Railroad Preemption Manual

May 2026

Manual Notice: 2026-1

From: Don Franks, Rail Division Director

Manual: *Railroad Preemption Manual*

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Purpose

The Texas Department of Transportation (TxDOT) Railroad Preemption Manual is being issued to provide the appropriate tools, guidance, and standards regarding railroad preemption systems, design, implementation, and maintenance throughout the State of Texas.

Contents

Chapter 1, *Introduction*, describes the purpose, common definitions and abbreviations, and existing technical references applicable for this manual.

Chapter 2, *Identifying the Need for Preemption*, describes how to determine if preemption is needed at a specific location and potential preemption operations.

Chapter 3, *Preemption Time Calculations*, describes how preemption timing parameters are calculated and how said parameters can determine and affect the overall railroad approach time needed at grade crossings.

Chapter 4, *Railroad Relays and Systems*, describes railroad relays – including various types, functions, and applicability. It also discusses preemption request forms and limitations of the railroad equipment to consider when implementing preemption.

Chapter 5, *Equipment Standards*, describes components within traffic signal cabinets and their interface with the railroad equipment during preemption.

Chapter 6, *Interconnected Crossing Design*, describes design techniques, strategies, guidance, and standards on how to design at grade crossings with traffic signal interconnection.

Chapter 7, *Construction and Implementation*, describes the preemption implementation process and defines the responsibilities of TxDOT and the appropriate railroad authority as related to traffic signal interconnection.

Chapter 8, *Inspection and Maintenance Considerations*, describes the necessary inspection and maintenance processes to identify and troubleshoot the quality and functionality of existing preemption operations

Contact

Questions on the manual or its contents may be directed to the Rail Division.

Archives

No archives exist for this manual since this is the first publication.

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Chapter 1: Introduction

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Section 1: Overview

General

Traffic signal railroad preemption is defined as the transfer of a traffic signal's normal operation to a special timing sequence prior to the arrival of a train when a grade crossing is located near a signalized intersection. The purpose of this manual is to provide the appropriate tools, guidance, and standards regarding railroad preemption systems, design, implementation, and maintenance throughout the State of Texas. When railroad preemption is properly installed, motorists are able to safely and efficiently maneuver through grade crossings as well as the adjacent interconnected signalized intersections. Throughout this manual, **railroad preemption** is referred to as **preemption**.

Manual Organization

This manual is organized in three main topics to describe the overall preemption process. Chapters 1 through 3 define various aspects of preemption and guide readers to a better understanding of each element involved. Chapters 4 through 7 describe the different design elements and proper implementation of preemption. Chapter 8 discusses the traffic signal and railroad maintenance procedures and responsibilities of the relevant stakeholders.

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Existing Technical References

Table 1-1 below lists various technical documents that provide industry standards and recommended practices and are referenced throughout this manual.

Table 1-1. Technical Standards and Guidance

Technical Reference Name	Agency	Year Published
AREMA Communications and Signals Manual[1]	AREMA	2025
ITE Preemption of Traffic Signals Near Railroad Crossings	ITE	2021
Traffic Signals Manual	TxDOT	2020
FHWA Railroad-Highway Grade Crossing Handbook	FHWA	2019
Form 2304 and 2304-I	TxDOT	2019
Form 2625 and 2625-I	TxDOT	2023
Rail-Highway Operations Manual	TxDOT	2023
ITE Traffic Control Devices Handbook	ITE	2013
Texas Manual on Uniform Traffic Control Devices	TxDOT	2025
At-Grade Intersections Near Highway-Railroad Grade Crossings	TxDOT	2001

[1]Note this manual is updated annually

Abbreviations and Definitions

Table 1-2 below lists the common abbreviations used throughout this manual. Other more specific abbreviations will be defined later in the appropriate chapters.

Table 1-2. Common Abbreviations

Abbreviation	Term
APT	Advance Preemption Time
AREMA	American Railway Engineering and Maintenance-of-Way Association
CFR	Code of Federal Regulations
ERT	Equipment Response Time
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
ITE	Institute of Transportation Engineers
MT	Minimum Time

Table 1-2. Common Abbreviations

Abbreviation	Term
TMUTCD	Texas Manual on Uniform Traffic Control Devices
TxDOT	Texas Department of Transportation
RRD-RSS	Rail Division-Rail Safety Section (TxDOT)
RRD	Rail Division (TxDOT)

Table 1-3 lists some common definitions used throughout this manual. Other more specific definitions will be defined later in the appropriate chapters.

Table 1-3. Common Definitions

Term	Definition
Grade Crossing Warning System	The flashing-light signals, with or without crossing gates, together with the necessary control equipment used to inform road users of the approach or presence of rail traffic at a grade crossing.
At-Grade Crossing (Grade Crossing)	The general area where a highway and a railroad and/or light rail transit route cross at the same level, within which are included the tracks, highway, and traffic control devices for traffic traversing that area.
Diagnostic Team	A group of knowledgeable representatives of the parties of interest in a grade crossing or group of grade crossings (see 23 CFR Part 646.204). A railroad company signal maintainer, local government representative, and FHWA or FRA representative are also included as needed (TxDOT Rail-Highway Operations Manual, pg. 4-9).
Highway Agency	Agency that owns or has jurisdiction over the relevant highway or roadway. The Highway Agency may be TxDOT or a local agency (City or County).
Interconnected Railroad Crossing	A railroad at-grade crossing which has an electrical connection between the railroad signal system and a traffic signal system for the purpose of providing preemption.
Railroad Company	Railroad company that owns, maintains, and/or operates at the relevant railroad grade crossing. Note: There may be multiple railroad companies at a given grade crossing.
Traffic Signal Interconnection	The electrical connection between the railroad signal system and the traffic signal system for the purpose of providing preemption.

General Roles and Responsibilities

Table 1-4 details the roles and responsibilities of each typical stakeholder within this manual. Other more specific responsibilities will be defined later in the appropriate chapters.

Table 1-4. Titles and Roles/Responsibilities

Title	Role/Responsibility
TxDOT District Railroad Coordinator	Responsible for coordinating with the railroad regarding diagnostic meetings, joint maintenance inspections, and any grade crossing-related incidents. Also responsible for coordinating with local highway authorities regarding any construction work taking place near grade crossings including controller testing and cutover.
TxDOT District Traffic Engineer	Responsible for general traffic engineering within the District. Also, regarding interconnected crossings, responsible for coordinating annual joint maintenance inspections and being the primary point of contact for issues noted outside annual inspections. These responsibilities may be delegated to another qualified person.
Diagnostic Team	Group consisting of the railroad authority, highway authority, and project team to visit the project location and discuss the existing conditions as well as any proposed improvements. The role of the diagnostic team specific to interconnected railroad crossings is discussed further in Chapter 2 of this manual, with additional details provided in the TxDOT Rail-Highway Operations Manual.
Highway Agency	Owner of the roadway. For the purposes of railroad preemption, the agency responsible for maintaining the traffic signal.
Railroad Company	Owner and/or operator of the railroad line. For the purposes of preemption, the railroad company is responsible for maintaining the railroad warning devices and railroad circuitry.
TxDOT Railroad Investigators	Railroad investigators are not required to attend inspections; however, relevant information should be shared with them. Railroad investigators may participate in cutovers and diagnostic reviews, if necessary.
TxDOT Rail Division (RRD) Representative	Has the authority to implement rail improvements through public-private partnership agreements and provide investments in freight rail relocation projects, rail facility improvements, rail line consolidations, or new passenger rail developments. Provides guidance related to the railroad interconnection implementation process. This individual should be invited to maintenance meetings but is not required to attend.

Chapter 2: Identifying the Need for Preemption

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Section 1: Diagnostic Team Process

Diagnostic Team

This section defines the diagnostic team as it relates specifically to grade crossings with existing interconnection or potential for interconnection to nearby traffic signals (collectively interconnected crossings) by referring to existing TxDOT processes found in other manuals. This section further defines points of emphasis for interconnected crossings.

23 CFR Section 646, Part 6546.204 defines the diagnostic team as “a group of knowledgeable representatives of the parties of interest in a railroad-highway crossing or a group of grade crossings.” According to the TxDOT Rail-Highway Operations Manual, the diagnostic team consists of the following:

- District Railroad Coordinator
- Rail Division Representatives
- Railroad company Project Manager
- Railroad company Signal Maintainer (as needed)
- Local government representative (as needed)
- FHWA or FRA representative (as needed)

Note, quiet zone diagnostic reviews require participation from FRA whether the crossing is/will be interconnected or not.

Although typical TxDOT processes should be followed, interconnected crossings have unique complexities that should be carefully considered by the diagnostic team. Additional individuals that should be included in the diagnostic team for such crossings include the following:

- District Traffic Signal Specialist
- District Traffic Operations Engineer

TxDOT Rail-Highway Operations Manual, Chapter 4, Section 3 defines the areas of focus of the diagnostic team. For interconnected crossings the following elements are critical:

- Potential for on-track queuing
- Existing train operations and future plans
- Safety enhancements such as signing and striping, lighting, railroad flashing lights/gates/ cantilevers, and traffic signal preemption
- Additional turn lanes for improved normal and preemption operations
- Consideration for protected left-turns, especially for left-turns crossing and approaching the tracks

- Potential conflicts and clearances for placement of both traffic signal and railroad equipment
- Pedestrian considerations such as crosswalk placement and pedestrian demand

Table 2-1 below lists documents that provide additional information for the diagnostic team process.

Table 2-1. Diagnostic Team References

Technical Reference Name	Year Published
TxDOT Rail-Highway Operations Manual	2023
Texas Manual on Uniform Traffic Control Devices (TMUTCD)	2025

The Diagnostic Team should use this manual as a guide to inform decisions and to define standard application once a specific treatment is identified.

Section 2: Analysis Methods

Preemption Identification Process

The need to evaluate a location for preemption often begins with one of the following scenarios although other scenarios may present themselves.

- Railroad Investigator identifies a potential need through annual inspections
- A railroad or highway authority identifies a concern through inspection or routine maintenance
- Roadway or railroad improvements impact the operation of a crossing
- Crash Data or near miss reports from rail operator, highway authority, or other witnesses

The TxDOT Rail-Highway Operations Manual requires the District Railroad Coordinator to arrange to have TxDOT Form 2304 filled out in preparation for the diagnostic inspection. TMUTCD recommends "If a grade crossing is equipped with flashing-light signals and is located 200 feet or less from an intersection or midblock location controlled by a traffic control signal, a pedestrian hybrid beacon, or an emergency-vehicle hybrid beacon, the intersection should be provided with rail preemption in accordance with Section 4F.19 unless otherwise determined by the Diagnostic Team." Where a crossing is within 200 feet of an intersection or queuing is otherwise expected near the tracks, the District Railroad Coordinator shall require the requesting agency (RRD, railroad, or highway authority; referred to as the Requestor) to complete the following three steps to determine the need for preemption and TxDOT Form 2304 prior to the diagnostic:

- Step 1: Measure Available Storage Distance
- Step 2: Determine Queue Lengths
- Step 3: Determine the need for preemption

Step 1: Measure Available Storage Distance

At grade crossings, there are typically two types of potential queues, influence zone queues and gate spill back queues as illustrated in Figure 2-1. Both types of queues should be considered when determining the need for preemption.

