

Railroad-Highway Grade Crossing Handbook - Revised Second Edition August 2007

Section 4: Identification of Alternatives (continued)

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I. Active Traffic Control Devices

Active traffic control devices are those that give advance notice of the approach of a train. They are activated by the passage of a train over a detection circuit in the track, except in those few situations where manual control or manual operation is used. Active traffic control devices are supplemented with the same signs and pavement markings used for passive control, except that STOP or YIELD signs shall not be used where active traffic control devices are installed. Active traffic control devices include flashing light signals (both mast-mounted and cantilevered), bells, automatic gates, active advance warning devices, and highway traffic signals. Also included in this section is a description of the various methods of train detection.

Driving tasks at crossings with active traffic control devices differ somewhat from those at crossings with passive devices. Passive devices indicate that a crossing is present and that a highway user must look for an approaching train and take appropriate action. At crossings with active traffic control devices, a motorist is told when a train is approaching. The motorist must take appropriate action when the devices are activated.

Crossing traffic control devices that are train activated normally incorporate some “fail-safe” design principles. The warning system is designed to give an indication of an approaching train whenever the system has failed.

Active traffic control devices have proven an effective method of improving safety and operations at highway-railroad grade crossings. Effectiveness is the percentage reduction in collisions due to a crossing improvement. Utilizing data contained in the U.S. DOT National Highway-Rail Crossing Inventory and the Railroad Accident/Incident Reporting System databases, effectiveness factors have been developed for active devices. The effectiveness factors are shown in Table 40 along with results obtained from a California study and a study by William J. Hedley covering 23 years of experience on the Wabash Railroad.

The effectiveness factors presented in Table 40 were developed from before-and-after collision crash experience of groups of crossings actually improved. The same effectiveness would not necessarily be experienced at any other crossing where the same improvements (changes) were made. It should be remembered that, in those studies, the crossings were selected for improvement by competent authorities as a precondition to performance of the work. Similar effectiveness could be anticipated under similar conditions.

Table 40. Effectiveness of Active Crossing Warning Devices

	Effectiveness Factors (Percent)		
Category	1980 U.S. DOT	1974 California	1952 Hedley

Passive to Flashing Lights	70	64	63
Passive to Automatic Gates	83	88	96
Flashing Lights to Automatic Gates	69	66	68

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

The U.S. DOT Technical Working Group guidance document provides guidelines for selecting active devices (see Chapter V).

1. Flashing Light Signals

Flashing light signals consist of two light units that flash alternately at a rate of 45 to 65 times per minute. Thus, like their predecessor, the wigwag, they simulate a watchman swinging a red lantern. Wigwags consist of a single red light unit that sways back and forth.

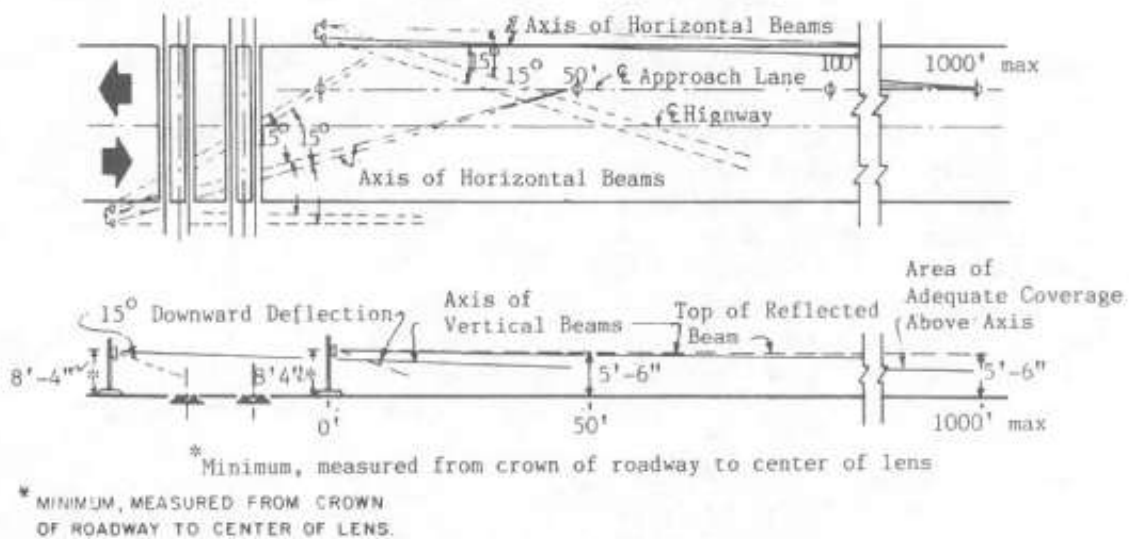
The main components of a flashing light unit are the hood, background, roundel, lamp, lampholder, reflector, and housing. The background is 20 or 24 inches in diameter and is painted a nonreflecting black to provide a contrast for the red light. The hood is also painted black.

Current standards call for the use of 12-inch diameter heads.

The roundel is red and comes in a variety of designs that direct the light toward the motorist. The “spreadlight” roundel distributes light through the entire angle, one-half the angle on each side of the beam axis. A deflecting roundel directs a portion of the light from the beam to one side of the axis in the direction indicated on the lens. A roundel having both spreadlight and deflecting features is designed so that the deflection is at a right angle to the spread. An example is the 3-degree horizontal deflection and 15-degree vertical spread. A roundel using a 20-degree spread and 32-degree downward deflection can be used on cantilevers. Back light units may use a 70-degree horizontal spread.

The lamp consists of a low-wattage bulb used to ensure operation on stand-by battery power should commercial power fail. The wattage most commonly used is 18 or 25 watts; however, some railroads use quartz iodide bulbs of 16 or 36 watts. The reflector, or mirror, is mounted behind the lamp and directs the light back through the roundel.

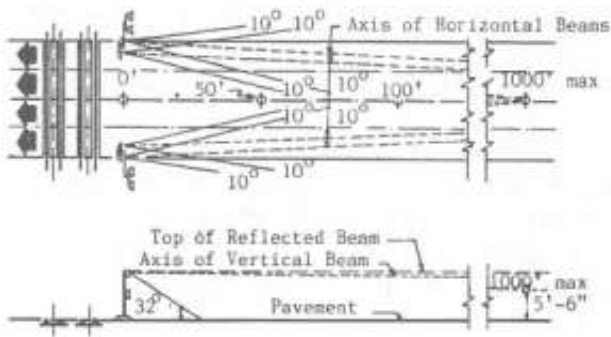
Figure 22. Typical Alignment Pattern for Flashing Light Signals with 30-15 Degree Roundel, Two-Lane, Two-Way Roadway



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

Proper alignment of the light is essential. The lamp must be precisely aligned to direct the narrow intense beam toward the approaching motorist. The flashing light unit on the right-hand side of the highway is usually aligned to cover a distance far from the crossing. The light units mounted on the back of the signals on the opposing approach and, thus, on the left, are usually aligned to cover the near approach to the crossing. Figures 22 and 23 show typical alignment patterns for a two-lane, two-way highway and for a multilane highway.

Figure 23. Typical Alignment Pattern for Flashing Light Signals with 20-32 Degree Roundel, Multilane Roadway



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

MUTCD provides that when indicating the approach or presence of a train, the flashing light signal shall display toward approaching highway traffic two red lights mounted in a horizontal line and flashing alternately. Flashing light signals shall be placed to the right of approaching highway traffic on all highway approaches to a highway-rail grade crossing. They shall be located laterally with respect to the highway in conformance with Figure 24, except where such location would adversely affect signal visibility. At highway-rail grade crossings with highway traffic in both directions, back-to-back pairs of lights shall be placed on each side of the tracks. On multilane one-way streets and divided highways, flashing light signals shall be placed on the approach side of the highway-rail

grade crossing on both sides of the roadway or shall be placed above the highway. A crossbuck is always used in conjunction with the flashing light signal and is usually mounted on the same post above the light units. Other supplementary signs may be mounted on the post, such as the “Do Not Stop on Tracks” sign (R8-8) and the “Number of Tracks” sign (R15-2). Flashing light signals are shown in Figures 25 and 26.

National warrants for the installation of flashing light signals have not been developed. Some states have established criteria based on exposure factors or priority indices. Other considerations include the following:

- Volume of vehicular traffic.
- Volume of railroad traffic.
- Speed of vehicular traffic.
- Speed of railroad traffic.
- Volume of pedestrian traffic.
- Collision record.
- Sight distance restrictions.

Specific criteria for the use of active warning devices such as flashing light assemblies are provided in the guidance document prepared by the U.S.DOT Technical Working Group (see Chapter V.)

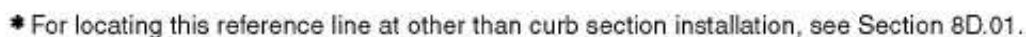
Post-mounted flashing light signals are normally located on the right side of the highway on all highway approaches to the crossing. Horizontal clearances for flashing light signals are discussed in the next section along with clearances for automatic gates.

2. Cantilevered Flashing Light Signals

Flashing light signals are generally post-mounted, but where improved visibility to approaching traffic is required, cantilevered flashing light signals are used. Cantilevered flashing lights may be appropriate when any of the following conditions exist:

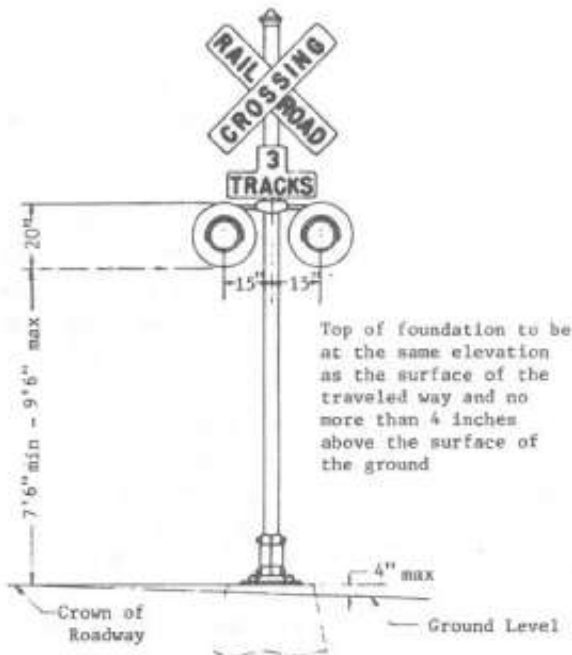
- Multilane highways (two or more lanes in one direction).
- Highways with paved shoulders or a parking lane that would require a post-mounted light to be more than 10 feet from the edge of the travel lane.
- Roadside foliage obstructing the view of post-mounted flashing light signals.
- A line of roadside obstacles such as utility poles (when minor lateral adjustment of the poles would not solve the problem).
- Distracting backgrounds such as an excessive number of neon signs (conversely, cantilevered flashing lights should not distract from nearby highway traffic signals).
- Horizontal or vertical curves at locations where the extension of flashing lights over the traffic lane will provide sufficient visibility for the required stopping sight distance.

Figure 24. Typical Clearances for Flashing Light Signals with Automatic Gates



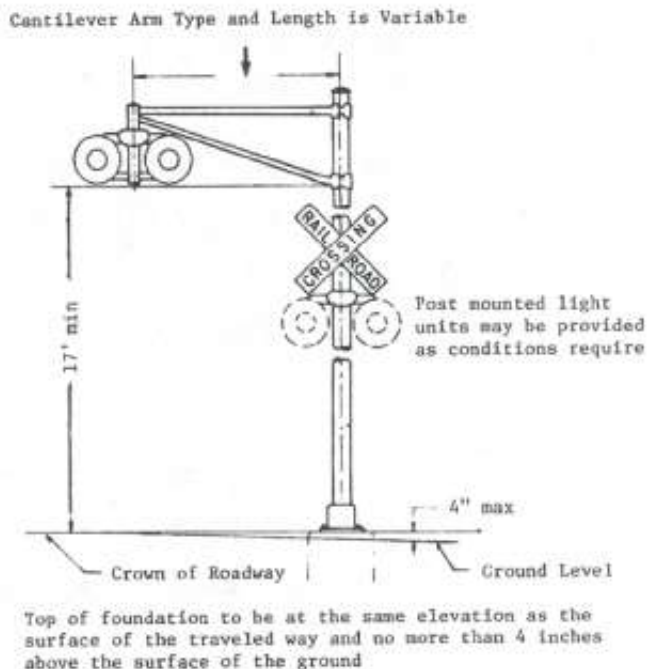
Source: Manual on Uniform Traffic Control Devices, 2003 Edition. Washington, DC: Federal Highway Administration, 2003.

Figure 25. Typical Flashing Light Signal— Post Mounted



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

Figure 26. Typical Flashing Light Signal— Cantilevered



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

Cantilevers are available with fixed, rotatable, or walkout supports. The primary disadvantage of the fixed support is that maintenance of the light unit is usually performed from equipment in the traffic

lane, thereby blocking highway traffic. Rotatable cantilevers can be turned to the side of the highway for maintenance but not for aligning the flashing lights.

Most current installations utilize walkout cantilevers. The inclusion of a ladder and access walkway allows for easier maintenance with less impact to highway traffic. Standard cantilevers for mounting flashing lights are made with arm lengths up to 40 feet. Where cantilever arm length in excess of 35 feet is required, a bridge structure is preferred.

3. Supplemental Flashing Light Signals

Additional pairs of light units may also be installed for side roads intersecting the approach highway near the crossing or for horizontal curves. Figure 27 shows the use of multiple pairs of lights to cover a horizontal curve to the left on the approach highway. A horizontal curve to the right may be covered by placing another roadside flashing light unit on the opposite side of the highway, as shown in Figure 28.

4. Light-Emitting Diode Flashing Light Signals

Light-emitting diode (LED) flashing light signal units may offer the following advantages over conventional incandescent lamps:

- Higher visibility at greater distances for in-line observations.
- Greater visibility on angles.
- Wider beam pattern and, therefore, easier beam alignment.
- Pure red signal with fast on-off transition, which improves conspicuity.
- Lower current consumption at nominal voltage, thereby suitable for solar-powered applications.
- Longer life expectancy.

Designers of LED systems should be aware of the voltage-current characteristics of the LED device they intend to use. The current versus voltage characteristic of an incandescent lamp is relatively linear over the normal operating range. At 5 volts, a 10-volt, 25-watt incandescent lamp draws approximately 1.8 amps. At 12 volts, it may draw 2.8 amps. Users should be aware that the current consumption of LED signals is dependent on the design of the LED array. Some LED flashing light units are resistive and, at 12 volts, may draw three times the current drawn at 10 volts. Other brands of LED flashing light units have power supplies designed to compensate for lower voltages. These lamps may draw more current when the voltage is less than 10 volts, which is a realistic concern during power outages. To avoid damaging control circuits, which may result in dark signals, designers of LED flashing light signal circuits should consider the maximum current drawn by LED units over the expected voltage range.

