- the crossing is regularly used by long tractor-trailer vehicles;
- the crossing is regularly used by vehicles required to make mandatory stops before proceeding over the crossing (e.g. school buses and hazardous materials vehicles);
- the crossing's active traffic control devices are interconnected with other highway traffic signal systems;
- provide at least 5 seconds between the time the approach lane gates to the crossing are fully lowered and when the train reaches the crossing, per 49 CFR Part 234;
- the crossing is regularly used by pedestrians and non-motorized components;
- where the crossing and approaches are not level and ;
- where additional warning time is needed to accommodate a four-quadrant gate system.

INTERFERENCE / INTEGRITY OF ACTIVE TRAFFIC CONTROL DEVICE SYSTEMS

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

TYPE OF DETECTION SYSTEM

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

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

Motion Sensitive Devices (MS)

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

Constant Warning Time (CWT) Systems

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

RAILROAD TRAIN DETECTION TIME AND APPROACH LENGTH CALCULATIONS

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

Design information about railroad interconnection circuits and approach length calculations can be found in the American Railway Engineering and Maintenance-of-Way Association (AREMA) Signal Manual[8], Manual Part 3.1.10, *Recommended Functional/Operating Guidelines for Interconnection Between Highway Traffic Signals and Highway - Rail Grade Crossing Warning Systems*; and Manual Part 3.3.10, *Recommended Instructions for Determining Warning Time and Calculating Minimum Approach Distance for Highway-Rail Grade Crossing Warning Systems.*

<u>PREEMPTION/INTERCONNECTION:</u>

WHEN TO INTERCONNECT

The guidance in the MUTCD states: "When a highway-rail grade is equipped with a flashing-light signal system and is located within 60 m (200 ft) of an intersection or mid-block location controlled by a traffic control signal, the traffic control signal should be provided with preemption in accordance with Section 4D.13." Recent studies indicate that when designing for the installation of a new traffic control signal substantially beyond 60 m (200 ft) (possibly 152-305m [500-

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

1000 ft]) of a highway-rail grade crossing, an estimate of the expected queue length should be performed. For estimation purposes, a 95% probability level should be used. If the resulting expected queue length is equal to or greater than the available storage distance, consideration should be given to interconnecting the traffic control signal with the active control system of the railroad crossing and providing a preemption sequence. Guidance on estimating queue length is available in the article, "Design Guidelines for Railroad Preemption at Signalized Intersections," *ITE Journal*, February 1997. Guidance on the design of preemption operation is available in *Preemption of Traffic Signals At or Near Railroad Grade Crossings with Active Warning Devices*, #RP-025A, Institute of Transportation Engineers, 1997 www.ite.org or 202-289-0222; and the *Implementation Report of the USDOT Grade Crossing Safety Task Force, June 1, 1997, U.S. Department of Transportation*, www.fhwa.dot.gov. The *Implementation Report* is an excellent source of definitions.

FACTORS TO CONSIDER

Joint Agency Coordination

Close coordination between the highway agency and the railroad company is required when interconnecting a traffic signal with active railroad traffic control devices. In order to properly design the highway-rail preemption system, both the railroad company and the highway agency should understand how each system operates. An engineering study should be conducted at each interconnected location to

determine the minimum preemption warning time necessary to adequately clear traffic from the crossing in the event of an approaching train. Factors that need to be considered when calculating this time are equipment response and programmed delay times, minimum traffic signal green times, traffic signal vehicular and pedestrian clearances, queue clearance times and train/vehicle separation time.