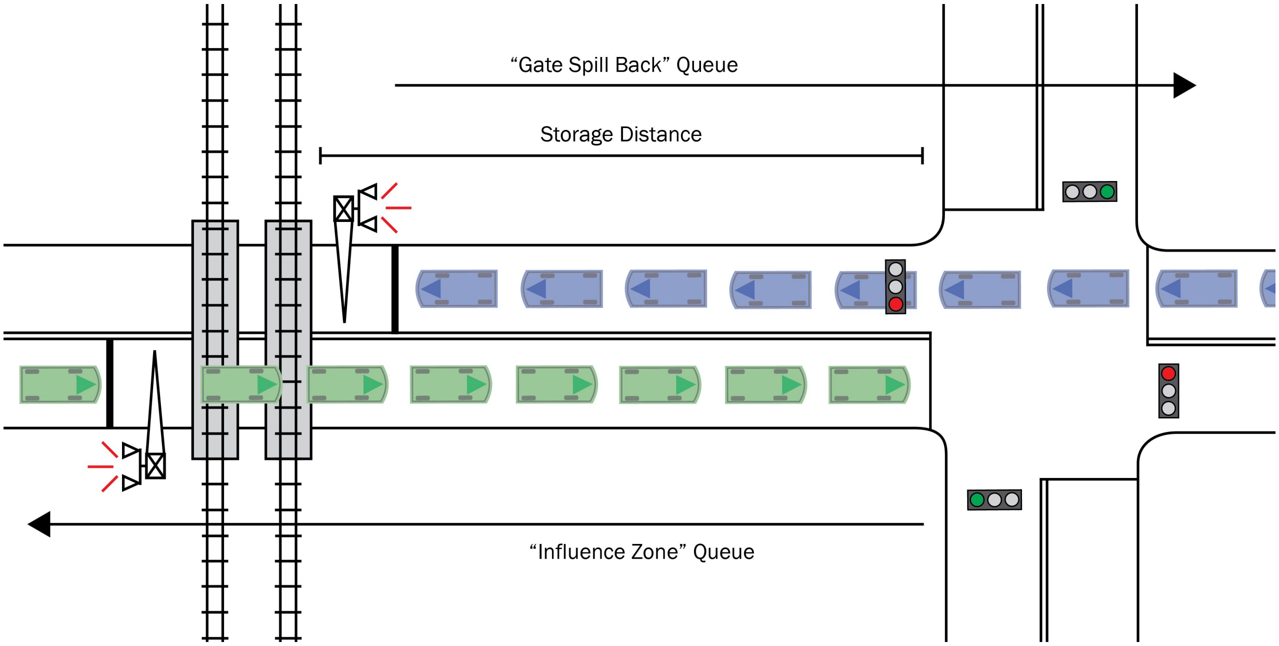


Figure 2–1. Queuing Near Railroad Crossings

The Requestor shall measure the Clear Storage Distance (CSD) as defined in TxDOT Form 2304-I and illustrated above. TXDOT prefers on-site measurements however the distance can be estimated via a desktop survey using reliable aerial imagery or design documents.

Step 2: Determine Queue Lengths

The ITE Preemption of Traffic Signals Near Railroad Crossings manual provides excellent guidance determining the need for preemption. In Texas, the Requestor shall apply at least one of following four methods to determine queue lengths.

- Anecdotal Evidence
- Field Observations
- Queue Length Calculations
- Traffic Simulation Modeling

Anecdotal Evidence

Local highway authority staff, police, train operators, or train dispatchers may note queuing issues and can help initiate further investigation such as timing of field observations. However, the CSD may occasionally be shorter than the length of the design vehicle. In this case, it may not be necessary to further review the queue lengths since vehicles are already likely to queue within the CSD and naturally encroach the tracks when doing so. Various queue mitigation strategies should be implemented to provide the on-track queue prevention.

Field Observations

The Requestor should complete field observations whenever possible to inform the diagnostic team with site specific data. Video surveillance can be used to review a location over an extended period and note motorist behavior and queuing at various times of day.

Queue Length Calculation

Locations where either the intersection, traffic signal, or grade crossing are not yet operational may necessitate queuing calculations to estimate queue lengths. The Requestor should refer to the ITE Preemption of Traffic Signals Near Railroad Grade Crossings manual for additional details regarding queue length calculations.

Traffic Simulation Modeling

When determining queue lengths at locations where the crossing or the intersection is not yet operational, the Requestor may also use traffic simulation modeling. Software running the current version of *Highway Capacity Manual* calculations or a traffic simulation model are acceptable as long as 95th percentile queue length are provided. The Requestor should also consider factors such as vehicle composition, platooning due to nearby signals, potential back-to-back preemption events, train length, and overall time in preemption to accurately estimate queue lengths.

Step 3: Determine the Need for Preemption

The Requestor should compare the results of Steps 1 and 2. If the measured distance (Step 1) is less than the queue lengths calculated (Step 2), the diagnostic team should consider preemption.

If a traffic signal is warranted under Warrant 9 in Section 4C.10 of the TMUTCD or any other warrant and queueing is anticipated at the crossing and the highway authority elects to install a signal at the intersection, TxDOT Form 2304 shall be completed and provided to the District Railroad Coordinator prior to the diagnostic inspection. TxDOT Form 2304-I provides information to assist with the completion of the TxDOT Form 2304. Chapter 3 of this manual builds on TxDOT Form 2304-I by providing guidance on collecting data and special preemption scenarios affecting preemption calculations. At the diagnostic inspection, the diagnostic team will discuss the safety implications of installing a traffic signal near a crossing and the specific preemption needs as discussed later in this manual.

When gate spillback queuing is observed, it can often be mitigated with strategies such as vehicle detection, phase omissions, and turn restrictions. If the signal operations can be designed such that on-track queuing is prevented at all times during both normal and preemption operations, then there may not be a significant need for railroad interconnection to be implemented. The diagnostic team should evaluate and observe each grade crossing carefully to determine the best solution.

Section 3: Advance and Simultaneous Preemption

TMUTCD 1C.02 defines two forms of preemption as follows:

- Simultaneous preemption: the notification of approaching rail traffic is forwarded to the highway traffic signal controller unit or assembly and railroad or light rail transit active warning devices at the same time.
- Advance preemption: the notification of approaching rail traffic that is forwarded to the highway traffic signal controller unit or assembly by the railroad or light rail transit equipment in advance of the activation of the railroad or light rail transit warning devices.

The primary function of either form of preemption is to have the grade crossing be vehicle-free prior to the arrival of the train. Preemption is initiated through an electrical connection between the traffic signal system and railroad warning system referred to as interconnection. The railroad relays and interconnection are discussed further in Chapter 4.

Figures 2-2 and 2-3 illustrate examples of simultaneous and advance preemption operations, respectively.