Figure 27. Use of Multiple Flashing Light Signals for Adequate Visibility Horizontal Curve to the Left

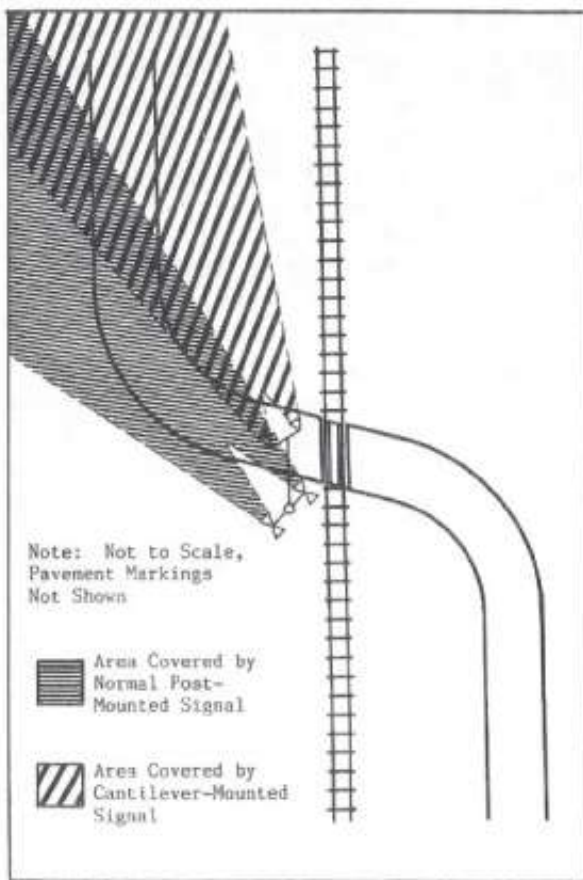
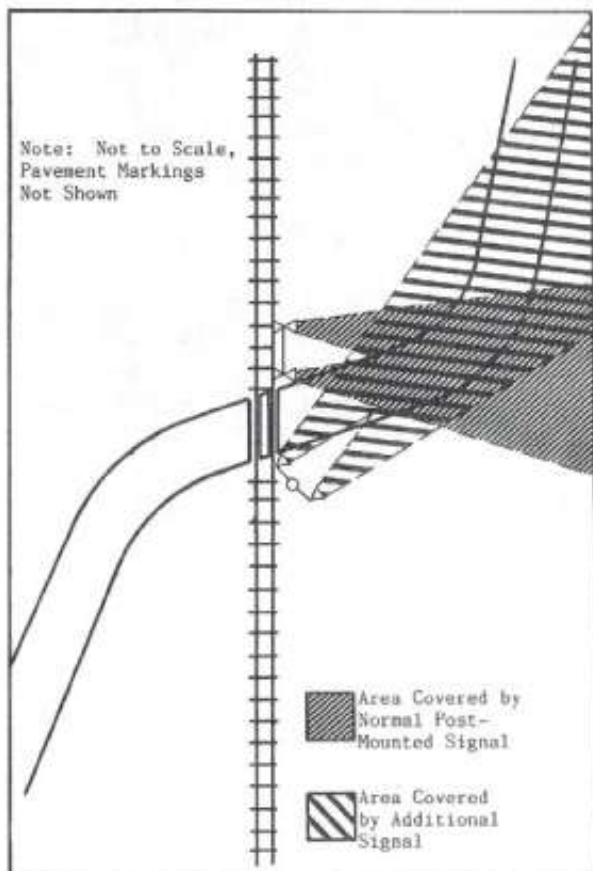


Figure 28. Use of Multiple Flashing Light Signals for Adequate Visibility Horizontal Curve to the Right



5. Automatic Gates

An automatic gate serves as a barrier across the highway when a train is approaching or occupying the crossing. The gate is reflectorized with 16-inch diagonal red and white stripes.⁹⁰ To enhance visibility during darkness, three red lights are placed on the gate arm. The light nearest to the tip burns steadily; the other two flash alternately. The gate is combined with a standard flashing light signal (see Figure 29 for a typical installation) that provides additional warning before the arm starts to descend, while the gate arm is across the highway, and until the gate arm ascends to clearance. The gate mechanism is either supported on the same post with the flashing light signal or separately mounted on a pedestal adjacent to the flashing light signal post.

In a normal sequence of operation, the flashing light signals and the lights on the gate arm in its normal upright position are activated immediately upon the detection or approach of a train. Industry standards require that the gate arm shall start its downward motion not less than 3 seconds after the signal lights start to operate; shall reach its horizontal position before the arrival of the train; and shall remain in that position as long as the train occupies the crossing. When the train clears the crossing, and no other train is approaching, the gate arm shall ascend to its upright position normally in not more than 12 seconds, following which the flashing lights and the lights on the gate arm shall cease operation. In the design of individual installations, consideration should be given to timing the operation of the gate arm to accommodate slow-moving trucks.

In determining the need for automatic gates, the following factors may be considered:

- Multiple mainline railroad tracks.
- Multiple tracks where a train on or near the crossing can obscure the movement of another train approaching the crossing.
- High-speed train operation combined with limited sight distance.
- A combination of high-speed and moderately high-volume highway and railroad traffic.
- Presence of school buses, transit buses, or farm vehicles in the traffic flow.
- Presence of trucks carrying hazardous materials, particularly when the view down the track from a stopped vehicle is obstructed (curve in track, etc.).
- Continuance of collisions after installation of flashing lights.
- Presence of passenger trains.

In addition to the above factors, some states utilize a specified level of exposure or the priority index as a guideline for the selection of automatic gates.

The most recent criteria for the use of automatic gates are provided in the guidance document prepared by the U.S. DOT Technical Working Group (see Chapter V).

On two-way streets, the gates should cover enough of the approach highway to physically block the

motorist from driving around the gate without going into the opposing traffic lane. On multilane divided highways, an opening of approximately 6 feet may be provided for emergency vehicles.

Gates may be made of aluminum, fiberglass, or wood. Fiberglass or aluminum gates may be designed with a breakaway feature so that the gate is disengaged from the mechanism when struck. The American Railway Engineering and Maintenance-of-Way Association (AREMA) *Communications and Signal Manual* sets a limit of 38 feet for the gate length. Some railroads request reconfiguration of the crossing when gate arm lengths would exceed 32 feet and it may be necessary to place gate assemblies in the median to cover the approach highway. In these cases, crash cushions or other safety barriers may be desirable. Under no circumstances should signals or gate assemblies be placed in an unprotected painted median. Conversely, some railroads would prefer longer gate arms rather than a gate mechanism in the median. A typical clearance plan for a flashing light signal with automatic gate is shown in Figure 24.

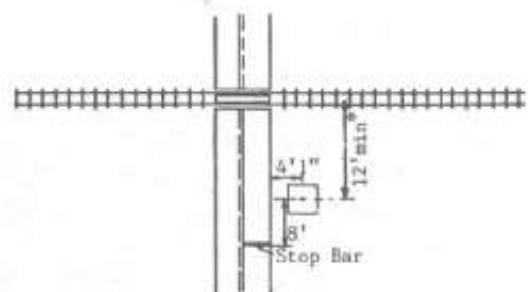
When no train is approaching or occupying the crossing, the gate arm is held in a vertical position and the minimum clearance from the face of the vertical curb to the nearest part of the gate arm or signal is 2 feet, for a distance of 17 feet above the highway. Where there is no curb, a minimum horizontal clearance of 2 feet from the edge of a paved or surfaced shoulder is required, with a minimum clearance of 6 feet from the edge of the traveled highway. Where there is no curb or shoulder, the minimum horizontal clearance from the traveled way is 6 feet. Where flashing lights or gates are located in the median, additional width may be required to provide the minimum clearances for the counterweight support.

The lateral location of flashing light and gate assemblies must also provide adequate clearances from the track as well as space for construction of the foundations. Figure 29 shows typical locational requirements for the foundations for flashing lights and cantilevered flashing lights with gates. The area for the foundation and excavation must be analyzed to determine the effect on sidewalks, utility facilities, and drainage. Although these plans indicate a 12-foot minimum clearance between the center of the flashing light assembly and the center of the tracks, some railroads prefer a 15-foot minimum clearance.

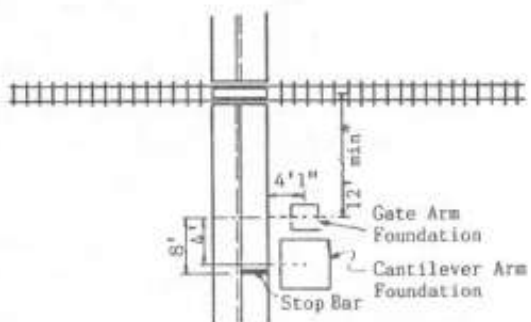
Figures 30 through 36 show typical location plans for flashing light signals with and without gates. If it is necessary to locate the supporting post in a potentially hazardous position to ensure adequate visibility, some type of safety barrier should be considered. These are discussed in a later section.

It should be noted that gate arms have a maximum standard length of 11.6 meters (38 feet). Some railroads prefer to limit arm lengths to 9.75 meters (32 feet). In addition, FRA requires that the gate arm cover 90 percent of the approach lane; a 7.3-meter (24-foot) gate arm would be required to control two 3-meter (10-foot) lanes if mounted with the center of the mast 1.5 meters (5 feet) back from the face of curb. Clearly, large multilane intersections and intersections with unusual configurations will require careful study to determine the appropriate layout of crossing gate locations. For such conditions, gate arm requirements may become a principal factor in the layout of the intersection geometry and channelization from the outset. The crossing gate (and, therefore, traffic control) treatment should be an integral part of the design of an intersection, not an afterthought.

Figure 29. Typical Location of Signal Devices



a. Flashing Lights with or without Gates



b. Cantilever Flashing Lights and Gates

* Some railroads require minimum clearance of 15 feet.

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

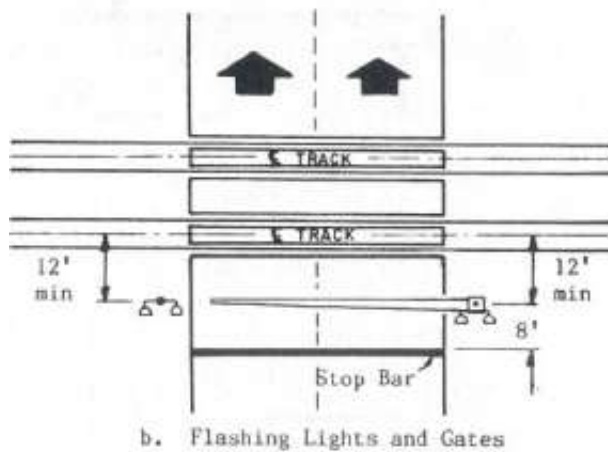
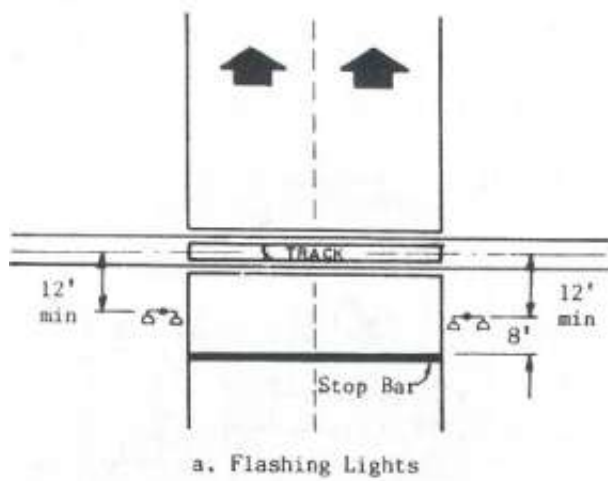
6. Four-Quadrant Gates

Four-quadrant gate systems consist of a series of automatic flashing light signals and gates in which the gates extend across both the approach and the departure side of roadway lanes. Unlike two-quadrant gate systems, four-quadrant gates provide additional visual constraints 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 United States, and they incorporate different types of designs to prevent vehicles from being trapped between the gates. In some installations, the exit gates are delayed to allow roadway vehicles to clear before the crossing is secured; other systems include vehicle presence detection to hold the exit gates up while vehicles are within the crossing zone.

Four-quadrant gates are recognized as a supplemental safety measure under the Final Rule for quiet zones (refer to Chapter II, Section B.) It should be noted that FRA has assigned a lower effectiveness to installations that include vehicle presence detection because the act of raising the exit gates may allow vehicles to enter the crossing. On the other hand, the California Public Utilities Commission, which has modified its General Orders to address use of four-quadrant gates, requires installation of a vehicle presence system “subject to a Commission staff diagnostic field meeting recommendation and an engineering study performed by railroad or local road agencies.”⁹¹

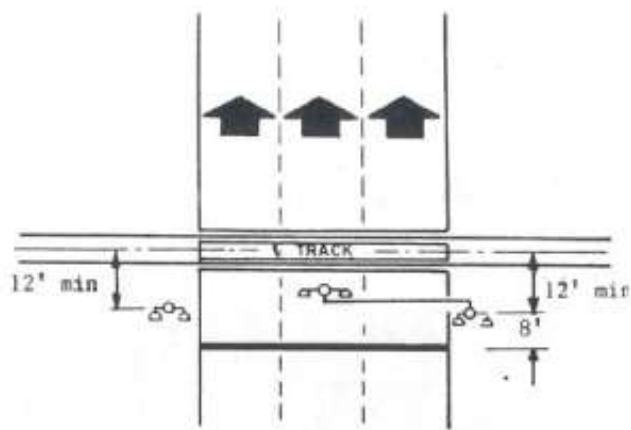
Figure 30. Typical Location Plan, Right Angle Crossing, One-Way, Two Lanes



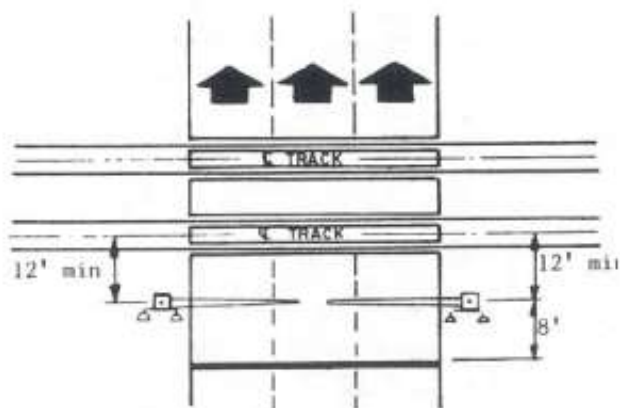
Note: Two gate arms may be used as an alternate.

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

Figure 31. Typical Location Plan, Right Angle Crossing, One-Way, Three Lanes



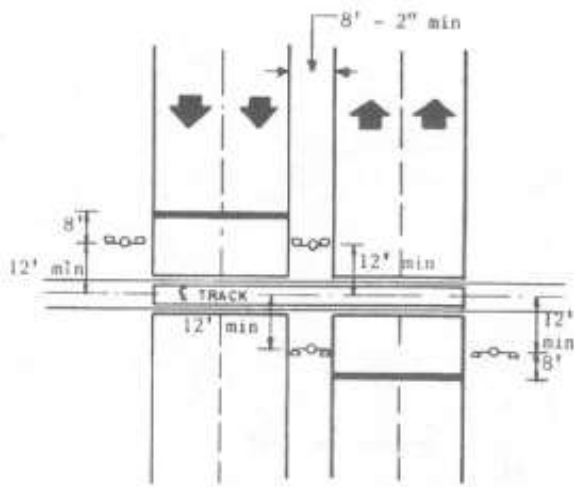
a. Flashing Lights



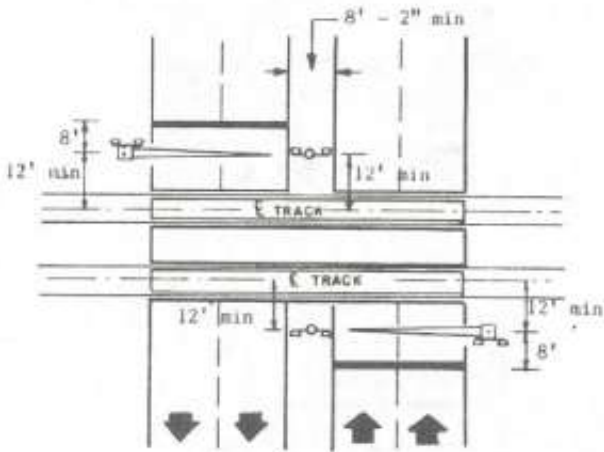
b. Flashing Lights and Gates

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

Figure 32. Typical Location Plan, Divided Highway with Signals in Median, Two Lanes Each Way



a. Flashing Lights



b. Flashing Lights and Gates

Note: The median width of 8'2" is an operation requirement and is not an AASHTO recommendation for median width.