Extended Advance Warning Times

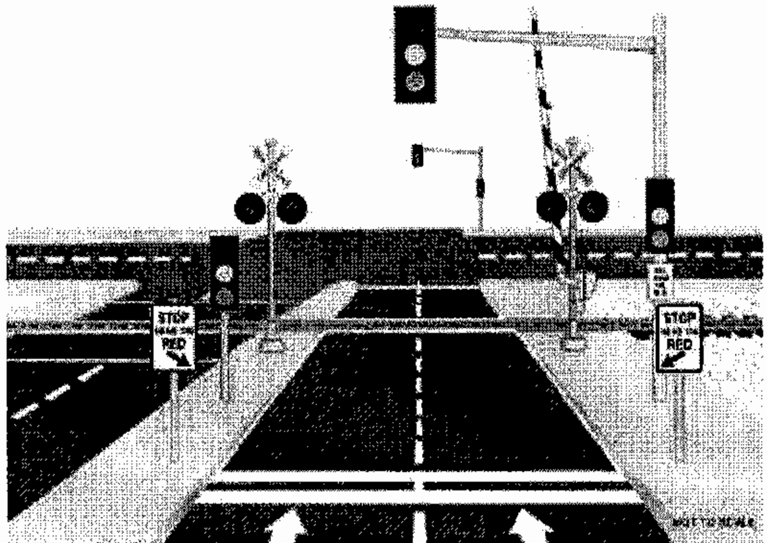
Whenever it becomes necessary at gated crossings to provide design advance warning times in excess of 45 seconds, whether for traffic signal preemption or other purposes, consideration should be given to including supplemental median treatments to discourage drivers from attempting to circumvent the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

Second Train Circuitry at Multiple Track Crossings

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

Diagonal Railroad Crossing Both Highway Approaches to the Intersection

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



PRE-SIGNAL LOCATION AT AUTOMATIC GATE CROSSING
FIGURE 4

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.

Pre-Signals

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

Figure 4

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

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

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

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

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

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

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

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

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

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

In cases where the crossing is located far from the highway intersection -- up to 305 m (1000 ft), the necessary minimum preemption warning time may be very high and in turn may require very long approach circuits along the tracks in order to provide such a time. Long track circuits can become extremely complex and expensive to implement, especially if located in an area where there are several adjacent crossings with overlapping track circuits, switching spurs, railroad junctions or commuter rail stations which could affect train operating speeds within the detection circuit. In addition, excessive preemption times may have detrimental effects on traffic flows within the vicinity of the crossing and may cause other problems such as traffic backing up along a route parallel to the crossing and backing up through another adjacent interconnected intersection. These are just a few factors to consider with a long distance interconnection.

Queue Cutter Flashing-light Beacon

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

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

Also See Appendix for additional information

OTHER SPECIAL CONDITIONS

POTENTIAL QUEUING ACROSS TRACKS

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

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

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

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

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

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

(SECOND) TRAIN COMING ACTIVE WARNING SIGN

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

PEDESTRIAN AND BICYCLIST CONSIDERATIONS

Non-motorist-crossing safety should be considered at all highway-rail grade crossings, particularly at or near commuter stations and at non-motorist facilities, such as bicycle/walking trails, pedestrian only facilities, and pedestrian malls.[9]

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

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

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

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

ALTERNATIVES TO MAINTAINING THE CROSSING

CROSSING CLOSURE

Eliminating redundant and unneeded crossings should be a high priority. Barring highway or railroad system requirements that require crossing elimination, the decision to close or consolidate crossings requires balancing public necessity, convenience and safety. The crossing closure decision should be based on economics; comparing the cost of retaining the crossing (maintenance, accidents, and cost to improve the crossing to an acceptable level if it would remain, etc.) against the cost (if any) of providing alternate access and any adverse travel costs incurred by users having to cross at some other location. Because this can be a local political and emotional issue, the economics of the situation cannot be ignored. This subject is addressed in a 1994 joint FRA/FHWA publication entitled *Highway-Railroad Grade Crossings: A Guide To Crossing Consolidation and Closure*, and a March 1995 AASHTO publication, *Highway-Rail Crossing Elimination and Consolidation*.[1]

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

GRADE SEPARATION

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

- eliminating train/vehicle collisions (including the resultant property damage and medical costs, and liability);
- savings in highway-rail grade crossing surface and crossing signal installation and maintenance costs;
- driver delay cost savings;
- costs associated with providing increased highway storage capacity (to accommodate traffic backed up by a train);
- fuel and pollution mitigation cost savings (from idling queued vehicles);
- effects of any "spillover" congestion on the rest of the roadway system;

[1] *See footnotes 20 and 21.*

- the benefits of improved emergency access;
- the potential for closing one or more additional adjacent crossings; and
- possible train derailment costs.