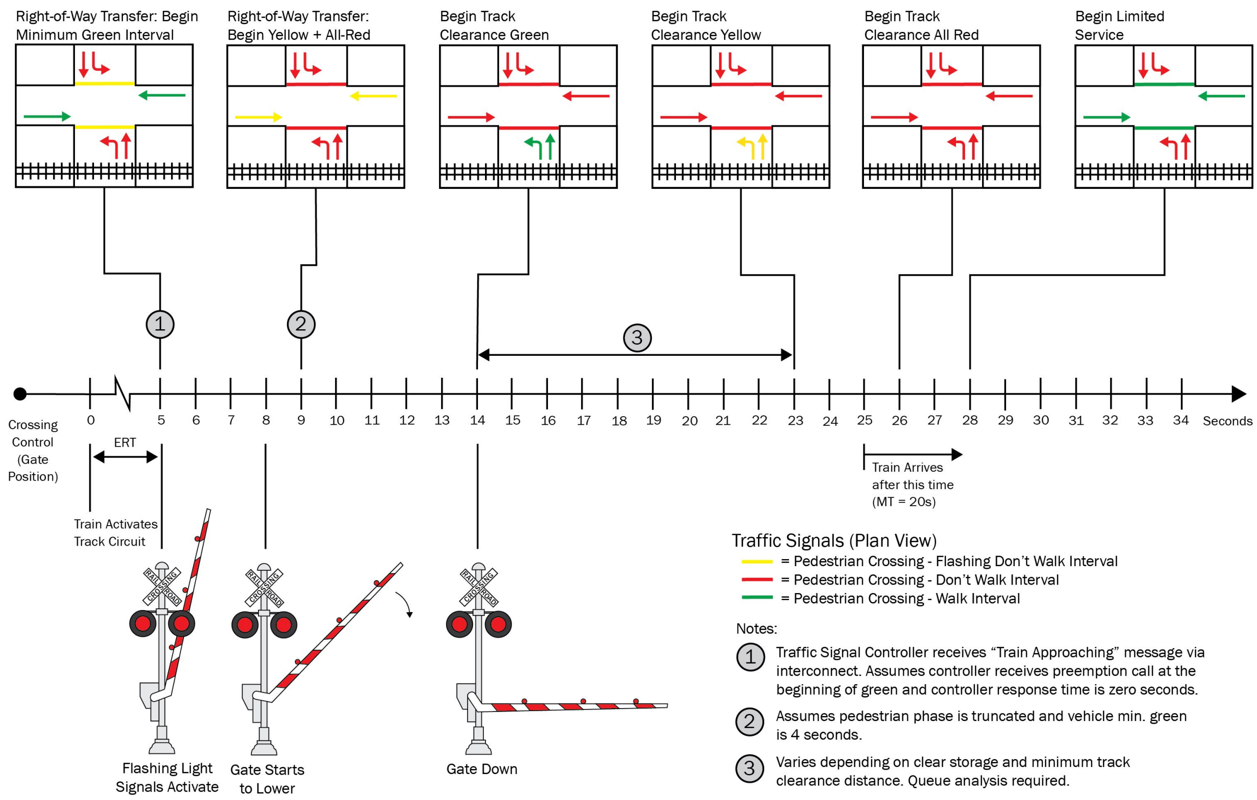


Figure 2–2. Simultaneous Preemption Operation

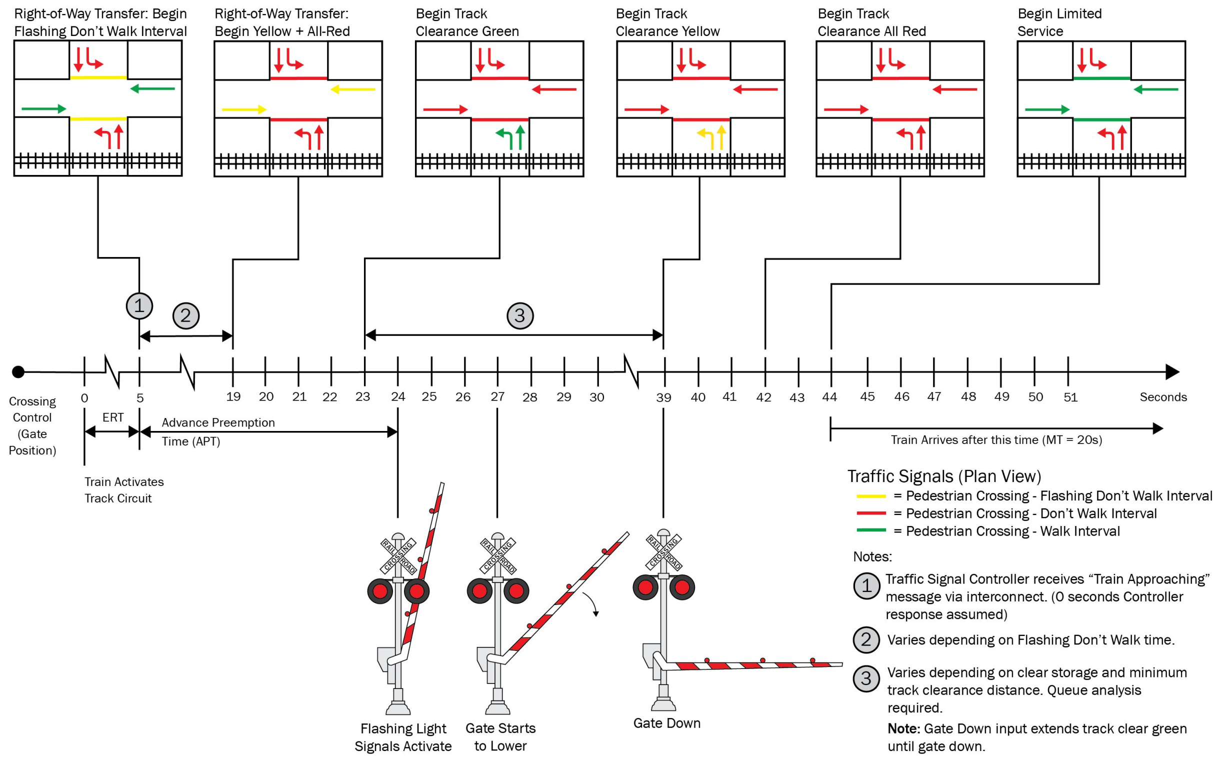


Figure 2–3. Advance Preemption Operation

There are various references outside of TxDOT that provide details regarding simultaneous and advance preemption operations, but generally simultaneous preemption should be limited to crossings where the tracks cross through the middle of the intersection. Advance preemption is a more complex operation but provides many benefits such as reducing the amount of time the railroad warning system is activated and potentially fewer gates striking vehicles and/or broken gates. Advance preemption is the standard method of preemption in Texas, unless engineering judgment shows that simultaneous preemption is appropriate for a specific location.

Due to the complexity of advance preemption operations, the highway authority and railroad must ensure that all parties have a basic understanding of the operation of each other's system. Later chapters of this manual will help develop an understanding of the two systems and standardize preemption operations in Texas.

Chapter 3: Preemption Calculations

Contents:

Section 1: Gathering Relevant Data

This section provides guidance on gathering relevant data to assist in the completion of [TxDOT Form 2304](). Since every crossing and associated intersection are unique, the physical and operational characteristics of each location can vary significantly. As such, the tools and methodology described herein are to be applied with engineering judgement to arrive at the most appropriate solution.

Collecting relevant data from a variety of sources is the first step in calculating the preemption time. The geometric data of the crossing and associated intersection is a key element in calculating the preemption timing. The Requestor shall measure the following, as defined in TxDOT Form 2304-I:

- Clear Storage Distance (CSD)
- Minimum Track Clearance Distance (MTCD)
- Stop Bar Setback Distance (SBD)
- Width of Receiving Approach (B)
- Offset Distance of Left Turn Stop Bar (OSB)
- Approach Grade
- Angle of Turn at Intersection (Q)

In addition to the geometric data, additional data such as the design vehicle selection, traffic signal timing, and railroad timing are critical information to calculate preemption timing. Figure 3-1 shows how the geometric data is measured at the grade crossing.

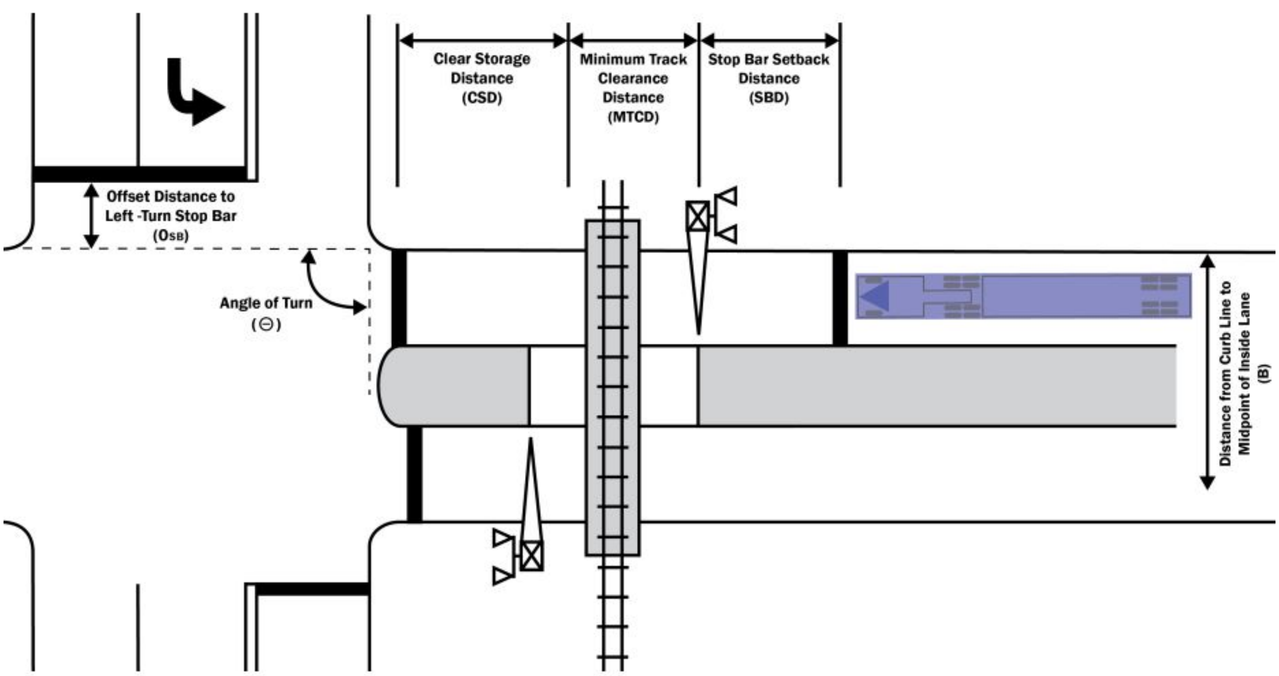


Figure 3–1. Geometric Data at a Grade Crossing

Design Vehicle Selection

The design and operation of the interconnected crossing should reflect the appropriate design vehicle. Typically, the longest vehicle permitted by the Highway Authority should be used as the design vehicle. Table 3-1 (reference from AASHTO's Policy of Geometric Design of Highways and Streets, 2018) lists the AASHTO designation for potential design vehicle types on TxDOT Form 2304. The TxDOT Form 2304 automatically populates the design vehicle length and centerline turning radius based on the selected vehicle design. TxDOT Form 2304 also allows custom vehicle length to be added for special circumstances.

Table 3-1. AASHTO Design Vehicle Length and Heights

Design Vehicle Type	Symbol	Length (ft)
School Bus	S-BUS 40	40
Intermediate Truck	WB-50	55
Interstate Semi-Truck	WB-67	75

The Requestor should be aware of which vehicles are allowed at the crossing and associated intersection. Engineering judgement should be applied to determine the most appropriate design vehicle for a crossing as the design vehicle selection is a critical element and may affect certain preemption timing elements including the following:

- Left Turns Towards the Tracks: Due to the difference in vehicle lengths, the time required for left turning vehicles to complete the turn will be affected.
- Queue Clearance Time: The queue clearance interval must be long enough to allow the design vehicle to clear the MTCD. Due to the difference in vehicle lengths, the time required for the design vehicle to start up, move through, and clear the entire MTCD will be affected. This time is also affected by the time required to clear left turns

Traffic Signal Timing

The Requestor shall request all information related to the traffic signal timing from the Highway Authority as it is necessary to determine the Right-of-Way Transfer Time (RWTT) and complete TxDOT Form 2304. If a new traffic signal is being proposed, the proposed times to be programmed to the controller should be provided. The traffic signal timing data shall include, but may not be limited to, the overall cycle length, default minimum times, guaranteed maximum times, track clearance green or Preemption Clearance Interval, signal phasing, and transition during a preemption event, which includes the following (note these times may be different during preemption than the default minimum times, except as noted below):

- Minimum Green Time
- Yellow Change Time (shall not be shortened or omitted)

- Red Clearance Time (shall not be shortened or omitted)
- Pedestrian Walk Time
- Pedestrian Clearance Time

The following parameters are defined by TMUTCD, AREMA and ITE and used to provide sufficient preemption time to the interconnected traffic signal prior to the arrival of a train at a crossing. The Requestor should understand these parameters when performing preemption calculations and the effect of signal timing on preemption to communicate preemption timing needs to the Railroad Authority.

Right-of-Way Transfer Time (RWTT) is the amount of time needed prior to display of the track clearance interval. This includes any time needed by the railroad, light rail transit, or highway traffic signal control equipment to react to a preemption call, and any traffic control signal green, pedestrian walk and clearance if used, yellow change, and red clearance intervals for conflicting traffic.

Since preemption may occur at any given moment during normal operations, enough time must be provided to safely transition any active phases to the Preemption Clearance Interval. In order to terminate any active phase prior to track clearance green, the minimum green, yellow change, red clearance, and pedestrian clearance intervals must be considered. The RWTT values in TxDOT Form 2304 shall reflect the worst-case scenario.

TxDOT Form 2304-I provides general guidance to assist the Requestor when it may be appropriate to truncate the pedestrian clearance time in the presence of a preemption call at a crossing. Consideration to truncate the pedestrian time includes the following:

- Pedestrian volumes
- Frequency of preemption events
- Vehicle minimum times
- Intersection geometry
- Types of pedestrian users

Limitations in railroad equipment may necessitate partial truncation of pedestrian clearance time at locations where the Highway Authority would otherwise desire full pedestrian clearance time. Details related to how to handle this scenario are discussed further in Chapter 4 of this manual.

Track Clearance Green (TCG) is the portion of the traffic signal sequence when the RWTT has completed and green signal indications are displayed to roadway users to clear the MTCD. Per TxDOT Form 2304-I, the TCG is the time required to avoid the preempt trap and provide enough time for the design vehicle to clear the portion of the CSD as defined in the calculations. TCG should be equal or exceed the queue clearance time. TCG is the Preemption Clearance Interval (PCI) where a green indication is required to allow vehicles to clear the tracks.

Queue Clearance Time (QCT) is the time required for the Design Vehicle stopped within the minimum track clearance distance to start up, move through and clear the MTCD. If pre-signals are present, this time should be long enough to allow the Design Vehicle to move through the intersection or clear the tracks if there is sufficient CSD. If a four-quadrant gate system is present, this time shall be long enough to permit the exit gate arm to lower after the Design Vehicle is clear of the MTCD.

Separation Time is the component of maximum highway traffic signal preemption time during which the MTCD is clear of vehicular traffic prior to the arrival of the train.

