intersection to the driver eye location of the first vehicle behind the pre-signal stop bar. Design of the visibility limited indications is quite complex and should consider a range of driver eye heights for the various vehicles expected on the roadway.

Long Distance between the Highway-Rail Crossing and the Highway Intersection

In cases where the crossing is located far from the highway intersection -- up to 305 m (1000 ft), the

necessary minimum preemption warning time may be very high and in turn may require very long approach circuits along the tracks in order to provide such a time. Long track circuits can become extremely complex and expensive to implement, especially if located in an area where there are several adjacent crossings with overlapping track circuits, switching spurs, railroad junctions or commuter rail stations which could affect train operating speeds within the detection circuit. In addition, excessive preemption times may have detrimental effects on traffic flows within the vicinity of the crossing and may cause other problems such as traffic backing up along a route parallel to the crossing and backing up through another adjacent interconnected intersection. These are just a few factors to consider with a long distance interconnection.

Queue Cutter Flashing-light Beacon

An alternative to interconnecting the two traffic control devices may be the use of an automated Queue Cutter Flashing-light Beacon upstream of the highway-rail grade crossing. They may be utilized in conjunction with DO NOT STOP ON TRACKS (R8-8) as stated in the MUTCD signs. Such beacons can be activated by an induction loop on the departure side of the highway-rail grade crossing that detects a growing queue between the crossing and the distant highway intersection. If the beacons are activated only when the traffic signals on that approach are not green, they can be more effective as opposed to flashing all the time.

These are some of the many factors that should be considered when interconnecting an active traffic control device at a highway-rail grade crossing to a nearby highway traffic signal. A separate Preemption/Interconnection appendix is included with this report to provide further explanation of this very complex subject. However, it is not the intent of this document to serve as a primer for this very complicated topic. It cannot be emphasized enough that design, construction, operation and maintenance of this type of system requires expert knowledge and full cooperation between highway and railroad authorities. Other special conditions are discussed in the following section.

Also See Appendix for additional information

OTHER SPECIAL CONDITIONS

POTENTIAL QUEUING ACROSS TRACKS

Where queuing across a highway-rail grade crossing is occasioned by a nearby highway intersection that is not equipped with a traffic signal, the traffic engineer has a number of options including:

- 1) Install a DO NOT STOP ON TRACKS sign;
- 2) Install an automated Queue Cutter Flashing-light Beacon (see prior discussion in “Factors to Consider”); and/or;
- 3) Install a traffic signal with railroad preemption at the highway/highway intersection.

Queues extending over the highway-rail grade crossing could be considered a possible need for the installation of a traffic signal at the nearby highway intersection. However, the third option needs to be considered very carefully considering the harmful effects of an otherwise unwarranted traffic signal.

TRAIN AND LIGHT RAIL TRANSIT (LRT) ACTIVATED HIGHWAY TRAFFIC SIGNALS

Urban city streets often pose a special case for the application of active grade crossing traffic control devices. Slow speed switching moves and mixed-use light rail transit (LRT) operations are often controlled by traffic signals. In such cases, traffic signal heads must be clearly visible to the train operator. Trains must stop short before entering these intersections. Train detection can be accomplished by the use

of island track circuits, key selector switches, inductive loops, train to way-side communications and other technologies.

Where LRT vehicles move within the street median or through the intersection of two or more city streets, and where train operating speeds and sight distances are consistent with safe stopping distances, the train may operate through these intersections controlled by traffic signal indications without stopping. In such cases, special transit signal aspects, which clearly indicate traffic signal controlled right-of-way, must govern train moves. Special transit indications may also provide information concerning track alignment to the transit operator. Automatic train stops and other train control devices may be used to enforce a train's compliance with the signal indication. Where special train aspects are present and safe stopping distance is assured, transit vehicles may utilize train to way-side communications, inductive loops, cantenary detector switches or other forms of detection to activate the traffic signals. Great care should be exercised in the location of special train indicators to avoid confusion to drivers approaching the intersection. Programmed heads and special aspects are helpful in this regard.