A recently released report, entitled "Grade Separations-When Do We Separate,[2]" provides a stepwise procedure for evaluating the grade separation decision. The report also contains a rough screening method based on train and roadway vehicular volumes. However, as pointed out in the report, the screening method should be used with caution and should be calibrated for values appropriate for the particular jurisdiction.

TRAFFIC SEPARATION STUDY APPROACH TO CROSSING CONSOLIDATION

Both the FRA [3] and the AASHTO [4] have provided guidelines for crossing consolidation. State DOTs, road authorities and local governments may choose to develop their own criteria for closures based on local conditions. Whatever the case, a specific criteria or approach should be used, so as to avoid arbitrarily selecting crossings for closure. An example is provided by the North Carolina DOT.[5]

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

Crossing information is collected at all public crossings in the municipality. Evaluation criteria include: collision history, current and projected vehicular and

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

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

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

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

train traffic, crossing condition, school bus and emergency routes, types of traffic control devices, feasibility for improvements and economic impact of crossing closures. After discussions with the local road authority, railroad, State DOT, municipal staff and local officials these recommendations may be modified. Reaching a "consensus" is essential prior to scheduling presentations to governing bodies and citizens.

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

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

NEW CROSSINGS

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

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

GUIDANCE

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

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

2. ***MINIMUM WIDTHS*** - All highway-rail grade crossing surfaces should be a minimum of one foot beyond the edge of the roadway shoulder measured perpendicular to the roadway center line, and should provide for any existing pedestrian facilities.

3. ***PASSIVE*** - Minimum Traffic Control Applications:
   A. A circular Railroad Advance Warning (W10-1) sign shall be used on each roadway in advance of every highway-rail grade crossing except as described in the MUTCD;

   B. An emergency phone number should be posted at the crossing. This posting should include the USDOT highway-rail grade crossing identification number, highway or street name or number, railroad milepost and other pertinent information;

C. Where the roadway approaches to the crossing are paved, pavement markings are to be installed as described in the MUTCD, subject to engineering evaluation;

D. Where applicable, the TRACKS OUT OF SERVICE sign should be placed to notify drivers that track use has been discontinued;

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

F. Supplemental Passive Traffic Control Applications (subject to engineering evaluation);
   1) Inadequate Stopping Sight Distance:
      a) Improve the roadway geometry;
      b) Install appropriate warning signs (including consideration of active types);
      c) Reduce the posted roadway speed in advance of the crossing:
         i) Advisory signing as a minimum;
         ii) Regulatory posted limit if it can be effectively enforced;
      d) Close the crossing;
      e) Reconfigure/relocate the crossing;
      f) Grade separate the crossing.
   2) Inadequate Approach (Corner) Sight Distance (Assuming Adequate Clearing Sight Distance):
      a) Remove the sight distance obstruction;
      b) Install appropriate warning signs;
      c) Reduce the posted roadway speed in advance of the crossing:
         i) Advisory signing as a minimum;
         ii) Regulatory posted limit if it can be effectively enforced;
      d) Install a YIELD (R1-2) sign, with advance warning sign (W3-2a) where warranted by the MUTCD (restricted visibility reduces safe approach speed to 16- 24 km/h [10-15 mph]);
      e) Install a STOP (R1-1) sign, with advance warning sign (W3-1a) where warranted by the MUTCD (restricted visibility requires drivers to stop at the crossing);

f) Install active devices;
g) Close the crossing;
h) Reconfigure/relocate the crossing;
i) Grade separate the crossing.