Maximum Highway Traffic Signal Preemption Time is the maximum amount of time needed following the initiation of the preemption sequence for the highway traffic signals to complete the timing of the RWTT, QCT, and Separation Time.

Railroad Timing

The Requestor shall collect applicable railroad warning times, existing advance preemption time, train speed, light flashing time before gate descent, gate descent time, buffer time, and railroad equipment response time from the Railroad. The understanding of these times will help the Requestor understand how the grade crossing will operate during a preemption event.

TxDOT Form 2304 automatically calculates the following railroad timing parameters:

- **Required Minimum Time (MT)**: The TxDOT Form provides the least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossing. Per TMUTCD, “Flashing-light signals shall operate for at least 20 seconds before the arrival of any rail traffic.”
- **Clearance Time (CT)**: The additional time that may be provided by the railroad to account for longer crossing time at a wide crossing. Per AREMA, “If the MTCD exceeds 35 ft, clearance time is one second for each additional 10 ft., or portion thereof, over 35 ft.”
- **Total Minimum Warning Time (MWT)**: is the sum of the minimum time (MT) and the clearance time (CT).
- **Advance Preemption Time (APT)**: is the period of time that is the difference between the required maximum highway traffic signal preemption time and the activation of the railroad or light rail transit warning devices. This value is calculated by subtracting the total minimum warning time from the maximum preemption time for queue clearance in Form 2304.

Section 2: Reviewing Special Scenarios

TxDOT Form 2304 is the standard form for preemption calculations. For most locations, the data collected as outline in Section 3-1 should be input directly into TxDOT Form 2304. TxDOT Form 2304-I can assist in the completion of TxDOT Form 2304. However, the designer may encounter special scenarios where the location, design, or operation of the interconnected crossing may require special consideration by the diagnostic team and when performing preemption calculations. This section details some of these special scenarios and provides guidance on how to address them. This list is not all inclusive. Engineering judgement should be applied to determine the most appropriate solution when performing preemption calculations.

Tracks Through the Middle of an Intersection

Tracks that cross through the middle of a signalized intersection need to be considered when performing preemption calculations as illustrated in Figure 3-2.

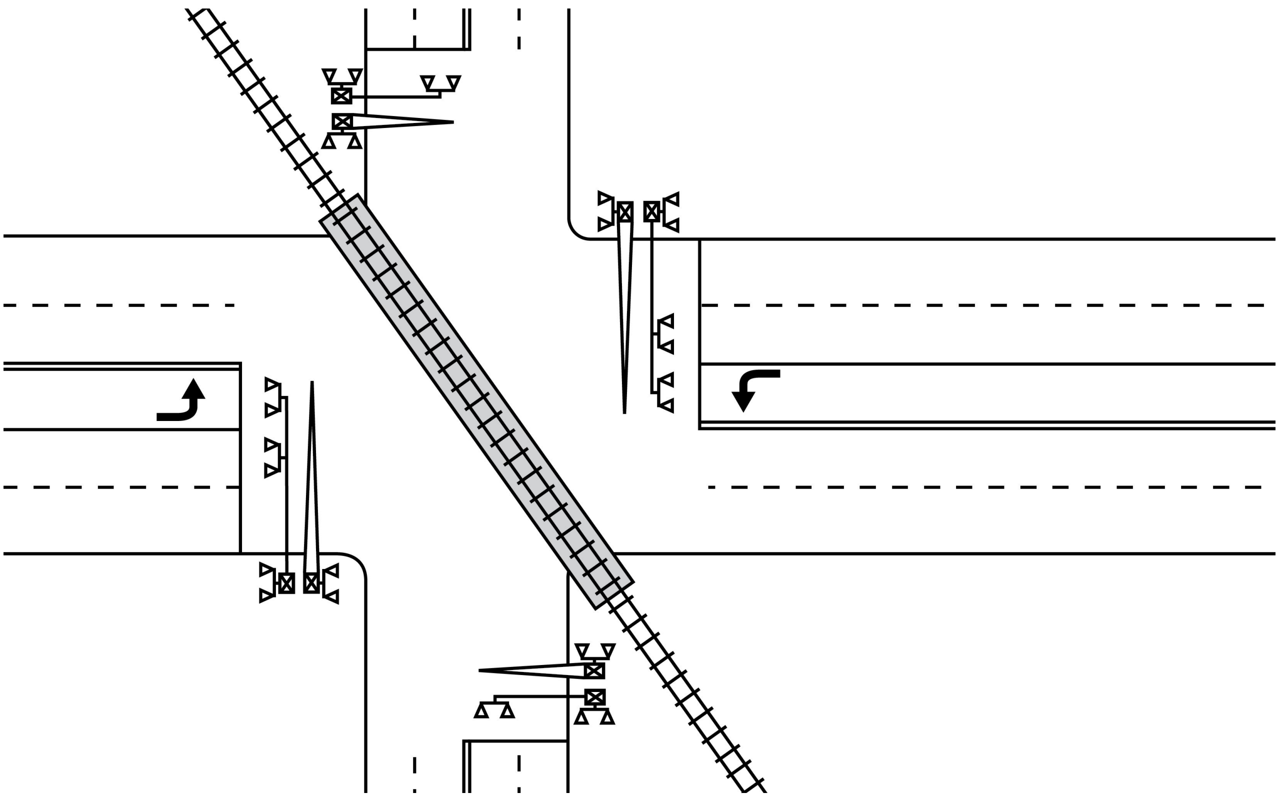


Figure 3–2. Crossing Through the Middle of a Signalized Intersection

When evaluating a crossing with tracks through the middle of the signalized intersection, the designer should synchronize the traffic signal all-red indication with the activation of the railroad flashing lights. The TxDOT Form 2304 should include the MTCD measurement to determine the clearance time for the crossing and RWTT. The railroad total warning time should be sufficient to clear all vehicles from the tracks, thus the calculated advance preemption time should be equal to or greater than the RWTT. Once right-of-way transfer is complete, the traffic signal shall hold an all-red indication as the Preemption Clearance Interval until the crossing is clear.

Locations with No Clear Storage Distance

Some crossings may have no CSD, where the 6 feet distance from the near rail is to the edge of the adjacent street as illustrated in Figure 3-3. Crossings with no CSD will generally have lower advance preemption time because no vehicles should be downstream of the crossing, which leads to a shorter queue start-up distance and track clearance green interval. When a crossing does not have a CSD, the designer should place railroad stop line upstream of the crossing in order to discourage motorists from stopping downstream of the grade crossing.

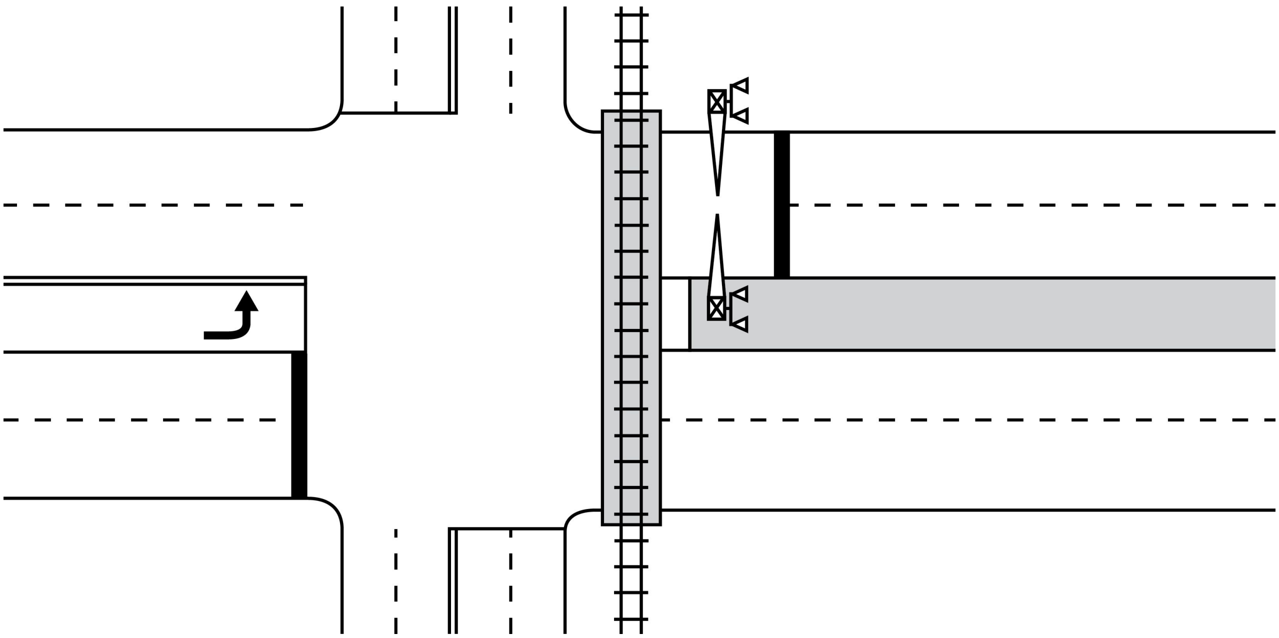


Figure 3–3. Crossing with No CSD

This scenario does not require any special manipulation of TxDOT Form 2304 except entering zero for the CSD.

Multiple Intersections Near One Crossing

At locations where the crossing has multiple signalized intersections near a crossing or is located between two signalized intersections as illustrated in Figure 3-4, the traffic signals should be interconnected and coordinated to reduce the potential for traffic to queue across the tracks. If geometrics and equipment constraints allow, both intersections should operate off the same traffic signal controller to ensure seamless coordination. During a preemption event, both signalized intersections shall allow track clearance green to allow vehicles to clear both the tracks and their respective downstream intersections. If the distance between the intersections is short, the traffic signals should operate to keep the roadway between the intersections clear during normal operations.

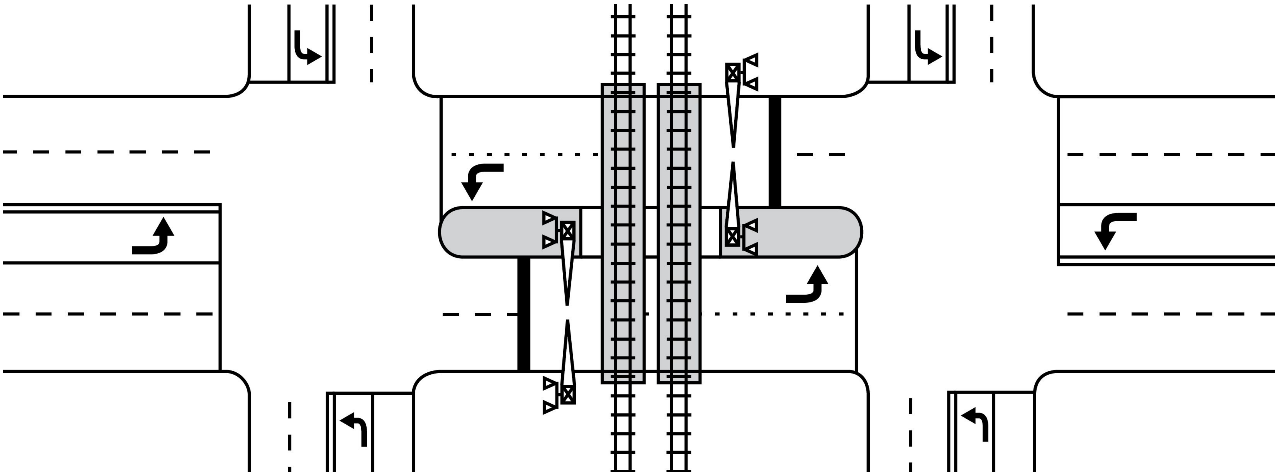


Figure 3–4. Location with Multiple Intersections Near One Crossing

When filling out TxDOT Form 2304, TXDOT recommends to perform preemption calculations for each signalized intersection that will be interconnected to the crossing. The preemption request shall be for the highest calculated advance preemption time. Since both intersections will be interconnected to the crossing, the MTCD should be the same for each form as the railroad will base the clearance time on the largest MTCD.