(SECOND) TRAIN COMING ACTIVE WARNING SIGN

Train detection systems can also be used to activate a "2nd Train Coming" supplemental warning sign. This sign is used on a limited basis, normally near commuter stations where multiple tracks and high volumes of pedestrian traffic are present. The sign will activate when a train is located within the crossing's approach circuits and a 2nd train approaches the crossing. It is also being evaluated at multiple track highway-rail grade crossings as a supplement to automatic gates. (Since this sign is not currently in the MUTCD, any jurisdictions wishing to use symbols to convey any part of this message, must request permission to experiment from the FHWA.)

PEDESTRIAN AND BICYCLIST CONSIDERATIONS

Non-motorist-crossing safety should be considered at all highway-rail grade crossings, particularly at or near commuter stations and at non-motorist facilities, such as bicycle/walking trails, pedestrian only facilities, and pedestrian malls.¹⁷

Passive and active devices may be used to supplement highway related active control devices to improve non-motorist safety at highway-rail crossings. Passive devices include fencing, swing gates, pedestrian barriers, pavement markings and texturing, refuge areas and fixed message signs. Active devices include flashers, audible active control devices, automated pedestrian gates, pedestrian signals, variable message signs and blank out signs.

These devices should be considered at crossings with high pedestrian traffic volumes, high train speeds or frequency, extremely wide crossings, complex highway-rail grade crossing geometry with complex right-of-way assignment, school zones, inadequate sight distance, and/or multiple tracks. All pedestrian facilities should be designed to minimize pedestrian crossing time and devices should be designed to avoid trapping pedestrians between sets of tracks.

Guidelines for the use of active and passive devices for Non-motorist Signals and Crossings are found in section 10D of Part 10 of the MUTCD.

¹⁷ *Traffic Control Devices Handbook*. Institute of Transportation Engineers. Washington, D.C.: 2001. Section 13.2.12, Railroad and Light Rail Transit Grad Crossings, www.ite.org or 202-289-0222.

ALTERNATIVES TO MAINTAINING THE CROSSING

CROSSING CLOSURE

Eliminating redundant and unneeded crossings should be a high priority. Barring highway or railroad system requirements that require crossing elimination, the decision to close or consolidate crossings requires balancing public necessity, convenience and safety. The crossing closure decision should be based on economics; comparing the cost of retaining the crossing (maintenance, accidents, and cost to improve the crossing to an acceptable level if it would remain, etc.) against the cost (if any) of providing alternate access and any adverse travel costs incurred by users having to cross at some other location. Because this can be a local political and emotional issue, the economics of the situation cannot be ignored. This subject is addressed in a 1994 joint FRA/FHWA publication entitled *Highway-Railroad Grade Crossings: A Guide To Crossing Consolidation and Closure*, and a March 1995 AASHTO publication, *Highway-Rail Crossing Elimination and Consolidation*.¹⁸

Whenever a crossing is closed, it is important to consider whether the diversion of highway traffic may be sufficient to change the type or level of traffic control needed at other crossings. The surrounding street system should be examined to assess the effects of diverted traffic. Often, coupling a closure with the installation of improved or upgraded traffic control devices at one or more adjacent crossings can be an effective means of mitigating local political resistance to the closure.

GRADE SEPARATION

The decision to grade separate a highway-rail crossing is primarily a matter of economics. Investment in a grade separation structure is long-term and impacts many users. Such decisions should be based on long term, fully allocated *life cycle* costs, including both highway and railroad user costs, rather than on initial construction costs. Such analysis should consider the following:

- eliminating train/vehicle collisions (including the resultant property damage and medical costs, and liability);
- savings in highway-rail grade crossing surface and crossing signal installation and maintenance costs;
- driver delay cost savings;
- costs associated with providing increased highway storage capacity (to accommodate traffic backed up by a train);
- fuel and pollution mitigation cost savings (from idling queued vehicles);
- effects of any “spillover” congestion on the rest of the roadway system;
- the benefits of improved emergency access;
- the potential for closing one or more additional adjacent crossings; and
- possible train derailment costs.