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

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

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

TABLE 6
GUIDELINES FOR ACTIVE DEVICES

Class of Track	Maximum Allowable Operating Speed For *Freight* Trains - Minimum Active Devices		Maximum Allowable Operating Speed For *Passenger* Trains - Minimum Active Devices	
Excepted track	10 mph	Flashers	N/A	N/A
Class 1 track	10 mph	Flashers	15 mph	Gates *
Class 2 track	25 mph	Flashers	30 mph	Gates *
Class 3 track	40 mph	Gates	60 mph **	Gates **
Class 4 track	60 mph	Gates	80 mph	Gates
Class 5 track	80 mph	Gates plus Supplemental Safety Devices	90 mph	Gates plus Supplemental Safety Devices
Class 6 track	110 mph with conditions	Gates plus Supplemental Safety Devices	110 mph	Gates plus Supplemental Safety Devices
Class 7 track	125 mph with conditions	Full Barrier Protection	125 mph	Full Barrier Protection
Class 8 track	160 mph with conditions	Grade Separation	160 mph	Grade Separation
Class 9 track	200 mph with conditions	Grade Separation	200 mph	Grade Separation

* Refer to MUTCD 2000 Edition, Part 10, transit and LRT in medians of city streets.
** Except 35 mph (56 km/h) for transit and LRT. Note: 1 mph = 1.61 km/h

A. Active devices ***with automatic gates*** should be considered at highway-rail grade crossings whenever an engineering study by a diagnostic team determines one or more of the following conditions exist:
   1) All crossings on the National Highway System, "U.S." marked routes or principal arterials not otherwise grade separated;
   2) If inadequate clearing sight distance exists in one or more approach quadrants, AND it is determined ALL of the following apply:
      a) It is not physically or economically feasible to correct the sight distance deficiency;
      b) An acceptable alternate access does not exist; and
      c) On a life cycle cost basis, the cost of providing acceptable alternate access or grade separation would exceed the cost of installing active devices with gates;

3) Regularly scheduled passenger trains operate in close proximity to industrial facilities, eg. stone quarries, log mills, cement plants, steel mills, oil refineries, chemical plants and land fills;
4) In close proximity to schools, industrial plants or commercial areas where there is substantially higher than normal usage by school buses, heavy trucks or trucks carrying dangerous or hazardous materials;
5) Based upon the number of passenger trains and/or the number and type of trucks, a diagnostic team determines a significantly higher then normal risk exists that a train-vehicle collision could result in death of or serious injury to rail passengers;
6) Multiple main or running tracks through the crossing;
7) The expected accident frequency (EAF) for active devices without gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.1;
8) In close proximity to a highway intersection or other highway-rail crossings and the traffic control devices at the nearby intersection cause traffic to queue on or across the tracks. (In such instances, if a nearby intersection has traffic signal control, it should be interconnected to provide preempted operation, and consider traffic signal control, if none); or
9) As otherwise recommended by an engineering study or diagnostic team.

B. Active devices, with automatic gates should be considered _as an option_ at public highway-rail grade crossings whenever they can be economically justified based on fully allocated life cycle costs _and_ one or more of the following conditions exist:
   1) Multiple tracks exist at or in the immediate crossing vicinity where the presence of a moving or standing train on one track effectively reduces the clearing sight distance below the minimum relative to a train approaching the crossing on an adjacent track (absent some other acceptable means of warning drivers to be alert for the possibility of a 2nd train); [See Figure 1.]
   2) An average of 20 or more trains per day;
   3) Posted highway speed exceeds 64 km/h (40mph) in urban areas, or exceeds 88 km/h (55 mph) in rural areas;
   4) Annual Average Daily Traffic (AADT) exceeds 2000 in urban areas, or 500 in rural areas;
   5) Multiple lanes of traffic in the same direction of travel (usually this will include cantilevered signals);
   6) The crossing exposure (the product of the number of trains per day and AADT) exceeds 5,000 in urban areas, or 4,000 in rural areas;
   7) The expected accident frequency (EAF) as calculated by the USDOT Accident Prediction formula, including 5-year accident history, exceeds 0.075;

8) An engineering study indicates that the absence of active devices would result in the highway facility performing at a level of service below Level C;
9) Any new project or installation of active devices to significantly replace or upgrade existing non-gated active devices. For purposes of this item, replacements or upgrades should be considered "significant" whenever the cost of the otherwise intended improvement (without gates) equals or exceeds one-half the cost of a comparable new installation, and should exclude maintenance replacement of individual system components and/or emergency replacement of damaged units; or
10) As otherwise recommended by an engineering study or diagnostic team.