Multiple Crossings Near One Intersection

The diagnostic team shall carefully review geometric configurations with multiple crossing approaches to provide queue prevention or queue clearance at each crossing location. Figure 3-5, illustrates a scenario where a track crosses two legs of a single intersection. Special consideration for a pre-signal or queue cutter signal to provide queue prevention is important where queues are likely at both crossings.

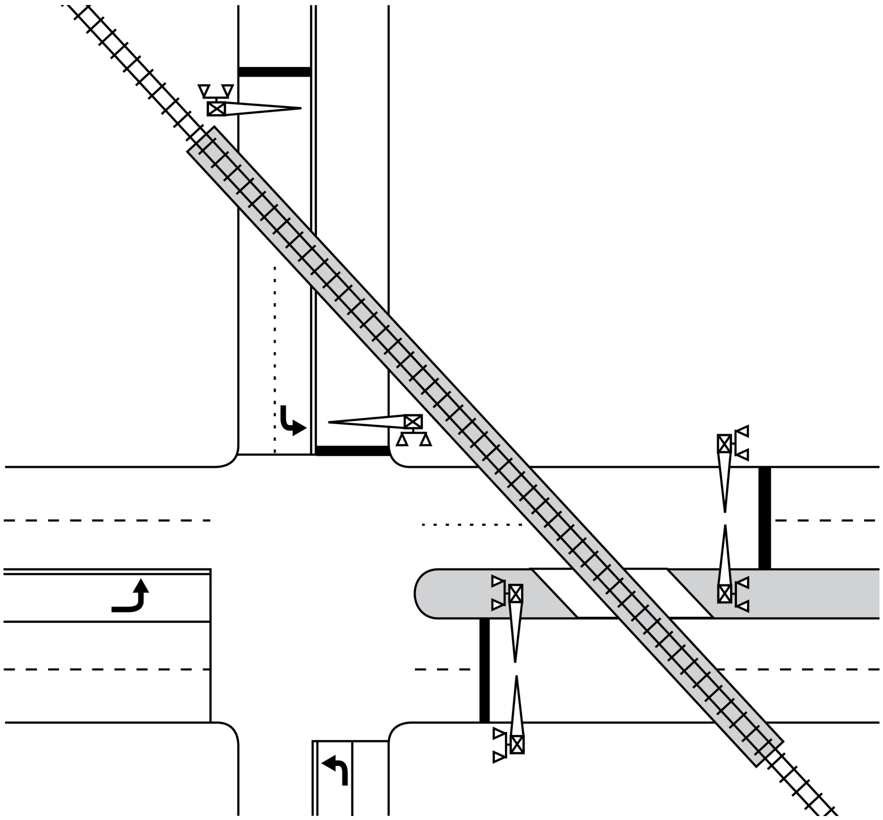


Figure 3–5. Location with Multiple Crossings Near One Intersection

If interconnection will be provided from each crossing location, one leg should first be cleared and the railroad warning devices activated to restrict additional vehicles proceeding over that grade crossing. For the TxDOT standard railroad preemption interface, the track clearance for the first leg should be terminated by a pseudo gate down timer (See Chapter 5, Section 3 related to active-style interfaces). The second approach should then be cleared and the railroad warning devices for the second crossing activated to restrict additional vehicles proceeding over that grade crossing. This can require substantial preemption time from the railroad and may not be feasible given railroad equipment limitations. The diagnostic team should review potential queue prevention for this geometric configuration.

Stop and Proceed Operations

The railroad may elect to operate under a "stop and proceed" order at a specific crossing. This operation is typically limited to low-speed industrial leads. During stop and proceed operations, the train stops at the island circuit (edge of the crossing) prior to entering the roadway. The train operator will wait at the island circuit until the crossing is clear before proceeding. The train operator will wait until the crossing is free of any vehicles and pedestrians and for the gates to be fully horizontal before proceeding through the crossing. Under a stop and proceed order, train operation is no longer bound by the AREMA 50 second rule as defined in Chapter 4.

Effect of Queue Prevention on Calculations

Preemption of Traffic Signals Near Railroad Crossings, 2nd Edition, ITE, 2021 (ITE manual) provides excellent guidance for pre-signals or queue cutter signals. Further guidance on selecting queue prevention strategies is presented in Chapter 6 of this manual. When filling out TxDOT Form 2304 and the design proposes a pre-signal:

- Preemption calculations should include the CSD to take account for any motorists that may have violated the pre-signal. However, the designer may omit the CSD, or a portion thereof, if needed to reduce the advance preemption time such as to comply with the AREMA 50 second rule.

When filling out TxDOT Form 2304 and the design proposes a queue cutter signal:

- Preemption calculations should omit the CSD since the adjacent intersection is far enough away from the grade crossing that vehicles will be able to safely queue within the CSD. The queue cutter will provide on-track queue prevention within the MTCD.
- RWTT should be limited to minimum green, yellow change and red clearance time.
- The advance preemption time should provide enough time to transition to the queue cutter to red prior to the activation of the railroad flashers. The queue cutter signal all-red indication should synchronize with activation of the railroad flashing lights.

Scenarios When Left Turns Towards Tracks Can Be Ignored

There may be a crossing where left turns are allowed towards the tracks but can be ignored in the preemption calculations due to the geometrics and/or operations of the crossing and adjacent intersection. If the following scenarios apply to the subject crossing, the design may omit the calculation of left turns towards the tracks by selecting “No” for Line 28 on TxDOT Form 2304.

At some crossings, the distance between the intersection and the tracks is approximately the design vehicle length (DVL) or greater, meaning there is enough space between the adjacent intersection and the grade crossing to store the design vehicle. The figures below present two potential scenarios with left turns towards the tracks and varying distances between the intersection and the crossing. Figure 3-6 provides an example where left turns towards the tracks should be included in the preemption calculations. Figure 3-7 illustrates a scenario where the designer may ignore left turns towards the tracks and omit them from the preemption calculations.