A recently released report, entitled “Grade Separations-When Do We Separate,¹⁹” provides a stepwise procedure for evaluating the grade separation decision. The report also contains a rough screening method based on train and roadway vehicular volumes. However, as pointed out in the report, the screening

¹⁸ See footnotes 20 and 21.

¹⁹ G. Rex Nicholson, Jr. & George L. Reed. *Grade Separations - When Do We Separate*. 1999 Highway-rail Grade Crossing Conference. Texas Transportation Institute. College Station Texas. 17-19 October 1999. www.tti.edu, or www.tamu.edu.

method should be used with caution and should be calibrated for values appropriate for the particular jurisdiction.

TRAFFIC SEPARATION STUDY APPROACH TO CROSSING CONSOLIDATION

Both the FRA ²⁰ and the AASHTO ²¹ have provided guidelines for crossing consolidation. State DOTs, road authorities and local governments may choose to develop their own criteria for closures based on local conditions. Whatever the case, a specific criteria or approach should be used, so as to avoid arbitrarily selecting crossings for closure. An example is provided by the North Carolina DOT.²²

To improve crossing safety and provide a comprehensive approach to crossing consolidation, the traffic separation study approach is a worthwhile option. As part of a comprehensive evaluation of traffic patterns and road usage for an entire municipality or region, traffic separation studies determine the need for improvements and/or elimination of public highway-rail grade crossings based on specific criteria. Traffic separation studies progress in three phases: preliminary planning, study and implementation.

Crossing information is collected at all public crossings in the municipality. Evaluation criteria include: collision history, current and projected vehicular and train traffic, crossing condition, school bus and emergency routes, types of traffic control devices, feasibility for improvements and economic impact of crossing closures. After discussions with the local road authority, railroad, State DOT, municipal staff and local officials these recommendations may be modified. Reaching a "consensus" is essential prior to scheduling presentations to governing bodies and citizens.

Recommendations may include: installation of flashing-lights and gates, enhanced devices such as four-quadrant gates and longer gate arms, installation of concrete or rubber crossings, median barrier installation, pavement markings, roadway approach modifications, crossing or roadway realignments, crossing closures and/or relocation of existing crossings to safer locations, connector roads, and feasibility studies to evaluate potential grade separation locations.

The most dynamic aspect of the public involvement process occurs at crossing safety workshops and public hearings. A goal of these forums is to exchange information and convey the community benefits of enhanced crossing safety, including the potential consequences to neighborhoods of train derailments containing hazardous materials resulting from crossing accidents. Equating rail crossings to highway interchanges, something the average citizen can relate to, greatly assist in reinforcing the need for eliminating low-volume and/or redundant crossings.

NEW CROSSINGS

Similar to crossing closure/consolidation, consideration of opening a new public highway-rail crossing should likewise consider public necessity, convenience, safety and economics. Generally, new grade crossings, particularly on main-line 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

²⁰ *Highway-Railroad Grade Crossings, a Guide to Crossing Consolidation and Closure.* Federal Railroad Administration/Federal Highway Administration. July 1994, www.fhwa.dot.gov or www.fra.dot.gov.

²¹ *Highway-Rail Crossing Elimination and Consolidation, A Public Safety Initiative.* National Conference of State Railway Officials. March 1995, www.fhwa.dot.gov or www.fra.dot.gov.

²² *Consolidating Railroad Crossings: on Track for Safety in North Carolina.* Rail Division, Engineering & Safety Branch. North Carolina Department Of Transportation. 2000, North Carolina DOT, available at: <http://www.dot.state.nc.us/>.

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.

GUIDANCE

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

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 one foot beyond the edge of the roadway shoulder measured perpendicular to the roadway center line, 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 the MUTCD;
 - B. An emergency phone number should be posted at the crossing. This posting should include the USDOT 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 the 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:
 - 1) 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.
 - 2) Strips of retroreflective white material not less than two 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.
 - 3) A strip of retroreflective white material, not less than two 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);

- 1) 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.
- 2) 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 the MUTCD (restricted visibility reduces safe approach speed to 16- 24 km/h [10-15 mph]);
 - e) Install a STOP (R1-1) sign, with advance warning sign (W3-1a) where warranted by the 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.
- 3) 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; and
 - 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.
- 4) 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; and
 - b) Temporarily restrict use of the roadway by the classes of vehicles.