C. Warning/Barrier Gate Systems should be considered as supplemental safety devices at:
1) Crossings with passenger trains;
2) Crossings with high-speed trains;
3) Crossings in quiet zones; or
4) As otherwise recommended by an engineering study or diagnostic team.

D. Enhancements for Pedestrian Treatments
1) Design to avoid stranding pedestrians between sets of tracks;
2) Add audible devices, based on an engineering study;
3) Consider swing gates carefully; the operation of the swing gate should be consistent with the requirements of Americans with Disability Act. The gate should be checked for pedestrian safety within the limits of its operation;
4) Provide for crossing control at pedestrian crossings where a station is located within the proximity of a crossing or within crossing approach track circuit for the highway-rail crossing;
5) Utilize a Train to Wayside Controller to reduce traffic delays in areas of stations; and
6) Delay the activation of the gates, flashers and bells for a period of time at the highway-rail grade crossing in station areas, based on an engineering study.

5. ***CLOSURE*** - Highway-rail grade crossings should be considered for closure and vacated across the railroad right-of-way whenever one or more of the following apply:
A. An engineering study determines a nearby crossing otherwise required to be improved or grade separated already has acceptable alternate vehicular access, and pedestrian access can continue at the subject crossing, if existing;

B. On a life cycle cost basis, the cost of implementing the recommended improvement would exceed the cost of providing an acceptable alternate access;

C. If an engineering study determines any of the following apply:
   1) FRA Class 1,2 or 3 track with daily train movements:
      a. AADT less than 500 in urban areas, acceptable alternate access across the rail line exists within .4 km (1/4 mi) and the median trip length normally made over the subject crossing would not increase by more than .8 km (1/2 mi);
      b. AADT less than 50 in rural areas, acceptable alternate access across the rail line exists within .8 km (1/2 mi) and the median trip length normally made over the subject crossing would not increase by more than 2.4 km (1-1/2 mi).
   2) FRA Class 4 or 5 track with active rail traffic:
      a. AADT less than 1000 in urban areas, acceptable alternate access across the rail line exists within .4 km (1/4 mi) and the median trip length normally made over the subject crossing would not increase by more than 1.2 km (3/4 mi);
      b. AADT less than 100 in rural areas, acceptable alternate access across the rail line exists within 1.61 km (1 mi) and the median trip length normally made over the subject crossing would not increase by more than 4.8 km (3 mi).
   3) FRA Class 6 or higher track with active rail traffic, AADT less than 250 in rural areas, an acceptable alternate access across the rail line exists within 2.4 km (1-1/2 mi) and the median trip length normally made over the subject crossing would not increase by more than 6.4 km (4 mi); and

D. An engineering study determines the crossing should be closed to vehicular and pedestrian traffic when railroad operations will occupy or block the crossing for extended periods of time on a routine basis and it is determined that it is not physically or economically feasible to either construct a grade separation or shift the train operation to another location. Such locations would typically include:
   1) Rail yards;
   2) Passing tracks primarily used for holding trains while waiting to meet or be passed by other trains;
   3) Locations where train crews are routinely required to stop their trains because of cross-traffic on intersecting rail lines or to pick up or set out blocks of cars or switch local industries en route;
   4) Switching leads at the ends of classification yards;
   5) Where trains are required to "double" in or out of yards and terminals;

6) In the proximity of stations where long distance passenger trains are required to make extended stops to transfer baggage, pick up or set out equipment or be serviced en route; and
7) Locations where trains must stop or wait for crew changes.

6. ***GRADE SEPARATION***

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

1) The highway is a part of the designated Interstate Highway System;
2) The highway is otherwise designed to have full controlled access;
3) The posted highway speed equals or exceeds 113 km/h (70 mph);
4) AADT exceeds 100,000 in urban areas or 50,000 in rural areas;
5) Maximum authorized train speed exceeds177 km/h (110 mph);
6) An average of 150 or more trains per day or 300 Million Gross Tons (MGT) per year;
7) An average of 75 or more passenger trains per day in urban areas or 30 or more passenger trains per day in rural areas;
8) Crossing exposure (the product of the number of trains per day and AADT) exceeds 1,000,000 in urban areas or 250,000 in rural areas; or
9) Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 800,000 in urban areas or 200,000 in rural areas.
10) The expected accident frequency (EAF) for active devices with gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.5;
11) Vehicle delay exceeds 40 vehicle hours per day.[1]