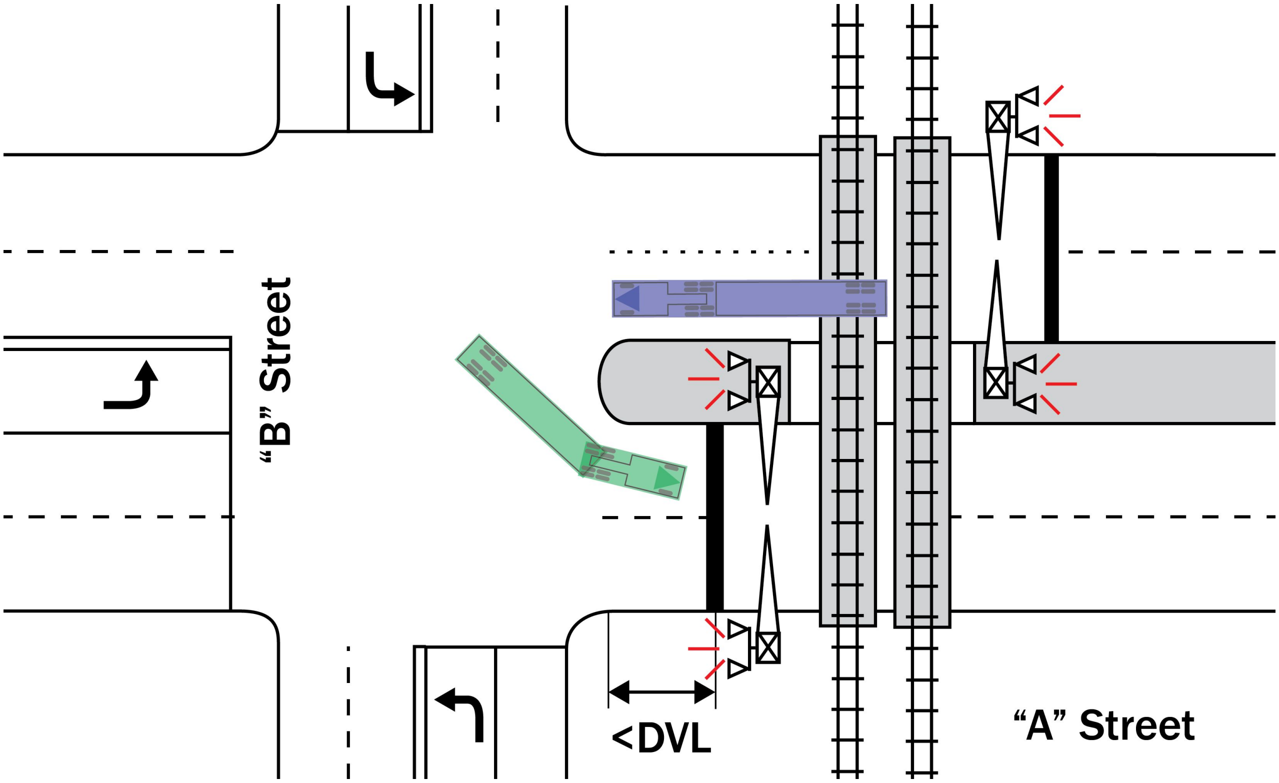


Figure 3–6. Left Turn Towards Tracks with Insufficient Storage

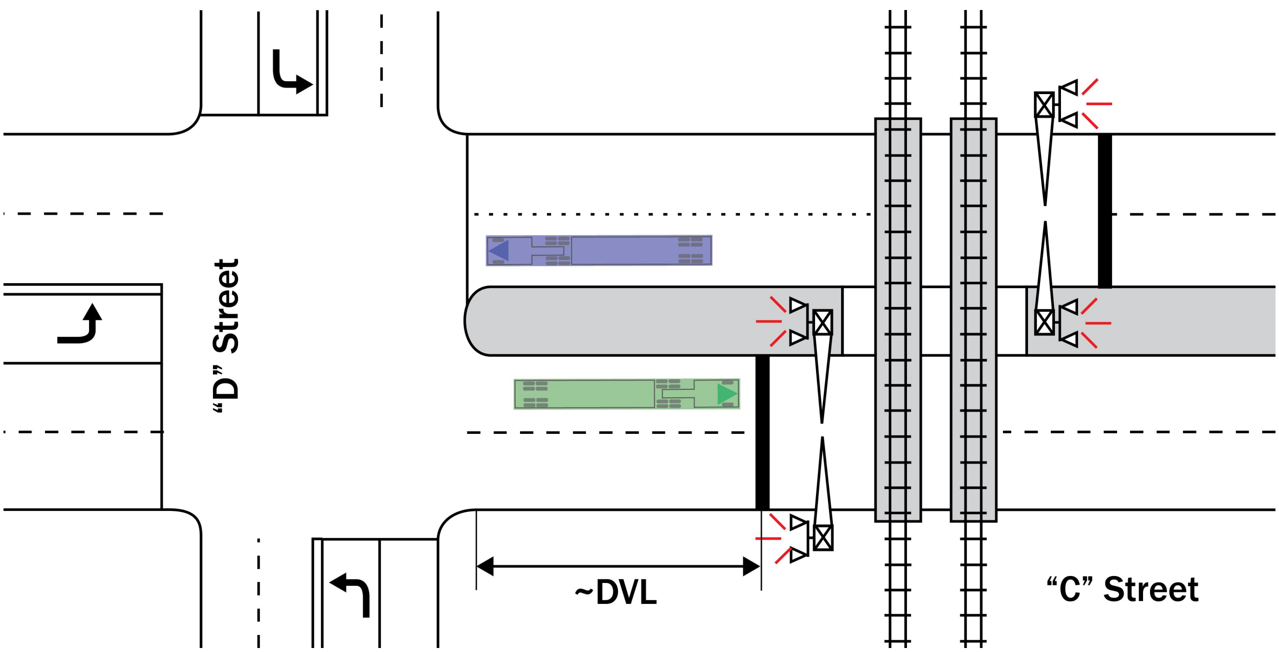


Figure 3–7. Left Turn Towards Tracks with Sufficient Storage

The designer may also ignore left turns towards the tracks where the left turn towards the tracks is a protect only left turn with sufficient yellow and red time to clear the design vehicle through the intersection.

Yellow Trap

A yellow trap, or lagging yellow, is a special scenario that the designer shall account for to mitigate collisions from occurring at intersections during preemption. A yellow trap occurs when the track clearance green phase and the opposing traffic's through and permissive left turn phases are being served prior to a preemption call. When preemption is activated, the traffic signal controller will hold the track clearance green phase, while the opposing signal heads will go to yellow. Opposing left-turn vehicles will wait in the intersection for an adequate gap. Depending on the traffic, motorists may need to wait until the traffic signal transitions from green to yellow or even red. Motorists typically assume the opposing traffic is transitioning as well. When the opposing motorists on the track clearance phase remain green, to transition to track clearance green sooner, a collision can occur since both drivers are used to seeing simultaneous yellows on both approaches when their phase ends. Figure 3-8 illustrates an example of a yellow trap occurring during preemption with a grade crossing located north of the displayed intersection.

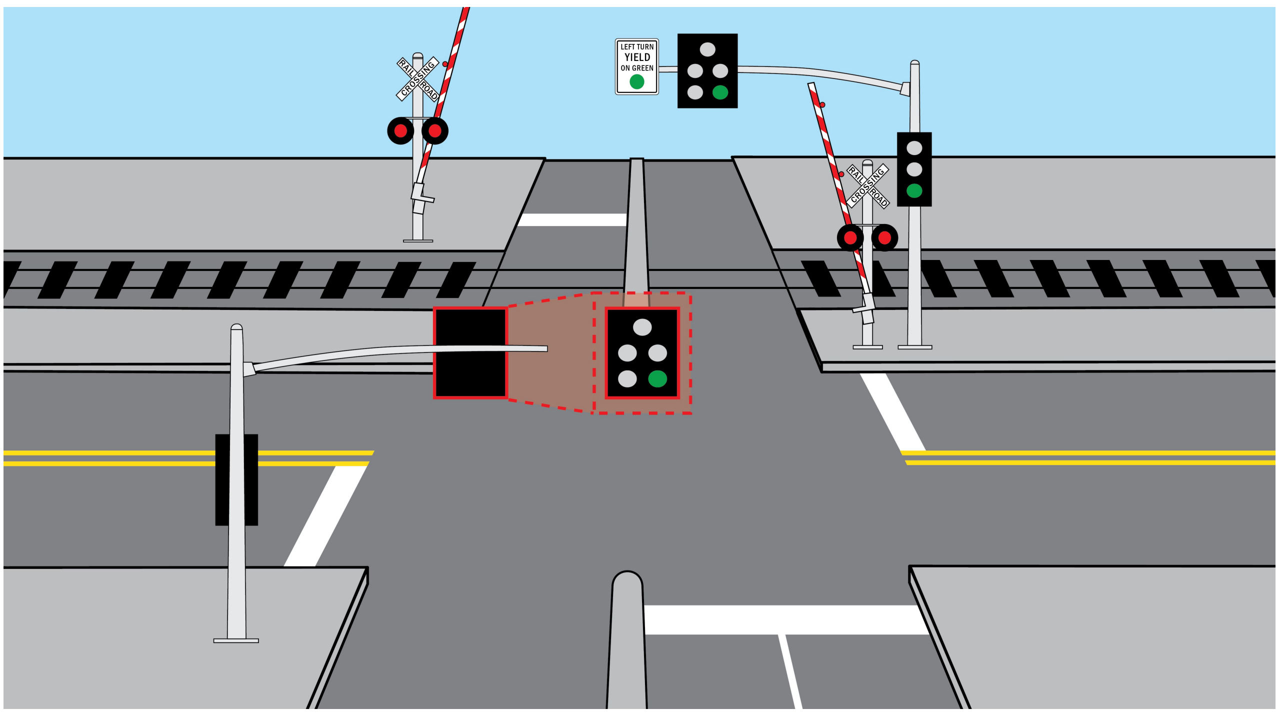


Figure 3–8. Yellow Trap During Preemption

The designer may apply either of the following methods to prevent a yellow trap during preemption:

- The traffic signal should have protected-only left turn for the track clearance green phase and opposing traffic, or
- If the design proposes permissive left turns for opposing traffic, transition the traffic signal to all-red when preemption is activated. Once the traffic signal is all-red then transition to track clearance green. The TxDOT Form 2304 should account for the amount of all-red time that will be provided during preemption to prevent the yellow trap.

Chapter 4: Railroad Relays and Systems

Contents:

Section 1: Railroad Relays and Usage in Traffic Signal Systems

Railroad Warning System

Per AREMA standards, the warning time the railroad provides in advance of the train's arrival at the crossing is referred to as the Total Approach Time (TAT). TAT is comprised of several values as shown in Figure 4-1. Several of these values (Required Minimum Time, Clearance Time, Minimum Warning Time, and Advance Preemption Time) are included in Chapter 3 of this manual and are also defined in [Form 2304-I](). Key components that are not needed for preemption calculations but are necessary for determining TAT include the following as defined by AREMA.

- Buffer Time (BT) is the discretionary time that may be added by the railroad to account for variations in train handling.
- Equipment Response Time (ERT) is added to provide for variation in railroad equipment response time.

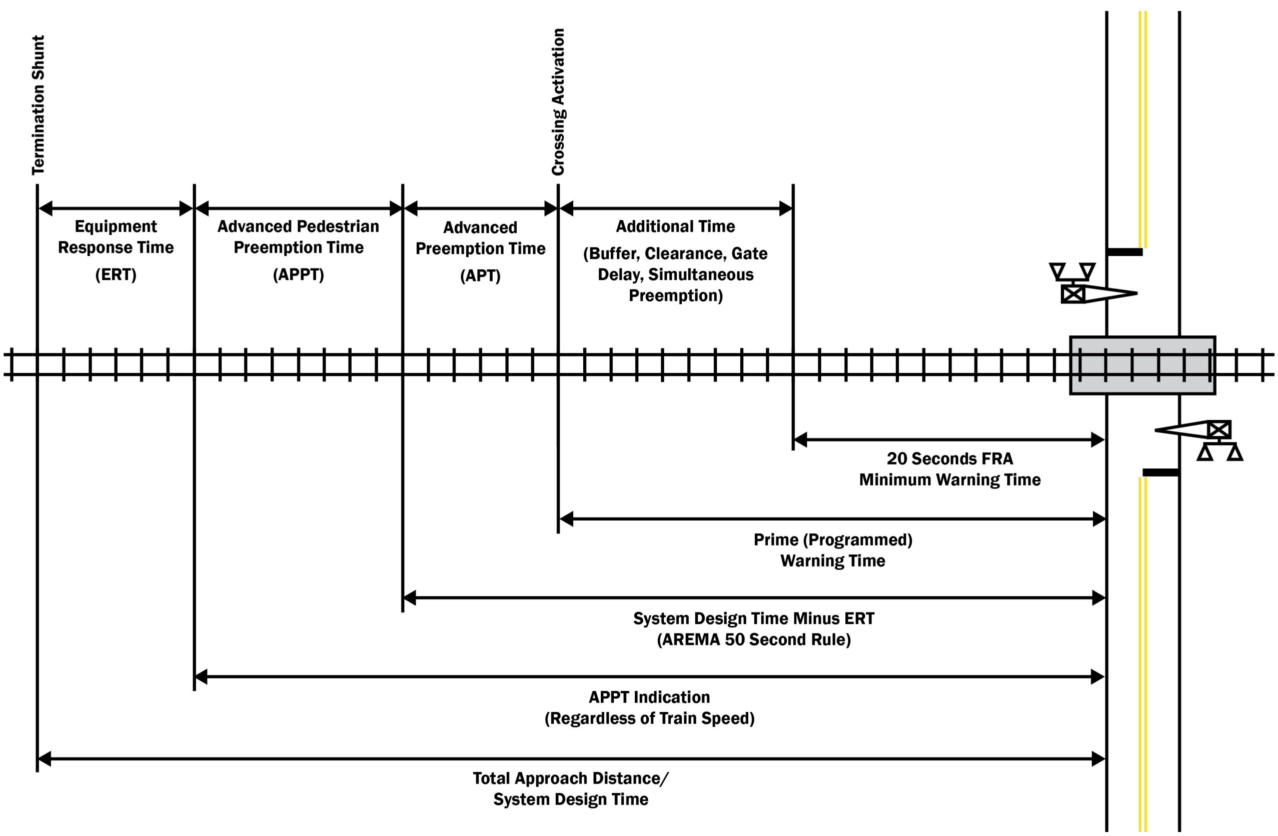


Figure 4–1. Typical Railroad Approach Timing Parameters

Railroads may use various types of detection systems to activate the railroad warning devices. Railroad detection systems generally consist of track circuits and island circuits. Track circuits are terminated by shunts on the tracks which are placed based on the required TAT as shown in Figure 4-1. Crossings with long railroad approaches and/or locations where multiple active warning crossings are in close proximity often use remote signal houses or DAX (Downstream Adjacent Crossing) locations.

Constant warning circuitry is used to provide more uniform warning times. Constant warning circuitry can detect the speed of an oncoming train to activate the railroad warning devices at the appropriate time. Constant warning circuitry also will deenergize the traffic control relay to communicate to the traffic signal controller to begin preemption. A major advantage of constant warning time is it predicts when to drop a preemption call if a train stops on the approach, as the case may be when a station or switch is located between the termination shunt and the grade crossing. Constant warning time may not be suitable for approaches where shunting is erratic due to rust or foreign material on the tracks. Future phases of positive train control (PTC) may add another potential detection type to railroad systems.