4. **ACTIVE** - If active devices are selected, the following devices should be considered:

TABLE 6
GUIDELINES FOR ACTIVE DEVICES

Class of Track	Maximum Allowable Operating Speed	Maximum Allowable Operating Speed
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	For Freight Trains - Minimum Active Devices		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

* Refer to MUTCD 2000 Edition, Part 10, transit and LRT in medians of city streets.

** Except 35 mph (56 km/h) for transit and LRT.

Note: 1 mph = 1.61 km/h

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:

- 1) All crossings on the National Highway System, "U.S." marked routes or principal arterials not otherwise grade separated;
- 2) 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; and
 - 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;
- 3) Regularly scheduled passenger trains operate in close proximity to industrial facilities, eg. stone quarries, log mills, cement plants, steel mills, oil refineries, chemical plants and land fills;
- 4) 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;
- 5) 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;
- 6) Multiple main or running tracks through the crossing;
- 7) The expected accident frequency (EAF) for active devices without gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.1;
- 8) 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); or
- 9) 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:

- 1) 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 2nd train); [See Figure 1.]
- 2) An average of 20 or more trains per day;
- 3) Posted highway speed exceeds 64 km/h (40mph) in urban areas, or exceeds 88 km/h (55 mph) in rural areas;
- 4) Annual Average Daily Traffic (AADT) exceeds 2000 in urban areas, or 500 in rural areas;
- 5) Multiple lanes of traffic in the same direction of travel (usually this will include cantilevered signals);
- 6) 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;
- 7) The expected accident frequency (EAF) as calculated by the USDOT Accident Prediction formula, including 5-year accident history, exceeds 0.075;
- 8) 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;
- 9) 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; or
- 10) As otherwise recommended by an engineering study or diagnostic team.

C. Warning/Barrier Gate Systems should be considered as supplemental safety devices at:

- 1) Crossings with passenger trains;
- 2) Crossings with high-speed trains;
- 3) Crossings in quiet zones; or
- 4) As otherwise recommended by an engineering study or diagnostic team.

D. Enhancements for Pedestrian Treatments

- 1) Design to avoid stranding pedestrians between sets of tracks;
- 2) Add audible devices, based on an engineering study;
- 3) Consider swing gates carefully; the operation of the swing gate should be consistent with the requirements of Americans with Disability Act. The gate should be checked for pedestrian safety within the limits of its operation;
- 4) Provide for crossing control at pedestrian crossings where a station is located within the proximity of a crossing or within crossing approach track circuit for the highway-rail crossing;
- 5) Utilize a Train to Wayside Controller to reduce traffic delays in areas of stations; and
- 6) 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:
 - 1) 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 (1/4 mi) and the median trip length normally made over the subject crossing would not increase by more than .8 km (1/2 mi);
 - b. AADT less than 50 in rural areas, acceptable alternate access across the rail line exists within .8 km (1/2 mi) and the median trip length normally made over the subject crossing would not increase by more than 2.4 km (1-1/2 mi).
 - 2) FRA Class 4 or 5 track with active rail traffic:
 - a. AADT less than 1000 in urban areas, acceptable alternate access across the rail line exists within .4 km (1/4 mi) and the median trip length normally made over the subject crossing would not increase by more than 1.2 km (3/4 mi);
 - b. AADT less than 100 in rural areas, acceptable alternate access across the rail line exists within 1.61 km (1 mi) and the median trip length normally made over the subject crossing would not increase by more than 4.8 km (3 mi).
 - 3) 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 (1-1/2 mi) and the median trip length normally made over the subject crossing would not increase by more than 6.4 km (4 mi); and
- 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:
 - 1) Rail yards;
 - 2) Passing tracks primarily used for holding trains while waiting to meet or be passed by other trains;
 - 3) 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;
 - 4) Switching leads at the ends of classification yards;
 - 5) Where trains are required to “double” in or out of yards and terminals;
 - 6) 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; and
 - 7) 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:
 - 1) The highway is a part of the designated Interstate Highway System;
 - 2) The highway is otherwise designed to have full controlled access;