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

7. Use of Channelization with Gates

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, drivers are able to cross the centerline pavement marking and drive around a gate with little difficulty. The number 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.

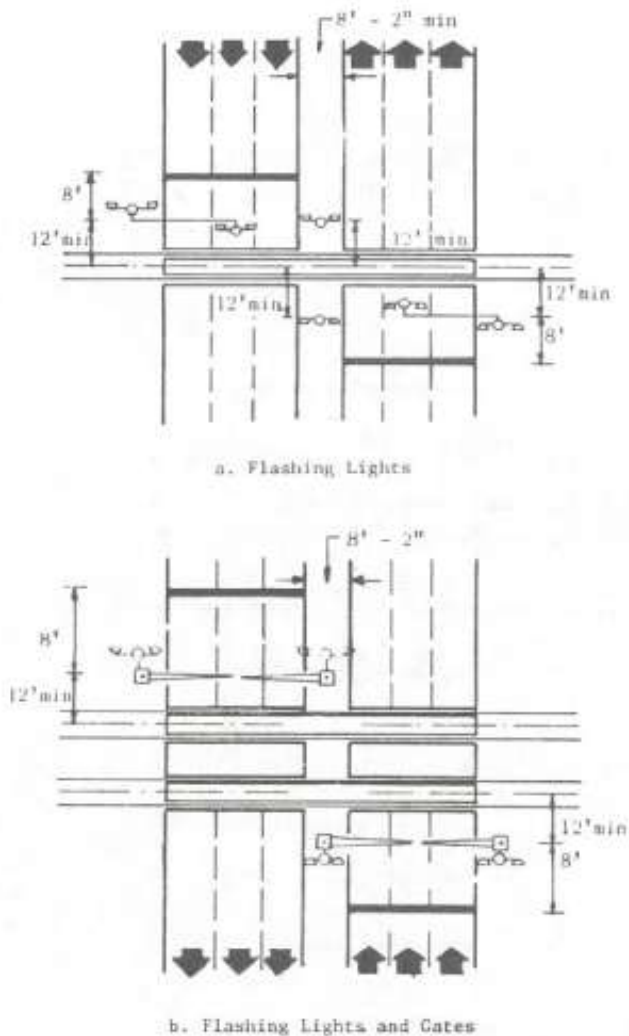
Limitations are common to the use of any form of traffic separation at highway-rail grade crossings. These include restricting access to intersecting streets, alleys, and driveways within the limits of the median, and possible adverse safety effects. The median should be designed to allow vehicles to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

It should be noted that median treatments meeting the requirements of 49 CFR 222 are considered supplemental safety measures by FRA for use in a quiet zone (refer to Chapter II, Components of a

Highway-Rail Grade Crossing).

Various styles of median treatments include barrier wall systems, wide raised medians, and mountable raised curb systems.

Figure 33. Typical Location Plan, Divided Highway with Signals in Median, Three Lanes Each Way

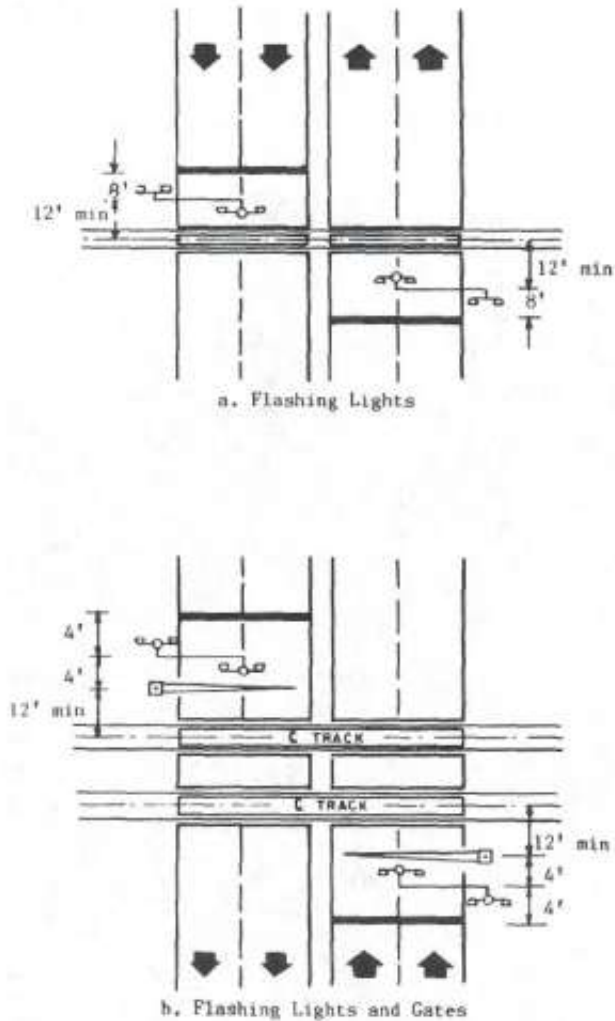


Note: The median width of 8'2" is an operation requirement and is not an AASHTO recommendation for median width.

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

Barrier wall 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. However, the road must be wide enough to accept the width of the barrier and the appropriate end treatment. Sight restrictions for vehicles with low driver eye heights and any special needs for emergency 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 meters (150 feet).

Figure 34. Typical Location Plan, Divided Highway with Insufficient Median for Signals, Two Lanes Each Way

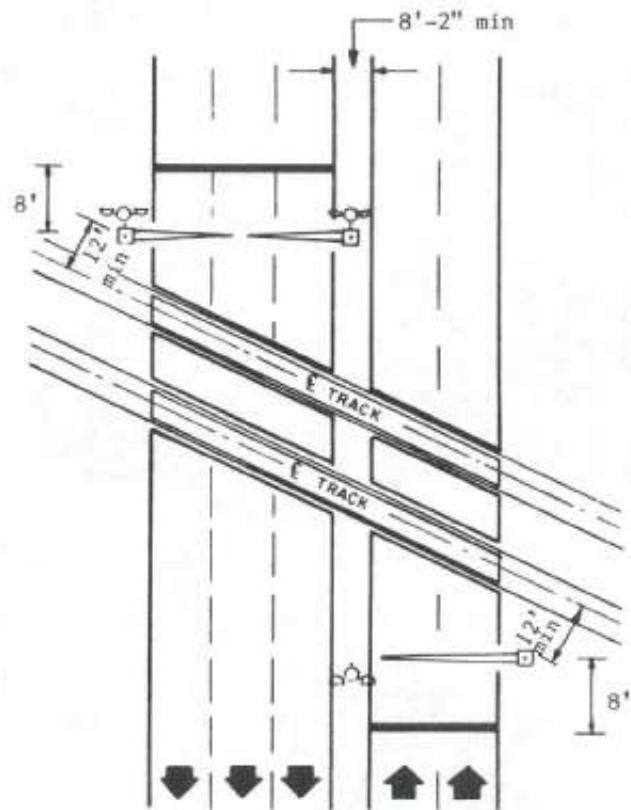


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

Wide raised medians. Curbed medians generally range in width from 1.2 to more than 30 meters (4 to 100 feet). Although they do not present a true barrier, wide medians can be nearly as effective because 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 the availability of sufficient right of way and the maintenance of surface and/or landscape. Additions such as trees, flowers, and other vegetation higher than .9 meter (3 feet) above the roadway can restrict 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 the total crash rate and the severity of collisions when struck by higher-speed vehicles (greater than 64 km/hr. (40 mph)).

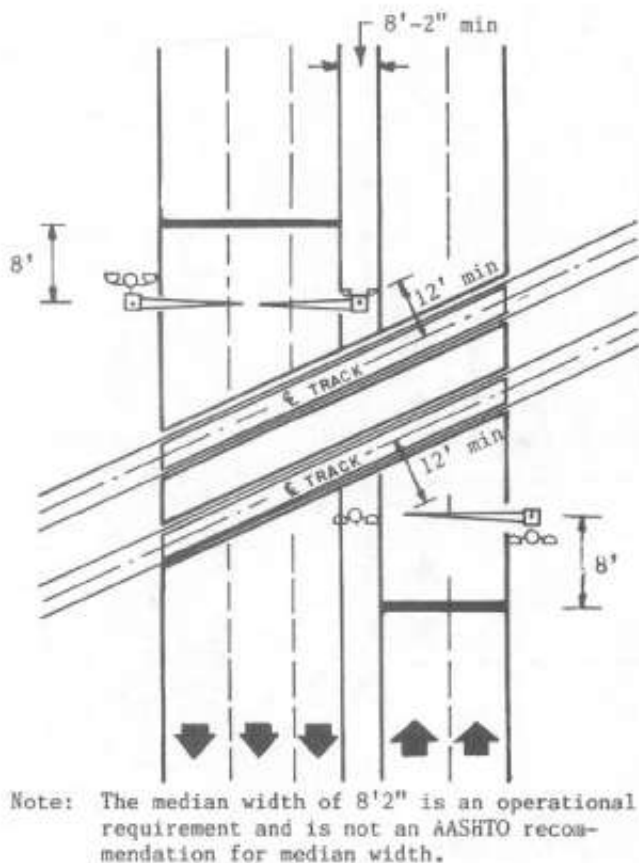
Figure 35. Typical Location Plan, Acute Angle Crossing for Divided Highway with Signals in Median, Two or Three Lanes Each Way



Note: The median width of 8'-2" is an operational requirement and is not an AASHTO recommendation for median width.

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

Figure 36. Typical Location Plan, Obtuse Angle Crossing for Divided Highway with Signals in Median, Two or Three Lanes Each Way



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

Non-mountable curb islands. Non-mountable curb islands are typically 6 to 9 inches in height and at least .6 meter (2 feet) wide and may have reboundable, reflectorized vertical markers. Drivers have significant difficulty attempting to violate these types of islands because the 6- to 9-inch heights cannot be easily mounted and crossed.

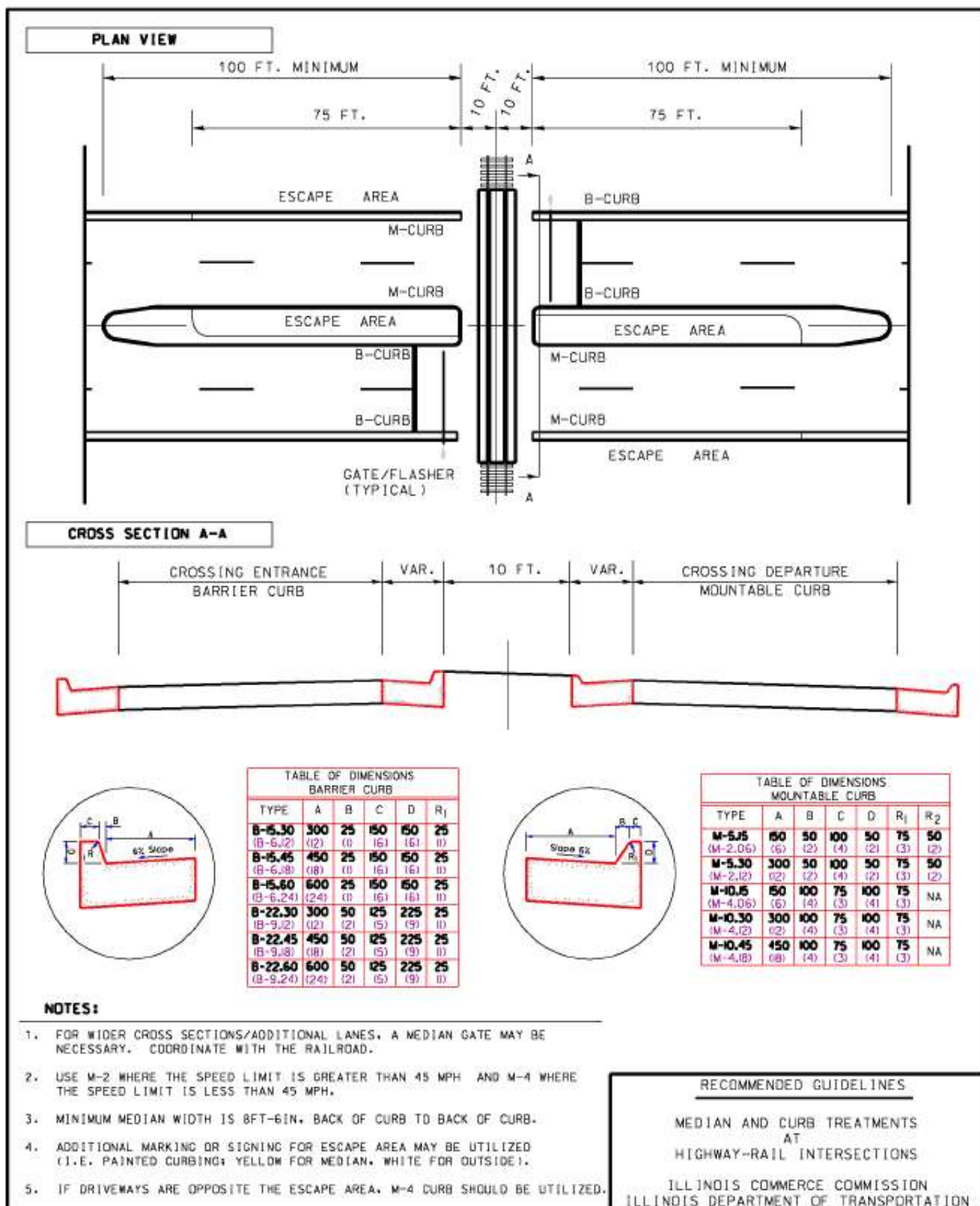
Some disadvantages should be considered. The road must be wide enough to accommodate a 2-foot median. The increased crash potential should be evaluated. AASHTO recommends that special attention be given to high visibility if such a narrow device is used in higher-speed (greater than 64 km/hr. (40 mph)) environments. 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.

The state of Illinois has developed a standard that uses a combination of mountable and non-mountable curbs to provide a wide raised median with escape zones both in the median as well as to the shoulder (see Figure 37).

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 6 inches in height, less than 12 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.

Figure 37. Example of Combination of Mountable and Non-Mountable Curbs from Illinois Department of Transportation



Source: Illinois Department of Transportation.