Railroad Relays

Traffic signal interconnection begins at the traffic signal cabinet with an output to the railroad signal house. Railroads use relays in a normally-closed (energized) or normally-open (deenergized) state to complete the circuit back the traffic controller.

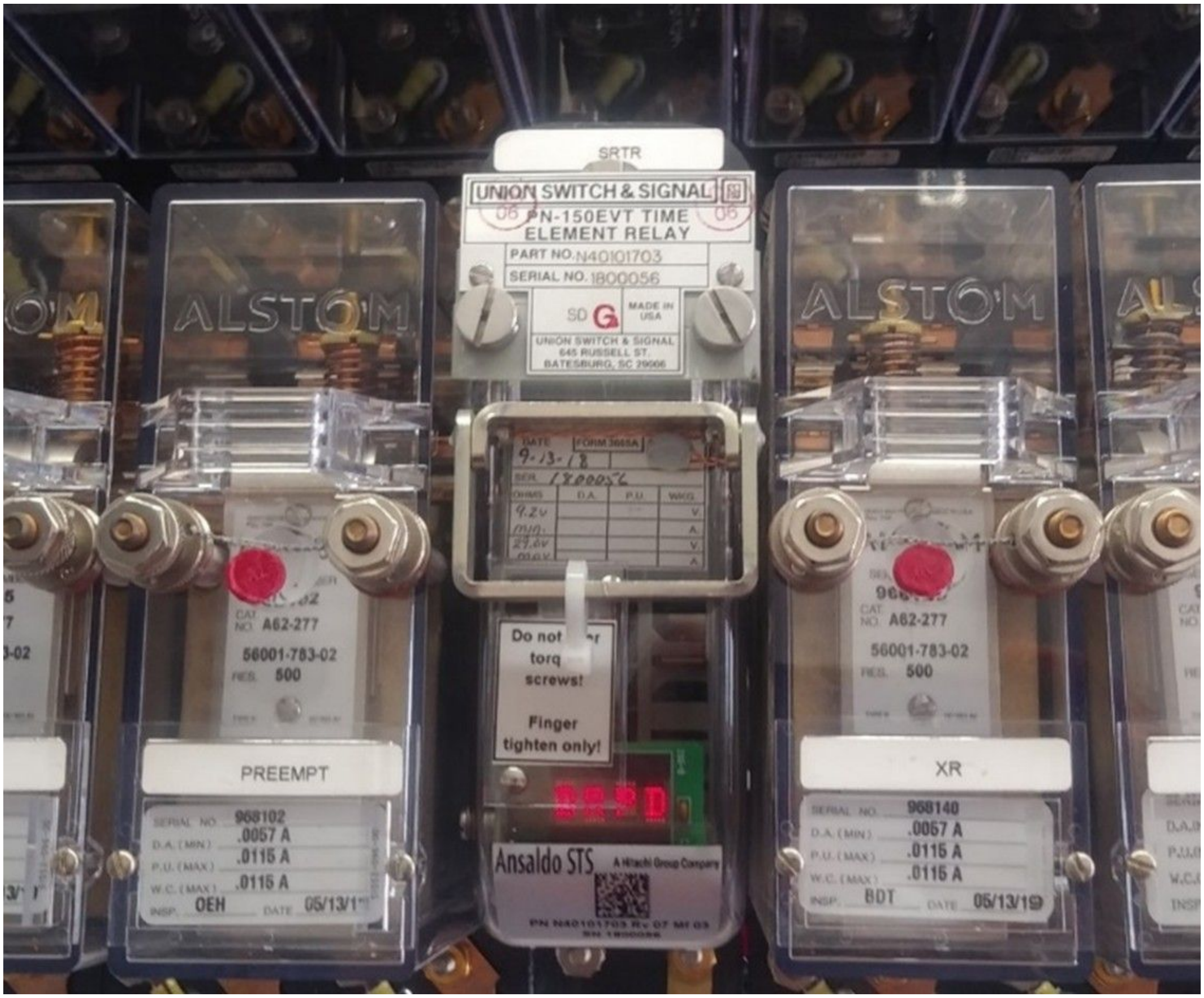


Figure 4–2. Railroad Relays

There are various railroad relays recommended by ITE and AREMA that the railroad may install to provide additional assistance in transitioning from normal to preemption operations. While not every relay is necessary for a successful and safe interconnected grade crossing, TxDOT recommends requesting them as they can transmit important information to the traffic signal controller, which can then respond more efficiently and reliably. Some railroad authorities also require certain relays to be installed alongside any new or modified interconnected grade crossings. These relays and their functions are outlined in Table 4-1 below.

Table 4-1. Common Railroad Relays

Term	Abbreviation	Function
Advance Pedestrian Preemption	APP	The advance pedestrian preemption relay is typically in a normally closed state. When activated, it notifies the traffic signal controller to finish serving pedestrian clearance on any active pedestrian phase (if applicable) prior to the start of the Preemption Clearance Interval for traffic signal modification projects or new installations. The advance pedestrian preemption relay shall be included where railroad interconnect and pedestrian clearance are needed and the track approach time (TAT) would otherwise violate the AREMA 50-Second Rule (as defined in Section 5-4).
Advance Preemption / Traffic Control Relay	ADV/TCR	The advance preemption relay is in a normally closed state. When activated, it notifies the traffic signal controller to begin preemption operations and begin right-of-way transfer. The advance preemption relay shall be included at all interconnected traffic signals as they are modified, or as new signals are installed, unless the diagnostic team determines that simultaneous preemption is most appropriate.
Crossing Active	XR	The crossing active relay is in a normally closed state. This relay acts as a re-start circuit for trains that are stopped within the approach where the full advance preemption time is not available. When activated, this relay notifies the traffic controller to immediately enter a special truncated preemption program to enter the Preemption Clearance Interval. Railroad warning equipment activates—flashers begin flashing and gates begin descending at the grade crossing. This circuit is often used to activate blank-out signs during preemption. The crossing active circuit shall be included at all interconnected traffic signals as they are modified, or as new signals are installed. At locations without gates, this circuit should be used to terminate the Preemption Clearance Interval.
Gate Down	GD	The gate down relay is in a normally open state. When activated, it notifies the traffic signal controller that the gates have descended to a nearly horizontal position, confirming that vehicles are physically restricted from entering the grade crossing area. Once the gates are down, the traffic signal must finish clearing vehicles that have already entered the crossing area. Upon serving any remaining Preemption Clearance Interval, the traffic signal controller terminates the interval and begins limited service operations. The gate down circuit shall be included at all interconnected traffic signals with railroad gates as they are modified or as new signals are installed to prevent a preemption trap.
Island	ISLD/ISLR	The island relay is in a normally closed state. When activated, it notifies the traffic signal controller that the train has reached the grade crossing. Consequently, this circuit should only be used as a fail-safe for the gate down circuit. It provides information for the traffic signal to transition to limited service operations.

Table 4-1. Common Railroad Relays

Term	Abbreviation	Function
Supervision (Supervised)	SUPR	A supervised circuit is normally in the opposite state from the circuit it is supervising to monitor the interconnection between the railroad equipment and the traffic signal. If the connection is broken, the traffic signal shall begin preemption and enter a fault condition. The fault condition should be flashing red. The advance preemption circuit shall be supervised at all interconnected traffic signals as they are modified, or as new signals are installed.
Traffic Signal Health	HLTH	The traffic signal health circuit notifies the railroad signal system of an unhealthy traffic signal system (for example, flashing-red operation, power outage). If a problem exists, the railroad signal system can activate the railroad warning equipment sooner in order to safeguard the grade crossing. Traffic signal health shall be included at all interconnected traffic signals as they are modified, or as new signals are installed.

Single Break and Double Break Circuits

TMUTCD states ” The preemption special control mode shall be activated by a supervised preemption interconnection using fail-safe design principles between the control circuits of the grade crossing warning system and the traffic signal controller unit.”

A single break circuit, as shown in Figure 4-2, is typically provided along with a supervision circuit to follow a fail-safe principle. This involves a deenergized and energized circuit. Both circuits change states when activated. If both circuits are energized or deenergized at the same time, this implies a faulty interconnection and the traffic signal shall immediately transition to preemption operations followed by a fault condition.

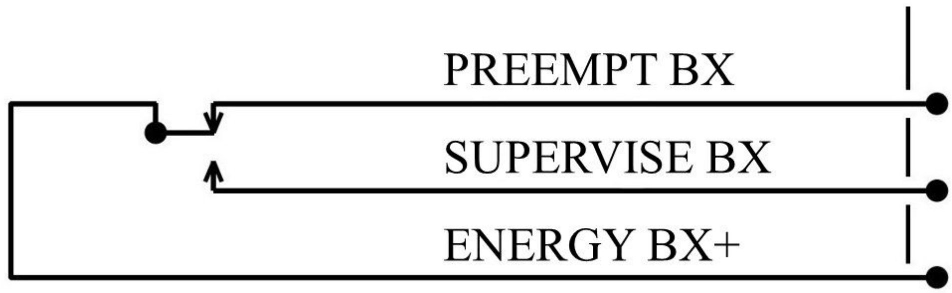


Figure 4–3. Single Break Circuit with Supervision

Per TMUTCD, “Instead of supervision, a double-break preemption interconnection circuit that uses two normally-closed circuits that open both the source and return energy circuits may be used.” Both are required A double break circuit schematic is shown in Figure 4-3 to change states in order to begin preemption. This provides a safety measure by ensuring that an electrical current will not mistakenly trigger a response and potentially transition to preemption by breaking both the positive and negative sides of the circuit.

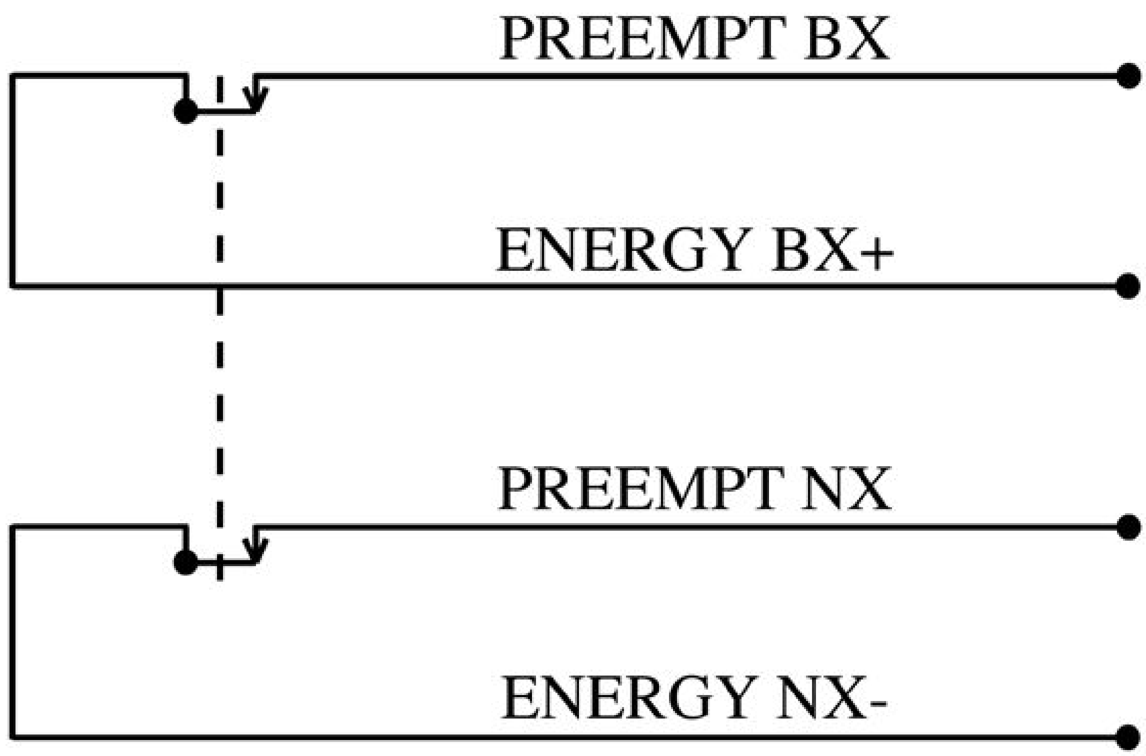


Figure 4–4. Double Break Circuit with Supervision

Although TMUTCD allows for either a single break supervised circuit or a double break circuit, the designer shall consider the type of traffic signal controller, preemption interface and the related software to ensure that the equipment is capable of handling those inputs. TMUTCD also dictates that "information regarding the type of preemption and any related timing parameters shall be provided to the railroad company or transit agency so that the railroad company or transit agency can design the appropriate train detection circuitry".