- 3) The posted highway speed equals or exceeds 113 km/h (70 mph);
 - 4) AADT exceeds 100,000 in urban areas or 50,000 in rural areas;
 - 5) Maximum authorized train speed exceeds 177 km/h (110 mph);
 - 6) An average of 150 or more trains per day or 300 Million Gross Tons (MGT) per year;
 - 7) An average of 75 or more passenger trains per day in urban areas or 30 or more passenger trains per day in rural areas;
 - 8) Crossing exposure (the product of the number of trains per day and AADT) exceeds 1,000,000 in urban areas or 250,000 in rural areas; or
 - 9) 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.
 - 10) The expected accident frequency (EAF) for active devices with gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.5;
 - 11) Vehicle delay exceeds 40 vehicle hours per day.²³
- 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:
- 1) The highway is a part of the designated National Highway System;
 - 2) The highway is otherwise designed to have partial controlled access;
 - 3) The posted highway speed exceeds 88 km/h (55 mph);
 - 4) AADT exceeds 50,000 in urban areas or 25,000 in rural areas;
 - 5) Maximum authorized train speed exceeds 161 km/h (100 mph);
 - 6) An average of 75 or more trains per day or 150 MGT per year;
 - 7) An average of 50 or more passenger trains per day in urban areas or 12 or more passenger trains per day in rural areas;
 - 8) 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
 - 9) 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;
 - 10) The expected accident frequency (EAF) for active devices with gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.2;
 - 11) Vehicle delay exceeding 30 vehicle hours per day;²⁴
 - 12) 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% 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 7 for LRT grade separation:

TABLE 7

²³ San Gabriel Valley Grade Crossings Study, Final Report. Prepared for San Gabriel Valley Council of Governments. Korve Engineering. January 1997, bogden@korve.com

²⁴ Ibid.

Trains Per Hour	Peak Hour Volume (vehicles per lane)	Source: <i>Light Rail Transit Grade Separation Guidelines. An Informational Report.</i> Institute of Transportation Engineers. Technical Committee 6A-42. March 1992
40	900	
30	1000	
20	1100	
10	1180	
5	1200	

7. **NEW CROSSINGS**

- A. Should only be permitted to cross existing railroad tracks at-grade when it can be demonstrated:
1. 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);
 2. 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
 3. There are no other viable alternatives.
- B. If a crossing is permitted, the following conditions should apply:
1. If it is a main track, the crossing will be equipped with active devices with gates;
 2. 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 DOT or other State agency vested with the authority to approve new crossings, and the operating railroad;
 3. 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;
 4. Whenever new public highway-rail crossings are permitted, they should fully comply with all applicable provisions of this proposed recommended practice; and
 5. Whenever a new highway-rail crossing is constructed, consideration should be given to closing one or more adjacent crossings.

TRAFFIC CONTROL DEVICE SELECTION PROCEDURE

Step 1 - **Minimum Highway-Rail Grade Crossing Criteria:** (see report for full description)

A. Gather preliminary crossing data:

1. 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); and
 - g. Availability and proximity of alternate routes and/or crossings.
2. 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; and
 - e. Crossing signal control circuitry.
3. Traffic Control Device:
 - a. Passive or active;
 - b. Advance;
 - c. At crossing; or
 - d. Supplemental.
4. 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:

1. If acceptable alternate route(s) is/are available; or
2. If an adjacent crossing is improved, can this crossing be closed? or
3. 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:
 - 1. Try to correct the sight distance limitation;
 - 2. 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;
 - 3. 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;
 - 4. 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:
 - 1. Economic analysis should consider fully allocated life-cycle costs;
 - 2. Consider highway classification and level of service;
 - 3. 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 is indicated, 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 is indicated, 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 is indicated, document the fact that the crossing was evaluated and determined to be adequate.