Because mountable curbs are made to allow emergency vehicles to cross and 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 retroreflective devices or glass beads on the top and sides of the curb are maintained for night visibility. Curb colors should be consistent with the location and direction of traffic adjacent to the device.⁹²

These devices have proven a low-cost investment with a high rate of return in safety at crossings. The separators are installed along the centerline of roadways, in most cases extending approximately 20 to 30 meters (70 to 100 feet) from the crossing. They prevent motorists from crossing lanes to “run around” activated crossing gates. The separators consist of prefabricated, mountable islands made of a composite material. Attached to the islands are flat delineator panels or tubes with reflectorized taping for better visibility at night. The delineator panels are flexible yet securely anchored to return to their original positions if struck by a vehicle.

The use of median separators at the Sugar Creek Road crossing in the North Carolina Sealed Corridor Program has resulted in a 77-percent reduction in crossing violations. The use of median separators in conjunction with four-quadrant gates has produced a 98-percent reduction in crossing violations. Also being installed, especially in conjunction with roadway widening projects, are concrete median separators with tubular markers mounted on them.⁹³

8. Barrier Gate

The barrier gate is a movable automatic gate designed to close an approaching roadway temporarily at a highway-rail crossing. A typical installation includes a housing containing electromechanical components that lower and raise the gate arm, the arm itself, and a locking assembly bolted to a concrete foundation to receive and hold the lowered gate arm in place. The barrier gate arm itself has been installed with a system consisting of three steel cables, the top and bottom of which are enclosed aluminum tubes.

Barrier devices should at least meet the evaluation criteria for a National Cooperative Highway Research Program (NCHRP) Report 350 (Test Level 2) attenuator; stopping an empty, 4,500-pound pickup truck traveling at 70 km/hr. (43 mph). Barrier gates have been tested to safely stop a pick-up truck traveling at 72 km/hr. (45 mph) and have been installed in Madison, Wisconsin and Santa Clara County, California.

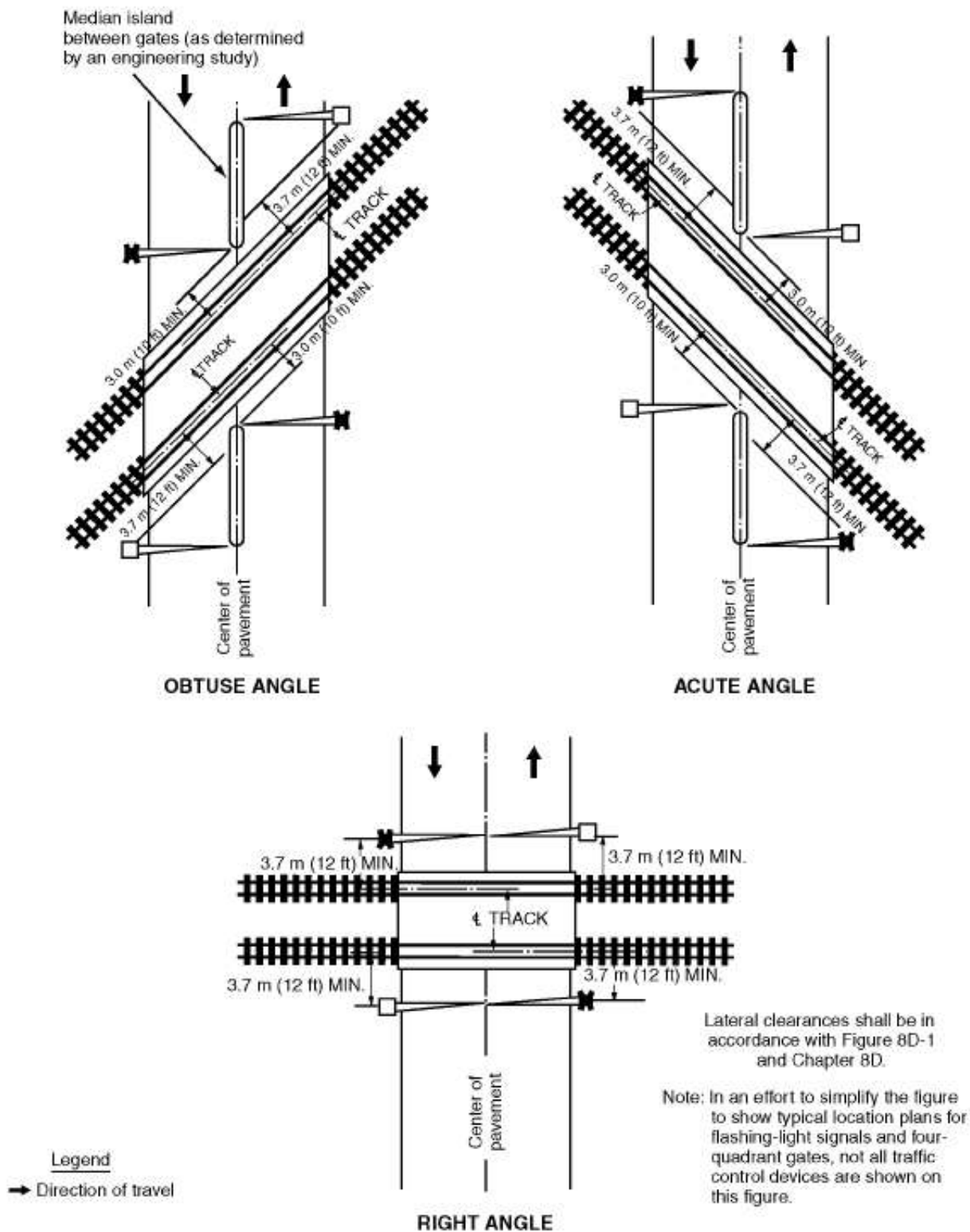
Barrier gates could be applied to situations requiring a positive barrier, such as in a down position, closing off-road traffic, and opening only on demand. FRA rules require consideration of barrier and/or enhanced warning systems subject to FRA approval for operation over 110 mph. FRA has indicated that a barrier gate, if equipped with monitoring and confirmation as required by the Final Rule, may be applicable to enforce a nighttime closure for partial quiet zones.

9. Warning Bell

A crossing bell is an audible warning device used to supplement other active traffic control devices. A bell is most effective as a warning to pedestrians and bicyclists.

When used, the bell is usually mounted on top of one of the signal support masts. The bell is usually activated whenever the flashing light signals are operating. Bell circuitry may be designed so that the bell stops ringing when the lead end of the train reaches the crossing. When gates are used, the bell may be silenced when the gate arms descend to within 10 degrees of the horizontal position. Silencing the bell when the train reaches the crossing or when the gates are down may be desired to accommodate residents of suburban areas.

Figure 38. Example of Location Plan for Flashing Light Signals and Four-Quadrant Gates



Source: Manual on Uniform Traffic Control Devices, 2003 Edition. Washington, DC: Federal Highway Administration, 2003.

10. Wayside Horn System

The wayside horn system consists of a horn or series of horns located at the highway-rail grade crossing and directed at oncoming motorists. The system is designed on fail-safe principles and

provides a means to verify sound output. The wayside horn system:

- Simulates the sound and pattern of a train horn.
- Provides similar (or safer) response from road users.
- Minimizes the audible impact on individuals located near the highway-rail grade crossing.

The purpose of the wayside horn system is to focus the horn sound level on the road user while minimizing the noise impact adjacent to the railroad from the point the train horn is required to be sounded.

The system is used as an adjunct to train-activated warning systems to provide audible warning of an approaching train for traffic on all approaches to the highway-rail grade crossing. It is not required to direct the wayside horn system toward approaching roadway users from roadways adjacent to the railroad if the roadway users' movements toward the crossing are controlled by a STOP sign or traffic signal.

When a wayside horn system is used at highway-rail grade crossings where the locomotive-mounted horn is not sounded, the highway-rail grade crossings must be equipped with flashing lights and gates and constant warning circuitry, where practical. In such instances, the wayside horn should also provide a “confirmation” indication to the locomotive engineer; in the absence of a confirmation signal, the engineer would need to activate the locomotive-mounted horn.

The wayside horn system simulates a train horn and sounds at a minimum of 15 seconds prior to the train's arrival at the highway-rail grade crossing, or simultaneously with the activation of the flashing lights or descent of the gate, until the lead locomotive has traversed the crossing. Where multiple tracks are present, the wayside horn system is immediately reactivated when another train is detected before the previous train clears the crossing. Wayside horn systems should include a 3- to 5-second delay after activation of flashing lights signals before sounding.

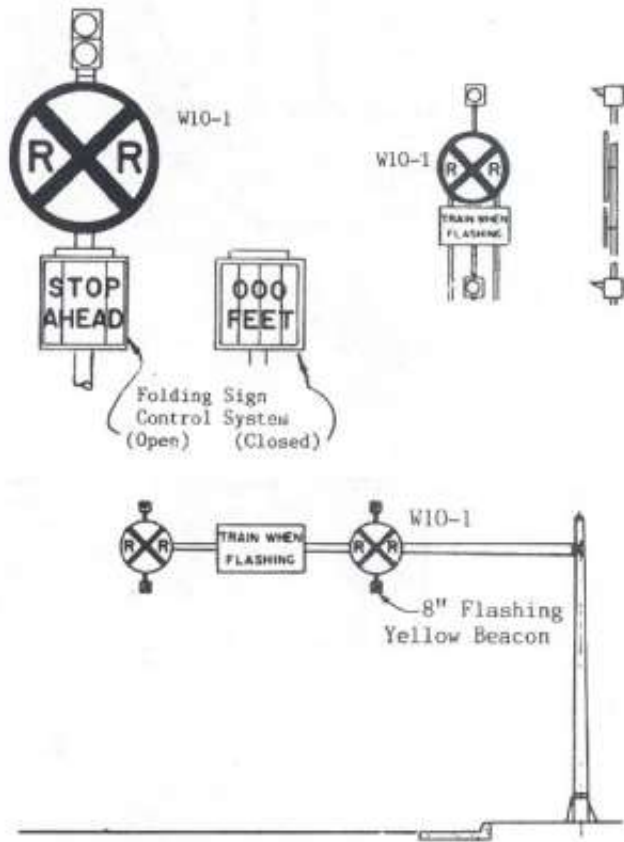
At its June 2006 meeting, the NCUTCD council approved a proposed new section to Part 8 of MUTCD to recognize use of the wayside horn either as a supplemental audible device or as an alternative to the sounding of a locomotive-mounted horn. The council also approved new language for Part 10, which allows use of the wayside horn for light rail. The text in Part 10 would allow a wayside horn to be used to reproduce the tone and sound level of wayside equipment. This would allow use of directional horns in lieu of traditional crossing bells at locations with light rail not subject to FRA jurisdiction, such as urban light-rail crossings.

11. Active Advance Warning Sign

The active advance warning sign (AAWS) consists of one or two 12-inch yellow hazard identification beacons mounted above the advance warning sign, as shown in Figure 39. An advisory speed plate sign indicating the safe approach speed also should be posted with the sign.⁹⁴ The AAWS provides motorists with advance warning that a train is approaching the crossing. The beacons are connected to the railroad track circuitry and activated on the approach of a train. The AAWS should continue to be activated until the crossing signals have been deactivated.

Figure 39. Examples of Active Advance Warning Signs and Cantilevered Active Advance

Warning Sign



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

A train-activated advance warning sign should be considered at locations where the crossing flashing light signals cannot be seen until an approaching motorist has passed the decision point (the distance from the track from which a safe stop can be made). Use of the AAWS may require some modification of the track circuitry. Consideration should be given to providing a back-up source of power in the event of commercial power failure.

AAWS is sometimes supplemented with a message, either active or passive, that indicates the meaning of the device, such as "Train When Flashing." A passive supplemental message remains constant; an active supplemental message changes when the device is activated by the approach of a train.

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 dependent on vehicle speed and the geometric conditions of the roadway.

AAWS should be placed at the location where the advance warning sign would normally be placed. To enhance visibility at crossings with unusual geometry or site conditions, the devices may be cantilevered or installed on both sides of the highway. An engineering study should determine the

most appropriate location.

12. “Second Train Coming” Active Warning Sign

Train detection systems can also be used to activate a “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 second train approaches the crossing. It is also being evaluated at multiple-track highway-rail grade crossings as a supplement to automatic gates. Because this sign is not currently in MUTCD, any jurisdictions wishing to use symbols to convey any part of this message must request permission to experiment from FHWA.⁹⁵ (Refer to Chapter X, Special Issues, for use of the “Second Train Coming” pedestrian device as well as the “Train Coming” icon active warning sign used at LRT crossings.)

13. Active Turn Restriction Signs

At a signalized intersection located within 60 meters (200 feet) of a highway-rail grade crossing, measured from the edge of the track to the edge of the roadway, where the intersection traffic control signals are preempted by the approach of a train, all existing turning movements toward the highway-rail grade crossing should be prohibited during the signal preemption sequences.

A blank-out or changeable message sign and/or appropriate highway traffic signal indication or other similar type sign may be used to prohibit turning movements toward the highway-rail grade crossing during preemption.⁹⁶

14. New Traffic Signals

During the time this handbook was being updated, NCUTCD and FHWA were considering a proposal to amend MUTCD to include a new traffic signal warrant that would apply, under certain conditions, to highway-highway intersections in close proximity to highway-railroad grade crossings.

The proposed warrant under consideration is specifically intended to apply to situations in which:

- A major roadway runs more or less parallel to a line of railroad, and a minor roadway intersects both the major roadway and the line of railroad at grade.
- The resulting highway-highway intersection does not otherwise meet any of the other currently approved traffic signal warrants in MUTCD.
- Motorist compliance with the existing (passive) traffic control devices at the highway-highway intersection often results in highway vehicles queuing across or fouling the nearby highway-railroad grade crossing.
- Other strategies to mitigate such queuing/ fouling are deemed impractical, inappropriate, or not feasible.

When applied, any traffic signals installed pursuant to this new warrant would also need to include provisions for railroad preemption (for example, if not already existing, some means of automatically detecting a train approaching the highway-railroad grade crossing would also need to be provided), to allow for clearing any queued vehicles off the grade crossing prior to the arrival of

a train.

Draft language proposing the new warrant was approved by the National Council at the June 2006 meeting of NCUTCD. This proposed warrant or some version thereof is likely to be included in a formal Notice of Proposed Amendment to MUTCD, which is currently expected to be issued by FHWA in late 2007 or early 2008. A Final Rule formally including it in MUTCD is expected to be issued in 2009.

15. Preemption of Traffic Signals

Where a signalized highway intersection exists in close proximity to a railroad crossing, the railroad and traffic signal control equipment should be interconnected, and the normal operation of the traffic signals controlling the intersection should be preempted to operate in a special control mode when trains are approaching (see MUTCD Sections 8D.07 and 10D.05). A preemption sequence compatible with railroad crossing active traffic control devices is extremely important to provide safe vehicular and pedestrian movements. Such preemption serves to ensure that the actions of these separate traffic control devices complement rather than conflict with each other. The text beginning on the next page incorporates key provisions of a recommended practice prepared by the Institute of Transportation Engineers (ITE).^{[97](#)}

16. Train Detection

To serve their purpose of advising motorists and pedestrians of the approach or presence of trains, active traffic control devices are activated by some form of train detection. Generally, the method is automatic and requires no personnel to operate it, although a small number of such installations are operated under manual control. The automatic method uses the railroad circuit. This electrical circuit uses the rails as conductors in such a way that the presence of a solid electrical path, as provided by the wheels and axles of a locomotive or railroad car, shunts the circuit. The system is also designed to be fail-safe; that is, any shunt of the circuit, whether by railroad equipment, vandalism, or an “open circuit,” such as a broken rail or track connection, causes the crossing signals to be activated.