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

1) The highway is a part of the designated National Highway System;
2) The highway is otherwise designed to have partial controlled access;
3) The posted highway speed exceeds 88 km/h (55 mph);
4) AADT exceeds 50,000 in urban areas or 25,000 in rural areas;
5) Maximum authorized train speed exceeds 161 km/h (100 mph);
6) An average of 75 or more trains per day or 150 MGT per year;
7) An average of 50 or more passenger trains per day in urban areas or 12 or more passenger trains per day in rural areas;

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

8) Crossing exposure (the product of the number of trains per day and AADT) exceeds 500,000 in urban areas or 125,000 in rural areas; or
9) Passenger train crossing exposure (the product of the number of passenger trains per day and AADT) exceeds 400,000 in urban areas or 100,000 in rural areas;
10) The expected accident frequency (EAF) for active devices with gates, as calculated by the USDOT Accident Prediction Formula including 5-year accident history, exceeds 0.2;
11) Vehicle delay exceeding 30 vehicle hours per day;[2]
12) An engineering study indicates that the absence of a grade separation structure would result in the highway facility performing at a level of service below its intended minimum design level 10% or more of the time.

C. Whenever a new grade separation is constructed, whether replacing an existing highway-rail grade crossing or otherwise, consideration should be given to the possibility of closing one or more adjacent grade crossings.

D. Utilize Table 7 for LRT grade separation:

TABLE 7

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

7. ***NEW CROSSINGS***

A. Should only be permitted to cross existing railroad tracks at-grade when it can be demonstrated:
   1. For new public highways or streets where there is a clear and compelling public need (other than enhancing the value or development potential of the adjoining property);
   2. Grade separation cannot be economically justified, i.e. benefit to cost ratio on a *fully allocated* cost basis is less than 1.0 (generally, when the crossing exposure exceeds 50,000 in urban areas or exceeds 25,000 in rural areas); and
   3. There are no other viable alternatives.

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

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[2] Ibid.

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

TRAFFIC CONTROL DEVICE SELECTION PROCEDURE

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

A. Gather preliminary crossing data:
   1. Highway:
      a. Geometric (number of approach lanes, alignment, median);
      b. AADT;
      c. Speed (posted limit or operating);
      d. Functional classification;
      e. Desired level of service;
      f. Proximity of other intersections (note active device interconnection); and
      g. Availability and proximity of alternate routes and/or crossings.
   2. Railroad:
      a. Number of tracks (type: FRA classification, mainline, siding, spur);
      b. Number of trains (passenger, freight, other);
      c. Maximum train speed and variability;
      d. Proximity of rail yards, stations and terminals; and
      e. Crossing signal control circuitry.
   3. Traffic Control Device:
      a. Passive or active;
      b. Advance;
      c. At crossing; or
      d. Supplemental.
   4. Prior collision history

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

C. Consider crossing closure or consolidation:
   1. If acceptable alternate route(s) is/are available; or
   2. If an adjacent crossing is improved, can this crossing be closed? or
   3. If this crossing is improved, can an adjacent crossing be closed?

D. For all crossings, evaluate stopping and clearing sight distances. If the conditions are inadequate for the existing control device, correct or compensate for the condition (see Step 3 below).

E. If a passive crossing, evaluate corner sight distance. If less than the required for the posted or legal approach speed, correct or compensate for the condition (see Step 3 below).