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GLOSSARY

Acceptable Alternate Access - For purposes of this guidance document, a roadway of at least comparable design, construction and utility as the roadway being closed, giving appropriate consideration to the additional traffic that would be diverted over it.

Active Crossing - All highway-rail grade crossings equipped with warning and/or traffic control devices that are activated by train detection.

CFR - Code of Federal Regulations

Clearance Time - The difference between vehicle crossing time and train arrival time.

Diagnostic Team - A group of knowledgeable representatives of the parties of interest in a highway-rail grade crossing or group of crossings.

Doubling Trains - When individual tracks in rail-yards are insufficient to hold an entire inbound or outbound train, it is necessary to “double” a train. For outbound trains, where the CFR requires an initial terminal brake test of the entire train, this requires assembling the entire train on one outbound track, usually the mainline, from several yard tracks. For inbound trains, when yarding the entire train on more than one yard track, this means leaving part of the train on the main line by either pulling through, then breaking the train, or initially pushing part of the train into a yard track, while holding the excess rail cars on a main track or lead, which are subsequently “yarded” on another track or tracks.

Passive Crossing - All highway-rail grade crossings having signs and pavement markings as traffic control devices that are not activated by trains, that identify and direct attention toward the location of a highway-rail grade crossing, and advise motorists, bicyclists, and pedestrians to take appropriate action.

Separation Time - The component of maximum preemption time during which the minimum track clearance distance is clear of vehicular traffic prior to the arrival of the train.

Train to Wayside Controller - Equipment sometimes employed by light rail transit systems to verify the identity of a light rail vehicle and perform numerous communication and signal functions. This is particularly effective on railroads with both heavy (freight) and LRT operation. As related to a passenger station near a highway-rail grade crossing, if the light rail vehicle is approaching the station to stop, such equipment reduces gate downtime by delaying activation of the gates at the crossing until the light rail vehicle is to depart the station rather than activating the gates as the light rail vehicle first approaches the station. (A through train would cause the gates to activate at the normal time).

Urban and Rural – “Urban and rural areas have fundamentally different characteristics with regard to density and types of land-use, density of street highway networks, nature of travel patterns, and the way in which these elements are related. Consequently, urban and rural functional systems are classified separately. Urban areas are considered those places within boundaries set by the responsible State and local officials having a population of 5,000 or more. Rural areas are those areas outside the boundaries of urban areas.” (Source AASHTO Green Book) In addition, urban areas are generally characterized by having higher density of access to adjacent land use, lower vehicle operating speeds and lower levels of service of traffic flow.

Warning Time - The amount of time provided between activation of a active traffic control device by a train and passage of the train to the crossing.

APPENDIX

PREEMPTION/INTERCONNECTION

The topic of highway traffic signal preemption and interconnection to active highway-rail grade crossings is very complex. It requires special traffic engineering evaluation, and close coordination between highway and railroad design and operation personnel. This appendix has been included to provide some guidance information on the subject, and provides detailed discussion on several elements. (Please refer to the main document for discussion on when to interconnect, agency coordination, accommodation of second train situations and references.)

PEDESTRIAN CLEARANCE PHASE

The MUTCD provides that the pedestrian clearance phase may be “abbreviated” during the railroad preemption of the traffic signals. Some agencies have elected to utilize the abbreviated interval, some eliminate entirely the pedestrian clearance phase during the preemption sequencing, while others provide full clearance intervals. Abbreviating the pedestrian “don’t walk” phase may expedite the intended vehicular cycle, however, it may not expedite pedestrian or driver behavior. Drivers may yield to pedestrians and thereby prevent vehicles behind them from clearing off the tracks. To minimize this potential, full pedestrian clearance may be provided, but consequently, additional minimum preemption warning time will be required. The preemption interconnect may consist of simultaneous preemption (traffic signals are preempted simultaneously with the activation of the railroad control devices), or advance preemption (traffic signals are preempted prior to the activation of the railroad control devices), or possibly a special design which could consist of two separate closed loop normally energized circuits. The first, pedestrian clearance call should occur a predetermined length of time to be defined by a traffic engineering study and continue until the train has departed the crossing. The purpose of the first call is to safely clear the pedestrian. The second, vehicle clearance call, programmed with a higher priority in the traffic signal controller than the first call, should occur a predetermined length of time to be determined in a traffic engineering study, but not less than 20 seconds prior to the arrival of a train, and continue until the train departs the crossing. The purpose of the second call is to clear motor vehicle queues, which may extend into the limits of the crossing. While one preemption interconnect circuit can be used to initially clear-out the pedestrian traffic and then a time delay used for the second vehicular clearance, a system with two separate circuits provides a more uniform timing if the train speed varies once preemption occurred. This is especially important if the train accelerates after the pedestrian clearance is initiated. A timing circuit may not provide adequate warning time.