Standard highway traffic signals display a green, yellow, or red light at all times except when power has failed and the signals are dark. Crossing signals are normally dark unless a train is approaching or occupying the crossing. There is no indication to the highway user when power has failed. Therefore, crossing control systems are designed to also operate on stand-by battery power should commercial power be terminated for any reason. Solar energy may be used to charge storage batteries to power signals at crossings in remote locations.

Storage battery stand-by power is provided to span periods of commercial power failure. The stand-by assures normal operation of crossing signals during a commercial power outage. When this practice was initiated, the crossing signals were normally supplied with AC power through a step-down transformer. The same AC source provided charging current through a rectifier for the stand-by battery to maintain the battery in a charged condition. When commercial AC power failed, crossing signal power connections were transferred from the AC source to the battery, as shown in Figure 45. This arrangement was necessary because the “constant current” rectifiers used in this service were unable to respond to changes in battery voltage or load.

Present day “constant voltage” rectifiers can respond to changes in battery voltage and load and can provide high DC current to the battery and load during periods when crossing signals are energized, tapering off quickly as soon as stand-by battery capacity has been replenished after the

crossing signals are de-energized. This ability of modern rectifiers permits DC operation of the signals whether AC supply voltage is present or not. The signals are connected directly to battery terminals and the power transfer is eliminated, as shown in Figure 40.

On tracks where trains operate at speeds of 20 mph or higher, the circuits controlling automatic flashing light signals shall provide for a minimum operation of 20 seconds before the arrival of any train. This 20-second warning time is a minimum. The warning time should be of sufficient length to ensure clearance of a vehicle that might have stopped at the crossing and then proceeded to cross just before the flashing lights began operation. Some railroads use a warning time of 25 seconds at crossings with automatic gates. Factors that can affect this time include the width of the crossing, the length and acceleration capabilities of vehicles using the crossing, highway grades, and the condition of the crossing surface.

PREEMPTION OF TRAFFIC SIGNALS NEAR RAILROAD CROSSINGS

The traffic engineer designing the preemption system must understand how the traffic signal controller unit operates in response to a call for a preemption sequence. The engineer must consult with railroad personnel who are responsible for railroad signal design and operations to ensure that appropriate equipment is specified and that both highway and railroad signal installations operate properly and with full compatibility. Continuous cooperation between highway and railroad personnel is essential for safe operation. Important information concerning the type of railroad signal equipment that can be used is available from the operating railroad and from the *AREMA Communications and Signal Manual*. In addition, state and local regulations should be consulted.

Preemption of traffic signals for railroad operations is very complex and must be designed and operated for a specific location, often with unique conditions. With the extremely large number of variables involved, it is difficult to simply quantify all the time and distance elements. The goal of this recommended practice is to identify as many elements as possible and provide references where feasible. Recommendations are therefore provided in the generic sense, with the expectation that applications will be designed for local conditions. The list of conditions requiring preemption is not intended to be complete but should provide an awareness of the factors necessitating preemption of normal traffic signal operation.

When to preempt. If either of the two conditions listed below prevails, consideration should be given to interconnecting traffic signals on public and private highways with active warning devices at railroad crossings:

- Highway traffic queues have the potential for extending across a nearby rail crossing; or
- Traffic backed up from a nearby downstream railroad crossing could interfere with signalized highway intersections.

A crossing equipped with a passive control device may need to be upgraded to include active warning devices so that preemption of the traffic signal can be implemented effectively. Such improvements are particularly important when the tracks are close to the signalized intersection or when certain conditions exist, such as high-speed train or highway approaches; tracks in highway medians; geometry such as steep grades; or

special vehicles using the crossing, such as trucks carrying hazardous material or school buses.

Where a crossing with active control devices is in close proximity to a STOP-sign controlled intersection, it may be necessary to consider the installation of traffic signals to clear queues from the crossing if an engineering study indicates that other solutions or traffic control devices will not be effective.

When designing a preemption system, many important items should be considered. These include distance between the tracks and signal; intersection and crossing geometry; approach speed of trains and vehicles; train frequency; vehicle flow rates; vehicle size and classification; and operation of the traffic signal controller unit.

Traffic approaching the intersection from the tracks—long distance. The 1948 edition of MUTCD stipulated the interconnection of traffic signals to crossings with “flashers, wigwags or gates” within about 500 to 1,000 feet (150 to 300 meters). The 1961 edition of MUTCD shortened the recommended distance to about 200 feet (65 meters), except under unusual conditions, and added the term “preemption.” Although this value seems subjective, it has been retained in succeeding editions of MUTCD (including the Millennium Edition) and is referenced by several other publications. Research, however, has found this distance inadequate. The current edition of MUTCD also mentions that coordination with the flashing light system should be considered for traffic signals located farther than 200 feet (60 meters) from the crossing.¹ Coordination could include, for example, queue detection that would omit some signal phases or activate variable message signs.

Where possible, field observations of traffic queue lengths during critical traffic periods can provide guidance on the need for signal preemption. Queue arrival and dissipation studies should be made during peak travel demand times at the site. Where field observation is not possible because the crossing is not yet in full operation, some intersection capacity analysis computer programs that provide an estimate of queue lengths can be used to determine whether the 95th-percentile queue from the signalized intersection will extend as far as the railroad crossing.

A simple but reasonably reliable estimate of 95th-percentile queue lengths (queues that will not be exceeded 95 percent of the time) can be calculated as:

Equation 1

$$L = 2qr(1+p)25$$

where:

L = length of queue (feet)

q = vehicle flow rate (vehicles per lane per second)

r = effective red time (red + yellow) (seconds)

p = proportion of heavy vehicles in traffic flow (as a decimal)

The factor of 25 represents the effective length of a passenger car (vehicle length plus

space between vehicles); the factor of 2 is a random arrival factor.

Equation 1 provides a good estimate of queue lengths where the volume-to-capacity ratio (v/c) of the signalized intersection is less than 0.90. However, for v/c ratios greater than 0.90, some overflow queues could occur as a result of fluctuations in arrival rates. To compensate for this condition, it is suggested that one vehicle be added to the estimated queue length for each 1-percent increase in the v/c ratio over 0.90. Accordingly, in cases where the v/c ratio ranges between 0.90 and 1.0, the following equation applies:

Equation 2

$$L = 2qr(1 + \Delta x)(1 + p)(25)$$

where:

$$\Delta = 100 (\text{v/c ratio} - 0.90)$$

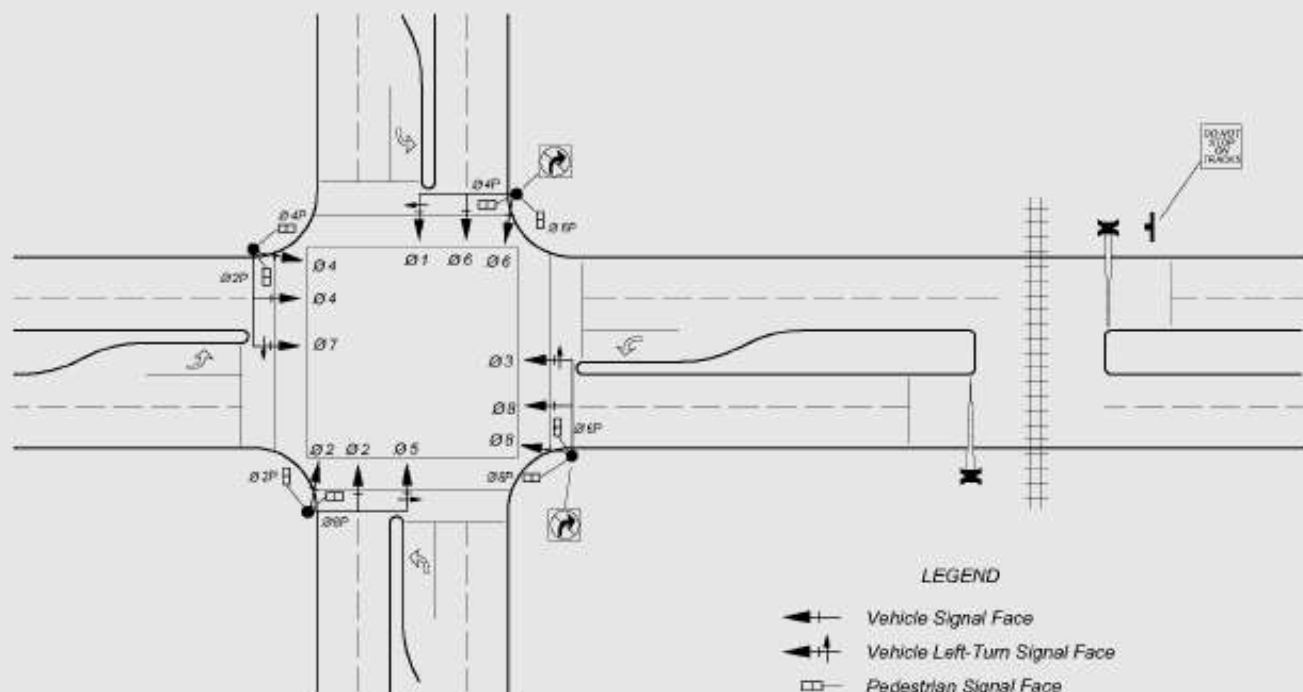
For a v/c ratio of 0.95, for example, $\Delta = 5$. Equation 2 cannot be used reliably if the v/c ratio is greater than 1.0—for example, if the intersection is oversaturated. Under these conditions, a *Highway Capacity Manual* analysis or traffic simulation model may be useful alternatives.²

It is not the intent of either MUTCD or the queue calculation equation to provide a specific distance as the sole criterion to interconnect railroad and highway signals. Special consideration should be given where upstream signals cause vehicles to arrive in platoons that could result in long queue lengths. Unusual 15-minute peak-period flow rates should be evaluated. Vehicle classification studies should be performed, because trucks must be factored separately, and some trucks may have unusual size and operating characteristics.^{3,4} Similar locations may be evaluated for comparative vehicle queuing.

In some cases, observed and/or predicted queues may be so long that preemption, even if provided, may not be adequate for vehicles to clear the tracks. In these circumstances, additional anti-queuing measures are available.

Traffic approaching the intersection from the tracks—short distance. Where the clear storage distance between the crossing and the highway intersection stop line is not sufficient to safely store a design vehicle (typically the longest legal truck combination), or if vehicles regularly queue across the tracks, a pre-signal should be considered. An engineering study should be performed to support this recommendation. The concept is illustrated in Exhibit 1. A pre-signal should also be considered if gates are not present. See the following section for additional information regarding the application and design of pre-signals.

Exhibit 1



Traffic approaching the tracks from the signalized intersection. The placement of train detection equipment should be governed by the preemption time required to clear the queues. This time should take into account the critical or design vehicle and should be sufficient for this vehicle to clear the intersection safely before the arrival of the train.

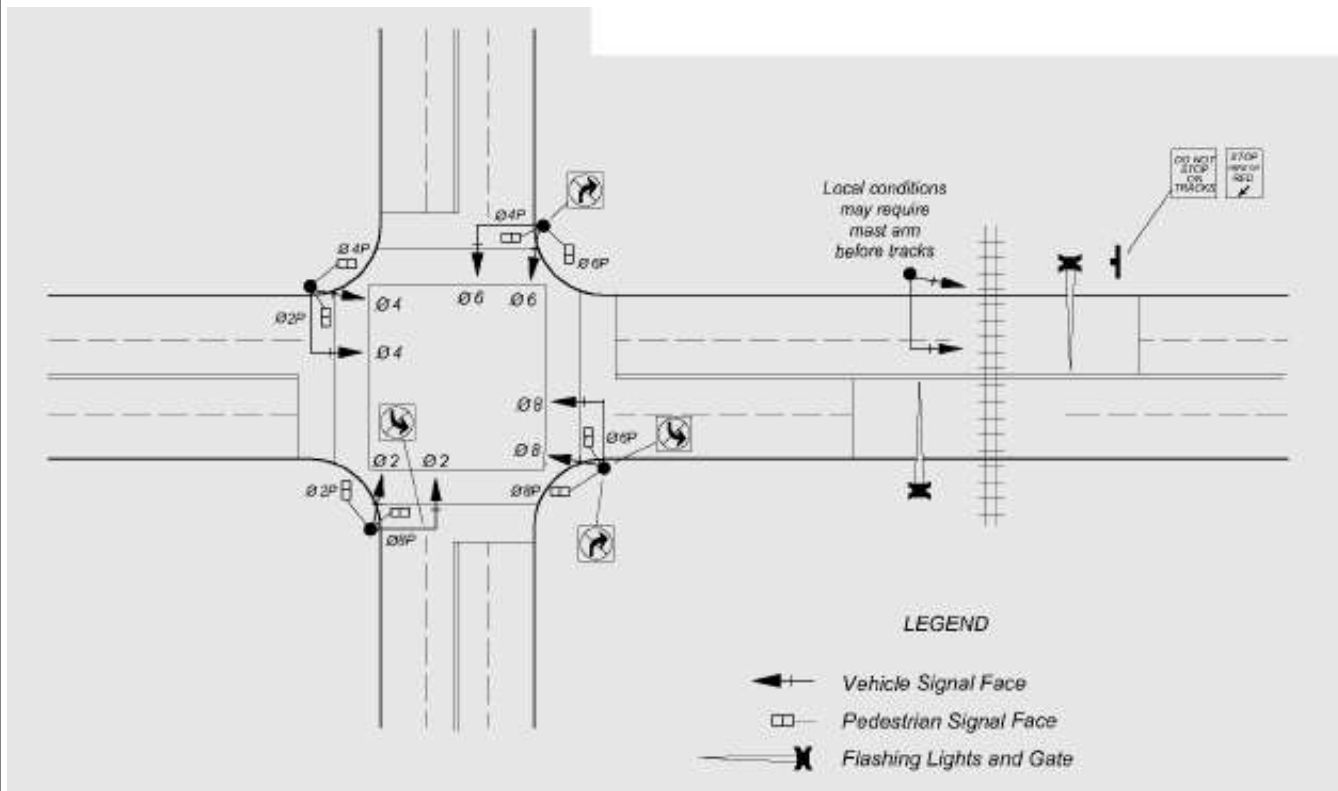
A long, slow-moving truck turning toward the tracks could have a problem clearing the intersection if a simultaneous preemption call occurs at the beginning of its turn, especially where the distance between the intersection and the vehicle stop line for the crossing is very short. If the truck makes the turn, encounters a lowering gate, and stops in compliance with the gate, the exit path from the crossing for vehicles approaching the intersection may be blocked even though the traffic signal preemption is functioning and displaying track clearance green. This condition should be studied as part of the system design and, if warranted, advance preemption should be employed to allow adequate time for a truck to clear prior to activating the railroad warning devices.

A long truck or a vehicle required to stop before crossing the tracks in low gear could have a problem clearing a lowering gate as well as clearing the intersection. Both of these scenarios should be considered in the design of the preemption operation if there is a significant volume of trucks. In this case, additional gate delay time may be necessary to allow these vehicles adequate time to restart and clear the crossing prior to lowering of the gates.