Step 2 - **Evaluate Highway Traffic Flow Characteristics:**

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

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

Step 3 - **Possible Revision to the Highway-Rail Grade Crossing:**

A. If there is inadequate sight distance related to the type of control device, consider measures such as:
   1. Try to correct the sight distance limitation;
   2. If stopping sight distance is less than "ideal" for the posted or operating vehicle approach speed and cannot be corrected, determine the safe approach speed and consider either posting an advisory speed plate at the advance warning sign or reduce the regulatory speed limit on the approach;
   3. If corner sight distance is inadequate and cannot be corrected, determine the safe approach speed and consider posting an advisory speed plate at the advance warning sign, or reduce the regulatory speed limit on the approach, or install STOP or YIELD signs at the crossing;
   4. If clearing sight distance is inadequate, upgrade a passive or flashing-light only traffic control device to active with gates, or close (consolidate) the crossing, or grade separate;

B. If highway and/or train volumes and/or speeds will not allow the highway to perform at an acceptable level of service, consider traffic control device upgrade to active (possibly with additional devices such as gates and medians), or closure (consolidation) or separation;

C. If crossing closure or consolidation is being considered, determine the feasibility and cost of providing of an acceptable alternate route and compare this to the feasibility and cost of improving the existing crossing;

D. If grade separation is being considered:
   1. Economic analysis should consider fully allocated life-cycle costs;
   2. Consider highway classification and level of service;
   3. Consider the possibility of closing one or more adjacent grade crossings.

Step 4 - **Interim Measures And/or Documentation:**

A. If the above analysis indicates a change or improvement in the crossing or type of traffic control devices is indicated, determine what if any interim measures can or should be taken until such time as recommended improvement can be implemented;

B. If the above analysis indicates a change or improvement in the crossing or type of traffic control devices is indicated, but there are other compelling reasons or circumstances for not implementing them, document the reasons and circumstances for your decision;

C. If the above analysis indicates no change or improvement in the crossing or type of traffic control devices is indicated, document the fact that the crossing was evaluated and determined to be adequate.

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GLOSSARY

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

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

CFR - Code of Federal Regulations

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

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

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

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

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

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

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

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

APPENDIX

PREEMPTION/INTERCONNECTION

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

PEDESTRIAN CLEARANCE PHASE

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

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

TRAFFIC SIGNAL CONTROLLER RE-SERVICE CONSIDERATIONS

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

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

PROGRAMMING SECURITY

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

SUPERVISED INTERCONNECT CIRCUITRY

The interconnection circuit between the highway traffic signal control cabinet and the railroad signal cabinet should be designed as a system. Frequently, the interconnect cable circuit is designed so that the preemption relay can be falsely de-energized, thereby causing a preempt call, without the railroad signals being activated. The traffic signals will then cycle through their clearance phase and remain at "stop" until the false preempt call is terminated. If a train approaches the crossing during the false preemption, the railroad signals will activate, but the traffic signals will not provide track clearance phases because they are still receiving the first false call. Even worse, a short between the wires in this type of circuit will virtually disable preemption and will only be recognizable once the railroad active control devices are activated with an approaching train. To address this potential problem supervised preemption circuits may be used. In its simplest form, the supervised circuit is formed by having two control relays in the traffic control cabinet each of which is energized by the railroad crossing relay. One relay, the Preemption Relay, is energized only when the railroad active control devices are off. The second relay, the Supervision Relay, is energized only when the railroad active control devices are operating. When circuited in this manner, only one control relay is energized at a time. If both relays are simultaneously energized or de-energized, the supervision logic determines that there is a problem and can implement action. This action may include initiating a clearance cycle and upon completion of the clearout, the traffic signals can go into an all-way flashing red instead of stop. The all-way flashing red will allow traffic to advance off the tracks instead of being held by the red signal. An engineering study may determine that the all-way flashing red is undesirable due to high highway traffic volumes compared to rail traffic. In all cases remote-monitoring devices that send alarm messages to the railroad and highway authority should be installed. Law enforcement traffic control should be used until repairs can be performed. More information on supervised circuits can be found in an article, *Supervised Interconnection Circuits at Highway-Rail Grade Crossings,* by Mansel, Waight, and Sharkey, ITE Journal, March 1999, Institute of Transportation Engineers available at www.ite.org

ADVANCE PREEMPTION AND USE OF TIMERS

When advance preemption is used the traffic signal preemption occurs prior to the active control devices being activated. This allows preemption to begin behind the scene and the active control time of the railroad signals is not necessarily increased. Railroads frequently use two detection times in their system. The first detection time is designed to initiate traffic signal preemption.

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

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

STANDBY POWER SOURCES

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