If the pedestrian clearance phase is abbreviated (or eliminated), additional signing alerting pedestrians of a shortened pedestrian cycle should be considered.

TRAFFIC SIGNAL CONTROLLER RE-SERVICE CONSIDERATIONS

Traffic signal controller re-service is the ability of the traffic signal controller to be able to accept and respond to a second demand for preemption immediately after a first demand for preemption has been released, even if the programmed preemption routine/sequence is not complete. In other words, if a traffic signal controller receives an initial preempt activation and shortly thereafter it is deactivated, most traffic signal controllers will continue to time out the preemption sequence; if a second demand for preemption is placed during this period, the traffic signal controller must return to the track clearance green. At any point in the preemption sequence, even during the track clear green interval, the controller must return to the start of a full track clearance green interval with a second preemption demand. Until recently, most traffic signal controllers were unable to recognize a second preempt until the entire preemption sequence of the first activation timed out. If the second demand occurred during the initial preemption sequence, the traffic

signal controllers continued the same sequence as if that was still the initial demand for preemption. The traffic signal controller re-service capability must be able to accept and respond to any number of demands for preemption.

The point in which preemption is released from the railroad active control devices to the traffic signals is critical to the proper operation of re-service. In order for the traffic signal controller to recognize a second demand, the first demand must be released, therefore the railroad active control devices must release the preempt activation just as the crossing gates begin to rise, not when they reach a fully vertical position. Otherwise, especially at locations with short storage areas between the crossing and the highway intersection, traffic may creep under the rising gates and with a second train, a second track clear green interval will not be provided if the gates never reach a fully vertical position.

PROGRAMMING SECURITY

Security of programmed parameters is critical to the proper operation of the highway-rail preemption system. As an absolute minimum, control equipment cabinets should be locked and secure to prevent tampering and controllers should be password protected. In addition to preventing malicious tampering of control devices, security should be considered to prevent accidental changes in timing parameters, especially in the traffic signal controller where a programming mistake can easily be made due to the large quantity of parameters even when just viewing the data. Some traffic signal controller manufacturers have designed systems where the critical railroad preemption parameters can not be changed without both proper software and physically making a hardwire change the traffic signal cabinet. Without proper data changes, the traffic signals will remain in a flashing red operation until the data is corrected. In addition, these systems prevent a different type of controller or even controller software from operating the traffic signals. It is important to preserve the integrity of the system once it is tested and proven to operate properly. Another method of preserving the proper timing parameters is remote monitoring of the traffic signal controller. Routine uploads of traffic signal timings can be compared to a database to check for unapproved changes in any timing parameters.