Special studies may be needed to determine if traffic approaching the crossing could queue and eventually block the adjacent intersection traffic flow. If determined to be appropriate by an engineering study, blank-out, internally illuminated, or variable message signs reading "No Left Turn" or "No Right Turn" should be used in those situations.⁵ Typical locations of such signs are illustrated in Exhibit 2. Note that if Phase 5 allows permissive left turns, a blank-out "No Left Turn" sign should be used to restrict the left-turn movement

during preemption. In addition, traffic signal phases conflicting with the crossing can be omitted from the preemption phasing sequence.

Exhibit 2



Equations 1 and 2 can also be used to estimate the queue length that is likely to develop for traffic approaching the railroad crossing. The factor q then represents the flow rate (per lane) approaching the crossing including both traffic passing straight through the signalized intersection toward the crossing as well as traffic that turns left and right off the street that parallels the tracks. The factor r represents the effective time the crossing would be blocked by a train, and can be estimated as:

$$r = 35 + \left(\frac{L}{1.47S} \right)$$

where:

L = train length (feet)

S = train speed (mph)

The factor of 35 assumes that approximately 25 seconds before the train enters the crossing plus 10 seconds after it clears the crossing, the crossing would still be blocked by the gates. These times may be adjusted as necessary for individual crossings.

Minimum warning time. MUTCD requires a 20-second minimum time for the railroad circuit to activate warning devices prior to arrival of a through train. Neither the basic 20 seconds nor an extended time computed by AREMA criteria (as prescribed by the AREMA

Communications and Signal Manual, Part 3.3.10), may be sufficient when highway traffic signals are interconnected to a railroad crossing with active warning devices.

The following items should be considered when designing time elements for a preemption operation:

- Approach speed of trains and vehicles on all approaches to the railroad crossing
- Intersection and crossing geometry (including crossing angle, number of tracks, minimum track clearance distance, intersection width, clear storage distance, approach grades, and parallel streets)
- Vehicle volumes
- Frequency of train movement (recognizing complicated, short headway commuter or LRT operations, or switch movements from nearby railroad yards)
- Train stops within the approach to the crossing, especially where stations are located in close proximity to the crossing
- Vehicle queue lengths and dissipation rates, which affect the duration of the clear track green interval⁶
- The design vehicle or special classes of vehicles (buses and large trucks or trucks carrying hazardous cargo). Because some of these vehicles are required to stop and proceed in low gear across the tracks, clearance time for both the tracks and the signalized intersection must be considered.
- Long right-of-way transfer times due to pedestrian intervals, minimum green times, high-speed highway approaches, or unusual intersection geometry
- Types of active warning (flashing light signals alone, flashing light signals with approach-side gates only, or with four-quadrant gates)
- Variability in the warning time provided by constant warning time train detection equipment; train acceleration and deceleration affect warning time; consultation with the railroad is essential for this item.

If one or a combination of the above items requires warning time in excess of the warning time recommended by AREMA criteria, the following techniques may be considered:

- Uniformly extend railroad circuit warning time for both the railroad and the traffic signal controller units, providing simultaneous preemption. This is accomplished by requiring additional clearance time from the railroad for simultaneous preemption. Note, however, that excessive clearance time may result in increased violation of lowered gates by motorists. For this reason, excessive clearance time should be avoided.
- Use advance preemption to start highway traffic signal preemption sequences before railroad warning devices are activated at the railroad crossing.

Systems approach. MUTCD points out the need for a systems approach when designing, installing, and operating highway traffic signals interconnected to railroad crossings. The *Traffic Control Devices Handbook* describes a diagnostic team that may include persons representing highway, railroad, regulatory, and utility agencies as well as manufacturers of highway and railroad equipment. The importance of cooperation and interaction among all responsible parties cannot be emphasized enough. Such cooperation not only encourages the safest design available by combining the latest technology available (or under development) in highway and railroad equipment but also ensures proper operation. Examples include:

- Fully programmable, multiple preemption sequences in highway traffic signal controller units, which allow more than one railroad preemption sequence on a priority basis. They also interact with lesser priority preemption programs from emergency and other special highway vehicles.
- Railroad constant warning time (CWT) devices, which provide relatively uniform advance warning time between the activation of warning devices and train arrival. CWT is particularly useful where trains travel at significantly different speeds or frequently stop within the control circuit limits (useful in commuter and switching operations).
- Visibility-limited traffic signal faces
- Crossing area vehicle detection systems, using various pavement-based sensing elements such as inductive loops, or non-pavement-based sensing technology such as microwave and video imaging detection equipment
- In-vehicle alert systems for emergency vehicles, school buses, and trucks hauling hazardous material; the systems would advise drivers of approaching trains.
- Supervised interconnect circuits, a circuit configuration that checks the integrity of the interconnect circuit between the railroad control cabinet and the traffic signal controller and minimizes the effect of a false preemption of the traffic signals while the railroad warning devices are not activated. The supervised circuitry can detect if the interconnect circuit is open or wires are crossed and set the traffic signals to flashing operation or send in an alarm.
- Remote monitoring of traffic signal controller assemblies and railroad signal control equipment
- Digital communication between the railroad control system and the traffic signal system; the proposed Institute of Electrical and Electronics Engineers (IEEE) Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection (IEEE 1570) defines the logical and physical interfaces and the performance attributes for communication between the two systems. Standardizing the interface will allow interoperability between wide varieties of equipment.
- Stand-by power systems for highway traffic signals⁷

- Train-activated variable message signs
- Pedestrian and bicycle warning devices

Pedestrian clearance phase. MUTCD provides that the pedestrian clearance phase may be “abbreviated” during the railroad preemption of traffic signals. Some agencies have elected to utilize the abbreviated interval; some eliminate the pedestrian clearance phase entirely during the preemption sequencing; 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), advance preemption (traffic signals are preempted prior to the activation of the railroad control devices), or, possibly, a special design that could consist of two separate closed-loop normally energized circuits. The first, a pedestrian clearance call, should occur at a predetermined length of time to be defined by a traffic engineering study and should continue until the train has departed the crossing. The purpose of the first call is to safely clear the pedestrian. The second, a vehicle clearance call, programmed with a higher priority in the traffic signal controller than the first call, should occur at 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 should 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.

One preemption interconnect circuit can be used to initially clear out the pedestrian traffic, then a time delay is 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 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 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 at which preemption is released from the railroad active control devices to the traffic signals is critical to the proper operation of re-service. 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 with 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.

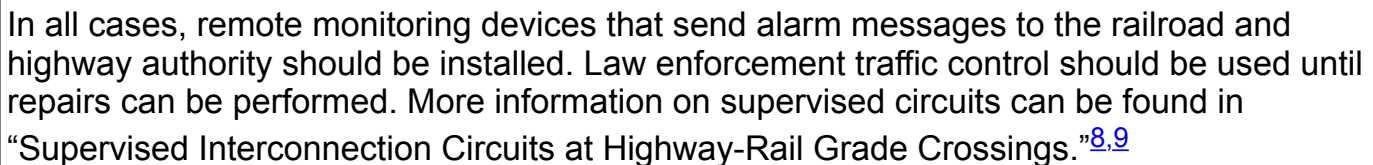
Some traffic signal controller manufacturers have designed systems in which the critical railroad preemption parameters can not be changed without both proper software and physically making a hardwire change in the traffic signal cabinet. Without proper data changes, the traffic signals will remain in a flashing red operation until the data are corrected. In addition, these systems prevent a different type of controller or 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 then will cycle through the 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.

Supervised preemption circuits may be used to address this potential problem. In its simplest form, the supervised circuit has two control relays in the traffic control cabinet, each of which is energized by the railroad crossing relay (see Exhibit 3).

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

Exhibit 3. Supervised Railroad Interconnect Circuit



Optional use of traffic signals where train movements are slow. Where train

movements are very slow, as at industrial crossings or with switching operations, highway traffic control signals can be used in lieu of railroad active warning devices (MUTCD, Section 8D.07). MUTCD stipulates that traffic control signals shall not be used in lieu of flashing light signals at a mainline railroad crossing, and that traffic control signals may be used at LRT crossings under some circumstances. If traffic control signals are used, care must be taken to assure that the system is fail-safe. Back-up power should be supplied for the traffic signals unless there is a signal indication for the train operator, and testing should be conducted to determine that no conditions exist where a green indication can be displayed to road users when a train is approaching or occupying the crossing.

Recommended treatment for crossing between two closely-spaced traffic signals.

Where a railroad crossing is located between two closely-spaced signalized intersections, the two highway traffic signals must be interconnected and their preemptions coordinated to permit the track to be cleared in both directions. If the two signals are operated by different public agencies, the agencies should participate in the design and operation of the signals and their preemption or assign responsibility to one agency.

Considerations for second train at multi-track crossings. Where a railroad crossing has more than one through track, special consideration must be given to operation of the warning devices and traffic signal when a second train approaches following the passage of the first train. Provisions may include use of an “extended hold” to maintain the crossing gates down until the second train has arrived, as well as use of traffic signal control logic, which assures that a second track clearance can be provided in the event the gates have been raised prior to the arrival of a second train.

Considerations for closely-spaced multiple railroad crossings. Where multiple tracks or tracks of different railroads cross a highway within preemption distance of the signalized intersection, all the tracks should be considered a single crossing, and the clear track green interval should be of sufficient length to allow a queue across all the tracks to clear. If one or more tracks are widely separated from other tracks closer to the intersection, special track clearance sequencing is necessary, and pre-signals may be considered. When more than one railroad is involved, all the railroads should participate in the design and operation of the preemption. Separate traffic controller unit inputs should be provided for each railroad so that the active track can be distinguished. The *AREMA Communications and Signal Manual*, Part 3.1.11, addresses the design criteria to be addressed by the railroads in the design and operation of the warning devices based on specific distances. Adjacent track clearance time must be determined and implemented in the operation of the warning devices and must also be taken into consideration in designing and operating traffic signal preemption.

Considerations for diagonal crossings. Where the railroad runs 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.¹⁰

Alternative treatments for long queues. In the event of very long queues, preemption may not be a practical method for clearing the tracks. An alternative treatment 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) signs, as stated in MUTCD. 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. (Refer also to the discussion of queue cutters and queue management strategies provided in Section 17, Pre-Signals.)

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. However, it is not the intent of this document to serve as a primer for this very complicated topic. Practitioners should fully familiarize themselves with the ITE recommended practice as well as any more recent guidance and should be sure that expert knowledge and full cooperation between highway and railroad authorities are brought to bear on technical issues regarding the design, construction, operation, and maintenance of interconnected systems.

Appendix I includes forms for computing preemption timing. For additional information, see “Design Guidelines for Railroad Preemption at Signalized Intersections” and “Timing of Traffic Signal Preemption at Intersections Near Highway-Railroad Grade Crossings.”^{11,12}

1 *Manual on Uniform Traffic Control Devices, 2003 Edition*. Washington, DC: FHWA, 2003.

2 *Highway Capacity Manual*. Washington, DC: Transportation Research Board, National Research Council, 2000.

3 Harwood, D.W. “Traffic and Vehicle Operating Characteristics.” In *Traffic Engineering Handbook*. Washington, DC: Institute of Transportation Engineers (ITE), 1992.

4 *Mandatory Stops at Railroad Grade Crossings, Appendix E*. U.S. DOT, FHWA, Report FHWA/RD/86/014, 1986.

5 Bowman, B.L. *Supplemental Advance Warning Devices*. National Cooperative Highway Research Program Synthesis of Highway Practice 198. 1993:48.

6 Kinzel, C.D. “Traffic Studies.” In *Traffic Engineering Handbook*. Washington, DC: ITE, 1992.

7 At the January 2006 meeting of NCUTCD, the council approved a change to indicate back-up power should be provided for traffic signals at locations where preemption or coordination with the railroad warning devices is provided (excepting light-rail transit) for incorporation into the next edition of MUTCD.

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

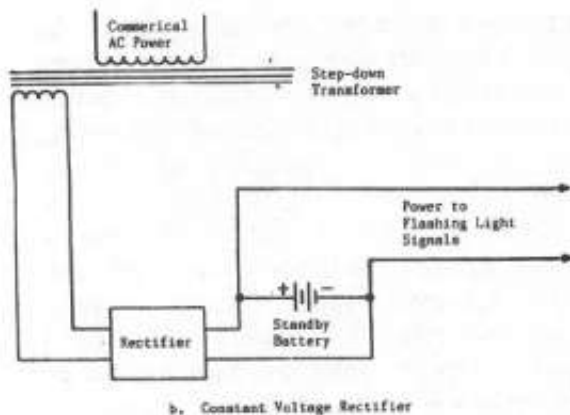
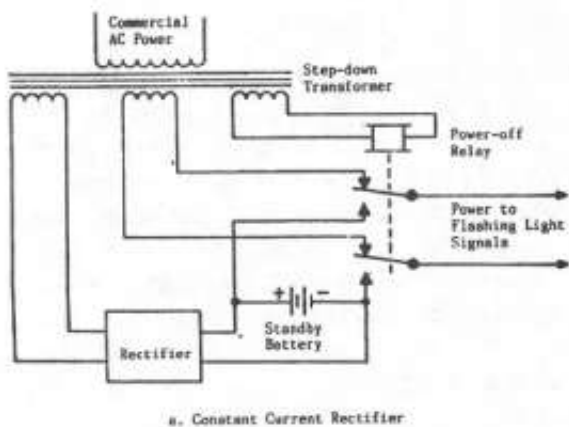
9 Mansel, D.M., V.H. Waight, and J.T. Sharkey. "Supervised Interconnection Circuits at Highway-Rail Grade Crossings." *ITE Journal*, Vol. 9, No. 3 (March 1999) (www.ite.org).

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

11 Marshall, Peter S. and William D. Berg. "Design Guidelines for Railroad Preemption at Signalized Intersections." *ITE Journal*, Vol. 67, No. 2 (February 1997).

12 Seyfried, Robert K. "Timing of Traffic Signal Preemption at Intersections Near Highway-Railroad Grade Crossings." Compendium of Technical Papers, 2001 Annual Meeting, Institute of Transportation Engineers, August 2001.

Figure 40. Stand-By Power Arrangement



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

Care should be taken to ensure that the warning time is not excessive. If the motorist cannot see the train approaching (due to sight obstructions or track curvature), excessive warning time may cause a motorist to attempt to cross the tracks despite the operation of the flashing light signals.

Excessive warning time has been determined to be a contributing factor in some collisions. Motorists who are stopped at an activated flashing light signal and see no train approaching or see a distant train moving very slowly might ignore the warning of the signals and cross the tracks. A collision could result. For example, the signals may have been activated by a high-speed passenger train just out of sight, not by the slower freight. However, if motorists are successful in clearing the tracks, they may assume that other crossings have excessive warning time. When they encounter a crossing with minimum warning time, they may ignore the signals, move onto the crossing, and become involved in a collision. This credibility problem is strengthened if motorists continue to successfully pass through activated signals with excessive warning time.

Equipment housing should be located where it is least likely to be struck by a vehicle leaving the roadway. It should not unduly obstruct motorists' view of an approaching train. Factors that may be considered in the design and installation of a train detection system include:

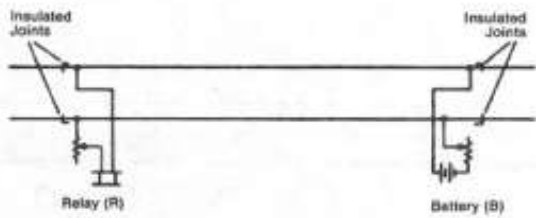
- Existing rail and ballast conditions.
- Volume, speed, and type of highway and rail traffic.
- Other train detection circuits that may be used on the same pair of rails for the regulation of train movements.
- Train propulsion currents on electrified lines.
- Track switch locations within the approach warning distances for a crossing.
- Train detection circuits used for other crossings within the approaches (overlapping).
- Number of tracks.

The design and application of train detection circuits are accomplished by railroad signal engineers. Five basic types of train detection systems are in use today:

- Direct current (DC) track circuit.
- AC-DC track circuit.
- Audio frequency overlay (AFO) track circuit.
- Motion-sensitive track circuit.
- Constant warning time track circuit.

DC track circuit. The DC track circuit, as shown in Figure 41, was the first means used for automatic train detection. It is a relatively simple circuit and is still used in many crossing warning systems. The maximum length of these circuits is more than adequate to provide the necessary warning time for crossing warning systems with today's train speeds.

Figure 41. DC Track Circuit

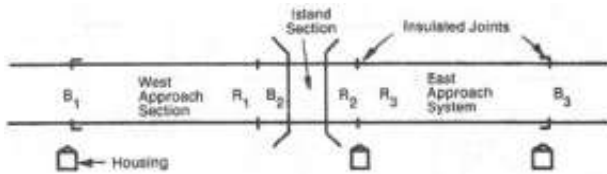


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

The rails are used as conductors of energy supplied by a battery. This energy flows through a limiting resistor to one rail, then through another limiting resistor to the coil of a DC relay, back over the other rail to the battery, thereby completing a simple series circuit. The relay is energized as long as the rails are intact and no train is present on the circuit between the battery and the relay. The limits of the circuit are established by the use of insulated joints, devices placed between adjoining rail sections to electrically isolate the two sections.

To provide a means for stopping the operation of the crossing warning system as soon as the train clears the crossing, three-track circuits, as shown in Figure 42, and associated logic elements are required per track. The logic elements are arranged such that, as the train moves through the crossing, the crossing clears for highway traffic as soon as the rear end of the train leaves the island section.

Figure 42. Three-Track Circuit System

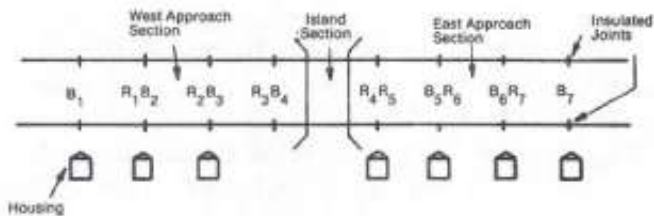


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

All trains activate the crossing warning system as soon as the first set of wheels of the train enters the approach track circuit. This track circuit must be long enough to provide the minimum warning time for the fastest train. A slow train will operate the crossing warning system for a longer period of time. If a train stops before it reaches the crossing, the crossing warning system continues to operate, which results in an additional delay to highway traffic.

To overcome this problem, approach sections may be divided into several short track circuits, as shown in Figure 43, and timers may be incorporated into the logic. This permits more consistent warning time. Also, if a train stops in the approach section, a "time-out" feature will deactivate the warning devices to allow highway traffic to move over the crossing.

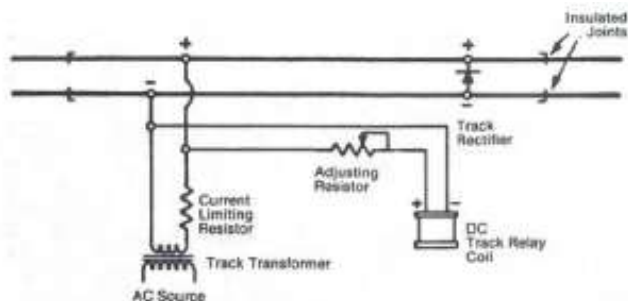
Figure 43. Track Circuits with Timing Sections



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

AC-DC track circuit. The AC-DC track circuit, as shown in Figure 44 (sometimes referred to as Type C), is used extensively when approach distances are less than 3,000 feet and no other circuits are present on the rails. The AC-DC track circuit is a half-wave rectified AC circuit with all operating equipment located at the crossing. A rectifier is connected across the rails at the far end of the track circuit. As is the case with DC circuits, insulated joints define the limits. An advantage of this circuit is that all control equipment is located in a single housing at the crossing. Shunting is also improved due to the somewhat higher voltages used across the rails.

Figure 44. AC-DC Track Circuit

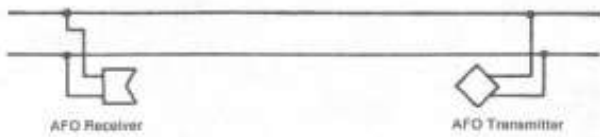


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

A simple explanation of the operation of the AC-DC (or Type C) track circuit is that the major portion of the transformer secondary current flows through the rectifier during one half-cycle and through the relay during the other half-cycle, providing a net DC component in the track relay. A shunt on the rails reduces the rail voltage, causing the track relay to release, thereby activating the system. As is the case with DC track circuits, three circuits are normally used to establish train direction.

AFO track circuit. The AFO track circuit, as shown in Figure 45, is similar in application to the DC track circuit, except that it can be superimposed over other circuits that may exist on the rails. Instead of the battery and relay used in the DC circuit, a transmitter and receiver of the same frequency are used for each AFO track circuit. No insulated joints are required with this type of circuit.

Figure 45. Audio Frequency Overlay Track Circuit



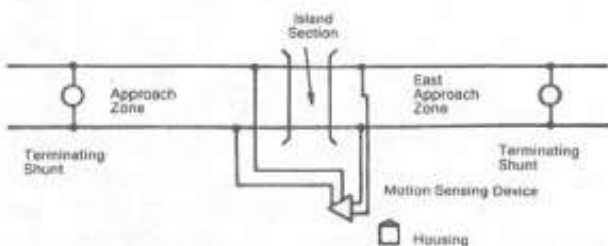
Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

The AFO track circuit uses an AC signal applied to the rails through a transmitter. This signal is transmitted via the rails to a receiver at the opposite end of the track circuit, which converts the AC signal to DC to operate a relay, which, in turn, performs the function of operating the warning devices via the control logic similar to the DC track circuit. Once again, three circuits are required to establish the direction in which the train is moving.

Motion-sensitive track circuit. This type of circuit employs audio frequencies similar to AFO equipment and is designed to detect the presence as well as the direction of motion of a train by continuously monitoring the track circuit impedance. As long as the track circuit is unoccupied or no train is moving within the approach, the impedance of the track circuit is relatively constant. Decreasing track circuit impedance indicates that a train is moving toward the crossing. If a train subsequently stops, the impedance will again remain at a constant value. If the train is moving away from a crossing, the impedance will increase. Thus, if the train stops on the approach or moves away from the crossing, the crossing warning system is deactivated and the crossing is cleared for highway traffic.

This type of circuit is advantageous where trains stop or conduct switching operations within the normal approach limits of a particular crossing. All powered equipment is located at the crossing, with the additional advantage that insulated joints are not required when applied in a bi-directional manner, as shown in Figure 46. Adjacent crossing circuits can be overlaid and overlapped with other train detection circuits. Tuned electrical shunts are required to define the end limits of motion sensitive circuits, and coupling units are required to bridge any existing insulated joints used in conjunction with other types of track circuits, such as might be required for wayside signaling purposes.

Figure 46. Motion-Sensitive Track Circuit, Bi-Directional Application

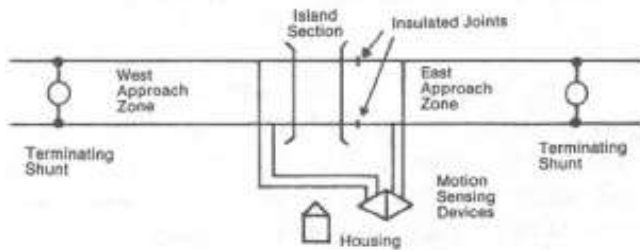


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

Where longer approach zones are required or where ballast or track conditions dictate, a uni-directional application may be desirable. In this type of application, one device is required for each approach zone, with insulated rail joints used to separate the two approach zones, as shown in

Figure 47.

Figure 47. Motion-Sensitive Track Circuit, Uni-Directional Application

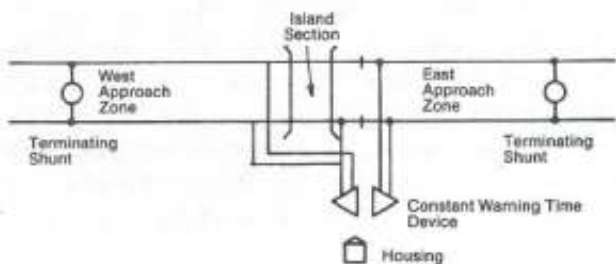


Source: Railroad-Highway Grade Crossing Handbook, Second Edition. Washington, DC: U.S. Department of Transportation, Federal Highway Administration, 1986.

Constant warning time track circuit. Constant warning time equipment has the capability to sense a train in the approach section, measure its speed and distance from the crossing, and activate the warning equipment to provide the selected minimum warning time. Thus, regardless of train speed, a uniform warning time is provided. If a train stops prior to reaching the crossing or is moving away from the crossing, the warning devices are deactivated to allow highway traffic to move over the crossing. With constant warning time equipment, trains beyond 700 feet (213 meters) can move or switch on the approaches without reaching the crossing and, depending on their speed, never cause the crossing warning devices to be activated, thus eliminating unnecessary delays to highway traffic.

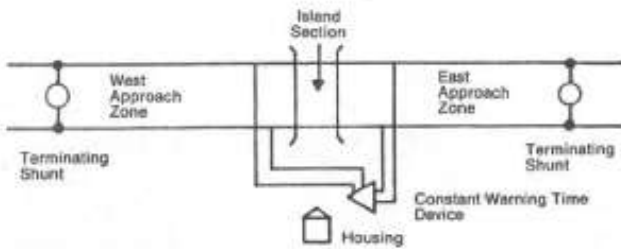
The latest constant warning time devices, like motion-sensitive devices, may be applied either in a unidirectional or bi-directional mode, as shown in Figures 48 and 49, respectively. A uni-directional application requires two devices, one monitoring each approach zone, with the approach zones separated by insulated rail joints. A terminating shunt is placed at the outermost end of each approach zone. The location of the terminating shunt is determined by the fastest train using the crossing.

Figure 48. Constant Warning Time Track Circuit, Uni-Directional Application



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

Figure 49. Constant Warning Time Track Circuit, Bi-Directional Application



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

A uni-directional application is suggested in situations where there are closely following train moves or to break up frequency pollution. Uni-directional installations are suggested to avoid bypassing insulated joint locations when bypassing these joints is not desirable.

A bi-directional application uses a single constant warning time device, which monitors both approach zones. Insulated rail joints are not required. Again, terminating shunts are placed at the outermost end of each approach zone. The bi-directional application is normally used where moderate train speeds are employed, thus requiring shorter approach zones, and where track and ballast conditions permit.

Motion-sensing and constant warning time track circuits should be considered for crossings on railroad mainlines, particularly at crossings with variations in train speeds and with a number of switching movements on the approach sections.

Warning time and system credibility.

Reasonable and consistent warning times reinforce system credibility. Unreasonable or inconsistent warning times may encourage undesirable driver behavior. Research has shown that 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. Although mandated maximum warning times do not yet exist, efforts should be made to ensure that 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 or 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, such as intercity 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 are needed between the highway agency and the 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, MUTCD requires that the system provide for a minimum of 20 seconds of warning time. When determining if the minimum 20 seconds of warning time should be increased, the following factors should be considered:

- Track clearance distances due to multiple tracks and/or angled crossings (add 1 second for each 3 meters (10 feet) of added crossing length in excess of 10.7 meters (35 feet)).
- 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 (such as school buses and hazardous materials vehicles).
- The crossing's active traffic control devices are interconnected with other highway traffic signal systems.
- 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.
- Where additional warning time is needed to accommodate a four-quadrant gate system.

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 AREMA *Communications and Signal Manual*, Part 3.1.10, "Recommended Functional/Operating Guidelines for Interconnection Between Highway Traffic Signals and Highway-Rail Grade Crossing Warning Systems," and Part 3.3.10, "Recommended Instructions for Determining Warning Time and Calculating Minimum Approach Distance for Highway-Rail Grade Crossing Warning Systems." [98](#)

17. Pre-Signals

A recent article in *ITE Journal* describes and summarizes the state of the practice regarding the use of pre-signals—highway signals installed to stop traffic before it crosses the railroad.^{[99](#)} The purpose of installing highway traffic signals in this manner at a crossing is to prevent vehicles from queuing across the grade crossing and finding themselves stopped on the tracks in the area now known as the minimum track clearance distance.

Differing names or descriptions were given to early pre-signal installations, such as double clearance signals, signals before the tracks, and overlap signals, among others. Previously, there were no broadly accepted guidelines for the use of these specialized signals. In June 1997, a U.S. DOT task force established industry-standard definitions relating to the interconnection of highway traffic signals with highway-rail grade crossing warning systems. In this report, pre-signals were defined as: “supplemental highway traffic signal faces [that are] operated as a part of the highway intersection traffic signals, [and are] located in a position that controls [highway] traffic approaching the railroad crossing and intersection.”¹⁰⁰

The timing and display of these highway traffic signals are integrated with the railroad's preemption program. FHWA's “Guidance on Traffic Control Devices at Highway-Rail Grade Crossings” illustrates a typical installation of pre-signals at a gated crossing. The illustration depicts the elements common to the pre-signal installations normally encountered.¹⁰¹

MUTCD Section 8D.07 lays out a framework of standards, guidance, and options for the use of pre-signals:

If used, the pre-signals shall display a red signal indication during the track clearance portion of a signal preemption sequence to prohibit additional vehicles from crossing the railroad track... If a pre-signal is installed at an interconnected highway-rail grade crossing near a signalized intersection, a STOP HERE ON RED (R10-6) sign shall be installed near the pre-signal or at the stop line if used. If there is a nearby signalized intersection with insufficient clear storage distance for a design vehicle, or the highway-rail grade crossing does not have gates, a NO TURN ON RED (R10-11) sign shall be installed for the approach that crosses the railroad track.

The option is offered in MUTCD Section 8D.07 to time the pre-signals with an offset from the signalized intersection (by providing a “green extension” at the downstream intersection signal); this would keep vehicles from occupying either the roadway area between the gates or the area between the grade crossing and the downstream signalized intersection. This option should be explored during a field review by the diagnostic team prior to the design and installation of the pre-signals.

Criteria for use. In 2004, ITE issued a recommended practice that provides the following guidance:¹⁰²

Pre-signals can be located to stop vehicular traffic before the railroad crossing where the clear storage distance (measured between 6 ft. (2 m) from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway) is 50 ft. (15 m) or less. At approaches where high percentages of multi-unit vehicles are evident, the distance should be increased to 75 ft. (23 m). A vehicle classification study should be conducted to determine the types of vehicles using the crossing. Where the clear storage distance is greater than 50 ft. (15 m) or 75 ft. (23 m), depending on the roadway vehicle design length, but less than 120 ft. (37 m), pre-signals can be used only after an engineering study determines that the queue extends into the track area.