SUPERVISED INTERCONNECT CIRCUITRY

The interconnection circuit between the highway traffic signal control cabinet and the railroad signal cabinet should be designed as a system. Frequently, the interconnect cable circuit is designed so that the preemption relay can be falsely de-energized, thereby causing a preempt call, without the railroad signals being activated. The traffic signals will then cycle through their clearance phase and remain at “stop” until the false preempt call is terminated. If a train approaches the crossing during the false preemption, the railroad signals will activate, but the traffic signals will not provide track clearance phases because they are still receiving the first false call. Even worse, a short between the wires in this type of circuit will virtually disable preemption and will only be recognizable once the railroad active control devices are activated with an approaching train. To address this potential problem supervised preemption circuits may be used. In its simplest form, the supervised circuit is formed by having two control relays in the traffic control cabinet each of which is energized by the railroad crossing relay. One relay, the Preemption Relay, is energized only when the railroad active control devices are off. The second relay, the Supervision Relay, is energized only when the railroad active control devices are operating. When circuited in this manner, only one control relay is energized at a time. If both relays are simultaneously energized or de-energized, the supervision logic determines that there is a problem and can implement action. This action may include initiating a clearance cycle and upon completion of the clearout, the traffic signals can go into an all-way flashing red instead of stop. The all-way flashing red will allow traffic to advance off the tracks instead of being held by the red signal. An engineering study may determine that the all-way flashing red is undesirable due to high highway traffic volumes compared to rail traffic. In all cases remote-monitoring devices that send alarm messages to the railroad and highway authority should be installed. Law

enforcement traffic control should be used until repairs can be performed. More information on supervised circuits can be found in an article, *Supervised Interconnection Circuits at Highway-Rail Grade Crossings*, by Mansel, Waight, and Sharkey, ITE Journal, March 1999, Institute of Transportation Engineers available at www.ite.org

ADVANCE PREEMPTION AND USE OF TIMERS

When advance preemption is used the traffic signal preemption occurs prior to the active control devices being activated. This allows preemption to begin behind the scene and the active control time of the railroad signals is not necessarily increased. Railroads frequently use two detection times in their system. The first detection time is designed to initiate traffic signal preemption. The second detection time is used to activate the active control devices. If the train is decelerating as it approaches the crossing, the time difference between initiation of preemption and activation of the active control devices will increase. It is imperative that the time difference does not increase to the point where the traffic signal clear out cycle ends (i.e. traffic signal turns red) before the active control devices turn on. To prevent re-queuing traffic on the tracks, a “not-to-exceed” timer should be installed to force the activation of the active control devices prior to the appropriate time in the clear out cycle. If the train accelerates toward the crossing the second detection time will activate the active control devices prior to expiration of the timing cycle. Another issue when designing advance preemption circuitry is multiple consecutive train movements can cause the traffic signals to remain in preemption due to a second approaching train, but the railroad active control devices deactivate after the first train just clears the crossing. In this case, the traffic signals will not provide a second track clearance indication since the first call is still present, therefore the railroad circuitry should be designed to prevent this from occurring. Also, when the traffic signals experience a loss of power or a malfunction which causes an all way red flash, the advance preemption time becomes ineffective in helping clear vehicles from the crossing and effectively, vehicles will have less time to clear the crossing. An additional interconnection circuit should be utilized between the railroad and the traffic signal controls, so that the railroad active control devices would activate at the same time as the advance preempt circuit would normally activate the traffic signals in the event of all-way-red flash or loss of power to the traffic signals.

If railroad gates are used, another method of minimizing the potential of the clearout cycle from ending while traffic is on the tracks is to continue the clearout cycle until the gates are in the lowered position. This requires an additional circuit between the railroad cabinet and the highway traffic control cabinet and special logic in the traffic signal control cabinet. The above mentioned techniques for the supervised circuit may be employed.

STANDBY POWER SOURCES

Railroad active control devices are normally off when no train is approaching; therefore, railroads install backup power systems to provide power to the signals during commercial power failures. This is different from traffic signals that generally are dark if the commercial power is off. When traffic signals are dark, motorists in most jurisdictions are expected to know that traffic signals are ahead, stop their vehicle at the stop bar, and proceed through the intersection as if the dark signal was a stop sign. Since dark traffic signals cannot display a clear out aspect to a motorist, backup power systems should be considered at interconnected locations. When considering power back up systems for traffic signals, it should be considered on a system wide basis rather than just at individual interconnected locations since other adjacent signalized intersections may just as well also stall traffic. The fail-safe mode of operation in the event of a traffic signal malfunction is an all way red flash, in which case power back up systems will have no effect. The use of remote monitoring and law enforcement traffic control can be used to minimize the requirements and cost of the backup power system.