If the clear storage distance is greater than 120 ft. (37 m), any traffic signal heads located at a railroad crossing should be considered to be a separate mid-block crossing (a “queue-cutter” signal), and not a pre-signal. However, coordination with the intersection signals may still be appropriate. Pre-signals or queue-cutter signals should also be used wherever traffic could queue across the tracks and railroad warning devices consist only of flashing light signals. However, this can result in conflicting signal indications between the flashing red lights at the crossing and a display of track clearance green beyond the crossing. The installation of gates will eliminate this

conflict.

Pre-signal location. Pre-signal mast arm poles can be located upstream or downstream from the railroad crossing. In all cases, pre-signal poles must be located to maintain visibility of the railroad flashing lights. If an existing railroad cantilever exists, and upstream pre-signals are used, the heads may be mounted on the cantilever if permitted by the railroad or regulatory agency. If they are on a separate mount, they must be located to avoid blockage or interference with the visibility of the railroad flashing lights. Railroad flashing lights should be located as specified in Chapter 8D of MUTCD. Refer also to AREMA *Communications and Signal Manual* Parts 3.1.36 and 3.1.37 for additional guidance regarding the location of railroad warning devices.¹⁰³ Figure 50 shows a pre-signal mounted on the railroad cantilever.

MUTCD Section 4D.15 (“Size, Number, and Location of Signal Faces by Approach”) establishes the standards for traffic signal faces that shall be satisfied by any installation of pre-signals. Specifically, Section 4D.15 states as a standard that signal faces for the major movement on the approach shall be located not less than 12 meters (40 feet) beyond the stop line. MUTCD Table 4D-1 contains the required minimum sight distance for a range of 85th-percentile approach speeds. If these minimums cannot be met on an approach, a sign shall be installed to warn approaching traffic of the traffic control signal. In Figure 51, the pre-signal stop bar has been displaced ahead of the grade crossing to comply with this provision where the pre-signal is mounted ahead of the grade crossing.

Downstream signal. *The downstream traffic signal faces at the roadway intersection that control the same approach as the pre-signal may be equipped with programmable-visibility heads or louvers as appropriate based on an engineering study. The purpose of the signal programmable-visibility heads or louvers is to limit visibility of the downstream signal faces to the area from the intersection stop line to the location of the first vehicle behind the pre-signal stop line. This is to prevent vehicles stopped at the railroad crossing stop line from seeing the distant green signal indication during the clear track green. An engineering study should be conducted to review the specific site conditions, including the eye heights of drivers of vehicles likely to use the crossing, and establish the final design necessary to meet the visibility requirements.*¹⁰⁴

Figure 50. Pre-Signal Mounted on Railroad Cantilever, Rollins Road and State Route 83 at Wisconsin Central, Round Lake, Illinois



Source: Korve Engineering, Inc.

Figure 51. Pre-Signal Located Ahead of Grade Crossing with Displaced Stop Bar, S. Mary and W. Evelyn at Caltrain Commuter Line, Sunnyvale, California



Source: Korve Engineering, Inc.

Figure 52. Pre-Signal with Louvered Downstream Intersection Signal, Sierra and Orange at



Source: Kolve Engineering, Inc.

Figure 52 shows a pre-signal with a louvered downstream intersection signal. The pre-signal has been installed beyond the grade crossing to address the previously mentioned MUTCD 40-foot set-back requirement for traffic signal heads.

Pre-signal and downstream signal operation.

The pre-signal intervals should be progressively timed with the downstream signal intervals to provide adequate time to clear vehicles from the track area and the downstream intersection. Vehicles that are required to make a mandatory stop such as school buses, vehicles hauling hazardous materials, etc., should be considered when determining the progressive timing to ensure that they will not be stopped within the minimum track clearance distance. Where the clear storage distance is inadequate to store a design vehicle clear of the minimum track clearance distance and crossing gates are present, consideration should be given to installation of vehicle detection within the clear storage distance to prevent vehicles from being trapped within the minimum track clearance distance by extending the clear track green interval.¹⁰⁵

Queue cutters. It is valuable to remember that although a queue cutter signal may in many ways resemble a pre-signal, it differs in certain ways. A signal should be used as a queue cutter when the clear storage distance exceeds 120 feet and the traffic signal uses downstream vehicle detection to change the signals to red when the standing queue from the downstream signal is about to extend into the minimum track clearance distance. Such a queue cutter signal will be interconnected for simultaneous preemption and may or may not function as a part of the

downstream intersection signal system. A field analysis and review should be conducted, sufficient to determine whether to pursue coordination of the queue cutter with the downstream intersection signals. Figure 53 indicates a stand-alone queue cutter (no other intersection signals are present).

Figure 53. Queue Cutter, Magnolia Street at Union Pacific Railroad, Riverside, California



Source: Korve Engineering, Inc.

Advance heads. Advance heads are traffic signal heads that provide the same display indication upstream from the grade crossing as the primary traffic signal heads mounted at the downstream intersection (see Figure 54). A vehicle that encounters a yellow indication at the advance head may not be able to clear the downstream intersection and, therefore, may stop in the clear storage area between the intersection and the grade crossing. For this reason, advance heads are best used when there is little or no clear storage distance beyond the grade crossing. However, vehicles arriving after the onset of the red phase will be held upstream from the grade crossing. Therefore, use of an advance head can reduce the likelihood of queuing on the tracks during the red phase. Advance heads can also address issues in which the intersection heads are not readily visible to drivers approaching the grade crossing due to roadway geometrics.

Overcoming resistance to pre-signals. Some traffic engineers may be reluctant to use pre-signals because they believe that vehicles stopped upstream from the crossing at the pre-signal will be prevented from being able to advance to the highway intersection and turn right on red. The temporary loss of flow due to right turn on red being precluded during the presence of a train is outweighed by the reduction in the potential for a severe collision between a stopped vehicle and a train. Unfortunately, the opportunity for this type of collision is frequent when viewed on a national basis. In addition, the capacity lost from right turns on red often can be recaptured by more precise timing of the traffic signal preemption sequence based upon site conditions, especially when the railroad crossing is frequently used by train traffic.

Figure 54. Advance Head, Broadway and Arguello at Caltrain Commuter Line, Redwood City, California



Source: Korve Engineering, Inc.

Avoiding common pitfalls of pre-signals. As stated in an *ITE Journal* article, pre-signals are a specialized tool with specific applications.¹⁰⁶ Traffic engineers should bear in mind several important principles when considering the use of a pre-signal system at a highway-rail grade crossing:

- A pre-signal is not a substitute for a proper track clearance green interval.
- Employing pre-signals requires that engineers consider the use of “No Turn on Red” signage at the pre-signal to deter drivers wishing to turn right on red at the downstream intersection from passing the pre-signals and crossing the tracks.
- A pre-signal face located less than 40 feet from the stop line will not be effective for motorists at the stop line. In the case of a shorter separation distance between pre-signal and stop line, motorists may be tempted to pull out onto the track when the track clearance green interval is displayed.
- A pre-signal is not an alternative to the use of advance preemption. Advance preemption is necessary where the right-of-way transfer time, queue clearance time, and separation time exceed the railroad warning time, and the clear storage distance exceeds approximately 80 feet (adequate storage distance for a 65-foot tractor-trailer combination). Advance preemption also may be required where this distance is less than 80 feet to prevent vehicle-gate interaction (striking the vehicle with the descending gate arm) or to prevent turning vehicles approaching the crossing from the intersection

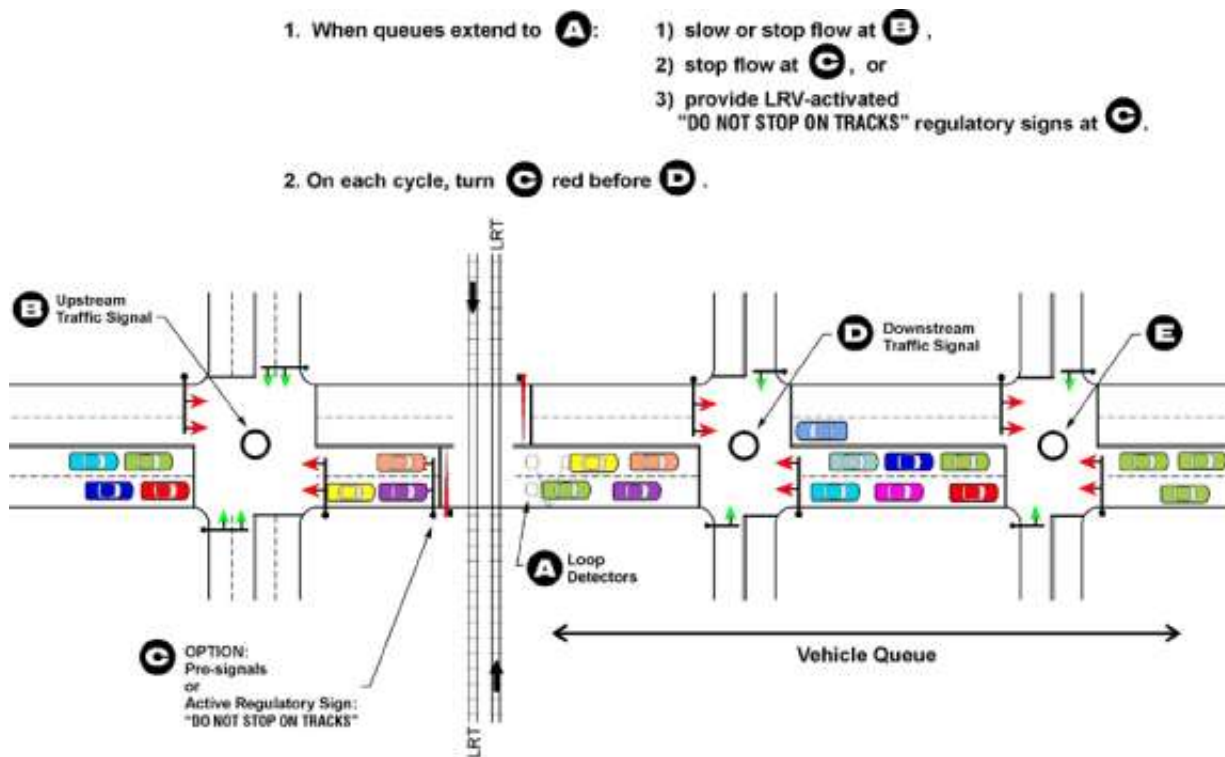
side from blocking the exit path of vehicles attempting to vacate the crossing during track clearance green.

- If a pre-signal is expected to keep vehicles off the tracks and function as a part of the preemption sequence, it must be provided with battery back-up equivalent to that provided for the railroad warning devices.

18. Queue Prevention Strategies

In the event that queuing extends across multiple intersections, use of preemption, pre-signals, and/or queue cutters may be ineffective, and a broader treatment may be required. The following guidance was adapted from material presented in the context of managing cross-street queuing at LRT grade crossings.^{[107](#)}

Figure 55. Queue Prevention Strategies



Source: Korve Engineering, Inc.

At highway-rail grade crossings located near signalized intersections, where traffic congestion precludes using standard traffic signal preemption, traffic control strategies may be used to prevent queues from extending back over the tracks (see Figure 55). Standard traffic signal preemption operates under the assumption that motor vehicles queue back from the nearby signalized intersection (signal **D** in Figure 55). The preemption sequence (occurring at the traffic signals downstream of the grade crossing) then clears these queued vehicles off the tracks before the train arrives at the crossing.

However, at some locations, it may not be practical or possible to clear vehicles from the tracks by preempting the downstream traffic signals. For example, if the roadway corridor extending downstream from the grade crossing is heavily congested, preempting the downstream traffic signals still may not allow motor vehicles to move forward enough to clear the crossing because of downstream congestion. If the level of traffic congestion is substantial, it may be necessary to

preempt several downstream traffic signals, which requires an approaching train to be detected (and predicted) several minutes before it arrives at the crossing. In such cases, a queue prevention strategy may be more appropriate.

The basic concept of queue prevention is as follows: If a queue is detected across a highway-rail grade crossing, traffic approaching the crossing will be stopped by a signal upstream of the grade crossing (signals B or C in Figure 55) to prevent the queue from building back across the tracks. As indicated, vehicle detectors can be installed at location A; if stopped or slow vehicles are detected at location A, logic built into the traffic signal system could:

- Stop the major flow of traffic at signal B (including control of turning traffic if necessary and appropriate).
- Stop the flow of traffic at signal C by using traffic signals on the near side of the LRT crossing (such as pre-signals, as previously described).
- Warn highway users not to stop on the tracks by providing an activated, internally illuminated “Do Not Stop on Tracks” sign (R8-8) mounted on a mast arm over each lane of traffic at location C (these signs would activate when queues are detected at location A).
- Provide exclusion zone diagonal striping as described elsewhere in this handbook. (The use of diagonal striping to provide an area where motorists cannot stop is standard practice in Illinois at all grade crossings that are interconnected to an adjacent traffic signal. The NCUTCD grade crossing committee is considering provisions for future versions of the manual).

In the event that such a queue management strategy were provided, the grade crossing would in principle be clear of highway users at all times, whether or not a train was approaching the crossing, and the use of preemption would operate more as a fail-safe measure rather than a primary measure for keeping the tracks clear.

Footnotes

90 At the January 2006 meeting of the National Committee on Uniform Traffic Control Devices (NCUTCD), the council approved a change that will require use of vertical red and white bands on crossing gate arms if incorporated into the *Manual on Uniform Traffic Control Devices* (MUTCD).

91 “Regulations Governing the Protection Of Crossings At Grade Of Roads, Highways And Streets With Railroads In The State Of California.” Section 6.71 (www.cpuc.ca.gov/word_pdf/GENERAL_ORDER/20555.doc).

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

93 North Carolina Department of Transportation Sealed Corridor Program Website, “Median Separators” (www.bytrain.org/safety/sealed.html).

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

95 Ibid.

96 *Manual on Uniform Traffic Control Devices, 2003 Edition*. Washington, DC: FHWA, 2003.

97 *Preemption of Traffic Signals Near Railroad Crossings: An ITE Recommended Practice*. Prepared by Traffic Engineering Council Committee TENC-99-06. Washington, DC: Institute of Transportation Engineers, 2006.

98 American Railway Engineering and Maintenance-of-Way Association. *Communications and Signal Manual*, Part 3.1.10 (www.arema.org/pubs/pubs.htm).

99 Gilleran, Brian F. "Use of Pre-Signals in Advance of a Highway-Rail Grade Crossing: A Specialized Tool with Specific Applications." *ITE Journal*, Vol. 76, No. 5 (May 2006): 22–25.

100 *Implementation Report of the U.S. DOT Grade Crossing Safety Task Force, Report to Secretary Rodney E. Slater*. FHWA-SA-97-085, Grade Crossing Safety Task Force, 1997.

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

102 *Preemption of Traffic Signals Near Railroad Crossings: An ITE Recommended Practice*. Prepared by Traffic Engineering Council Committee TENC-99-06. Washington, DC: Institute of Transportation Engineers, July 2003.

103 Ibid.

104 Ibid.

105 Ibid.

106 Gilleran, Brian F. "Use of Pre-Signals in Advance of a Highway-Rail Grade Crossing: A Specialized Tool with Specific Applications." *ITE Journal*, Vol. 76, No. 5 (May 2006): 22–25.

107 Korge, Hans W. , Brent D. Ogden, Joaquin T. Siques, D. Mansel, et al. *Light Rail Service: Pedestrian and Vehicular Safety*. Washington, DC: Transit Cooperative Research Program Report 69, National Academy Press, 2001, p. 85–86.

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