Section 2: Preemption Request Forms

A preemption request form is a useful technical document summarizing the basic crossing information, preemption timing parameters, and requested railroad circuitry configuration and relays for both highway and railroad authorities to easily reference. This information is especially important when project timelines stretch for longer durations than anticipated and for future reference during maintenance activities. Note that some of the information provided in a preemption request form shall also be specified in the preemption calculations and various plan sheets. It is important to provide consistent project details across all technical documents to prevent confusion or any misleading information. In addition, in order to accurately fill out the preemption request form, the designer should clearly understand how each railroad relay functions as well as the preemption timing.

Projects involving interconnection between traffic signal systems and railroad signal systems should be coordinated with RRD for proper execution. Refer to the TxDOT Rail-Highway Operations Manual for specific information related to approval of railroad related projects.

Class 1 railroads often have their own version of a preemption request form. However, for consistent documentation on all projects, the designer shall complete the Interconnection Worksheet (located in Appendix A) following the diagnostic review to define the circuits agreed upon by the diagnostic team as well as other interconnection details. The circuit information can later be transposed onto railroad specific preemption request forms. This worksheet shall be provided to TxDOT Rail Division for inclusion in the railroad agreement.

Section 3: Railroad Equipment Limitations

General Railroad Equipment Limitations

Several factors may impact the reliability of information from the railroad signal system due to limitations inherent in railroad warning systems. The termination shunts are placed a set distance from the grade crossing based on the train's maximum approach speed and the requested total approach time. Long approaches add complexity to the railroad warning system especially when approaches overlap with adjacent crossings. Additionally, when an environmental factor is introduced that causes varying train speeds, a consistent warning time becomes more difficult to replicate. Various factors include, but are not limited to:

- Multiple tracks at the grade crossing,
- Accelerating or decelerating trains,
- Train stations near the crossing, and
- Train yards and switching trains near the grade crossing.

AREMA 50 Second Rule

Advance preemption holds several benefits over simultaneous preemption, one of which is how advance preemption can provide a lower activation time for the railroad warning system at locations where a large APT is expected to adequately clear the crossing of any vehicles. As a result, advance preemption has garnered popularity over simultaneous preemption. However, this has led to highway authorities requesting increasingly higher preemption times, resulting in increased delays for motorists queued upstream of a grade crossing during preemption events. Long activation times can be linked to a lack of compliance with the warning system and can lead to undesirable motorist behavior.

Prior to 2018, as highway authorities requested longer preemption times at interconnected grade crossings, railroad warning times also began to fluctuate. This led to some concern regarding the reliability of railroad warning time. Grade crossing warning equipment manufacturers reported that as approach times increases, the railroad equipment's ability to accurately detect a train's approach became less reliable.

As a result, AREMA adopted the 50 second rule to encourage industry best practice to avoid unnecessarily increasing vehicular delays and provide reliable preemption timing at interconnected grade crossings.

Per the AREMA C&S Manual in Part 3.1.10, Section C, "For grade crossing warning systems, interconnected with highway traffic signals, System Design Time minus Equipment Response Time shall not exceed 50 seconds."

In this case, the term "System Design Time" may be used interchangeably with "Total Approach Time". Railroad authorities utilize various types of signal equipment, which can lead to varying ERT. The designer shall verify the railroad specific ERT and BT to confirm that the requested TAT will not exceed the AREMA 50 Second Rule. Long railroad approaches create complexities in the railroad warning system and can impact the reliability of warning times. See Figure 4-1 for a graphical representation of how System Design Time relates to the overall railroad approach.

Methods to Reduce Total Approach Time

When the initially calculated TAT exceeds the AREMA 50 second rule, various strategies may be employed to help reduce it.

Preemption Timing Strategies

Long right-of-way transfer times can be attributed to pedestrian clearance times, minimum green times, yellow intervals, red clearance intervals, and/or unusual roadway approach geometries.

One method of reducing the TAT is to fully (or partially) truncate the pedestrian phase when a preemption call is received. Where there are long crosswalks (without refuge areas) existing at the signalized intersection, pedestrian clearance times can increase the TAT by increasing the amount of time that must be provided prior to the Preemption Clearance Interval. Omitting the pedestrian clearance interval expedites the transition to the Preemption Clearance Interval as the train approaches the grade crossing. The designer shall follow the guidance in Form 2304-I to determine if full or partial truncation of the pedestrian clearance interval is reasonable. Where full pedestrian clearance is desired during preemption and results in a TAT that exceeds the AREMA 50 Second Rule, the designer should discuss the need for Advance Pedestrian Preemption Time (APPT) with the railroad. The total APPT should be determined by subtracting the APT without full pedestrian clearance from the APT with full pedestrian clearance.

APPT=APT (with pedestrian clearance)-APT (without pedestrian clearance)

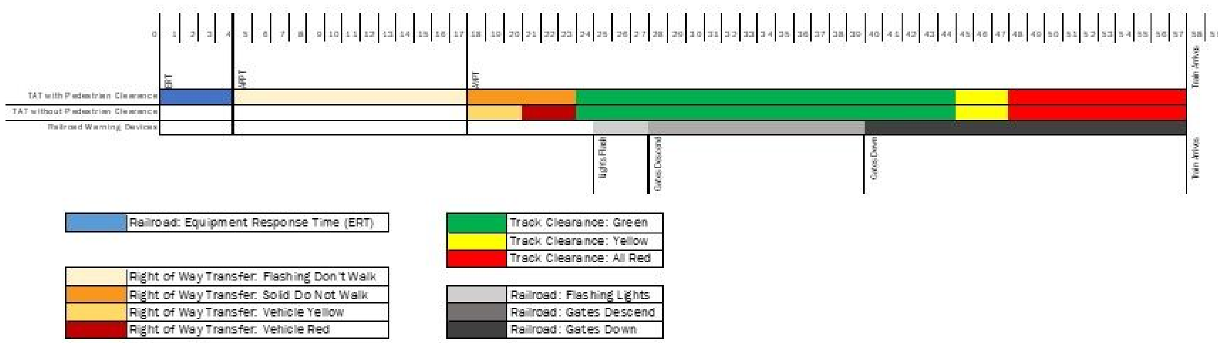


Figure 4–5. Traffic Signal Operations with APPT

Another method to reduce TAT is to reduce the minimum green time (Line 16 on Form 2304), which is defined as the minimum number of seconds that an active phase will display a green indication prior to transitioning to yellow and red clearance. Reducing the minimum green time decreases the right-of-way transfer time allowing the Preemption Clearance Interval to start sooner. This disadvantage of reducing minimum green is it may not meet driver expectations. Minimum green may be reduced to zero seconds unless the diagnostic team determines otherwise.

Minimum separation time (Line 43 on Form 2304) may also be reduced to meet the AREMA 50 Second Rule. Form 2304-I defines minimum separation time as a time “buffer” between the departure of the last vehicle from the railroad crossing and the arrival of the train. A minimum of four (4) seconds should be provided.

Queue Management Strategies

Queue management strategies may be implemented such that the calculated warning time may not need to account for the full queue clearance interval. Pre-signals can be used at locations where there is not enough storage space downstream for a design vehicle to safely queue between the tracks and the intersection. The pre-signal is intended to prevent queues on the grade crossing and stop vehicles from entering the grade crossing area during normal operations and during preemption.

A queue-cutter traffic signal, on the other hand, can be used to control traffic approaching the grade crossing by detecting vehicles downstream of the crossing and turning red before vehicles queue back onto the tracks. Guidance on preemption calculations for pre-signals and queue cutters is found in Chapter 3. Their design is discussed further in Chapter 6.

When calculating the preemption timing, the installation of a pre-signal or queue-cutter traffic signal can result in a shorter queue clearance time. Queue prevention is theoretically provided at all times, so queue clearance time only needs to clear the MTCD. These measures also help to provide more efficient queue management at the grade crossing and can improve overall traffic signal operations and traffic flow during normal operations.

Traffic Signal Operation Strategies

Certain traffic movements could be a leading factor in a TAT exceeding the AREMA 50 Second Rule. When a preemption call is sent to the traffic signal controller, the right-of-way transfer time interval must finish serving the current vehicular phase prior to the Preemption Clearance Interval. Any vehicular phases that cross the path of the track clearance phase may require longer right-of-way transfer time. One example is the left turn movement towards the tracks. For locations in which traffic on the street parallel to the tracks provides a permissive left turn movement but does not have enough storage length upstream of the tracks to allow a design vehicle to safely store, additional time is needed to allow the vehicle to complete the left turn and travel through the grade crossing area prior to crossing activation. Installing protected-only left turn phasing allows the conflicting vehicle to clear the intersection during normal operations and reducing the need to account for it in the preemption calculations during a preemption call.

The designer should make every effort to meet the AREMA 50 Second Rule while providing the time determined in the preemption calculations to effectively clear the tracks prior to arrival of the train. If site geometrics prevent compliance with the AREMA 50 Second Rule the designer shall notify the railroad as soon as possible to request a variance. A variance on the 50 Second Rule can be granted by the operating railroad in some special situations on a case-by-case review.

Multiple Track Crossings

Multiple track crossings have unique operations that can affect the operation of the traffic signal. Multiple tracks mean there is potential for back-to-back trains and preemption events. Depending on when the subsequent train enters the track circuit, the traffic signal may go from one preemption event and to another with little or no green time for the exit phase before returning to track clearance green. Crossings with multiple tracks should be designed to operate with the track clearance interval as the exit phase to minimize confusion to motorists. If a new preemption event occurs during the exit phase, the traffic signal should restart the track clearance interval and remain in track clearance green until the gate down input is received.

Train Stations, Rail Yards and Switching Trains

Where train stations, rail yards and/or train switching occurs in the railroad approaches there is potential for trains to be accelerating, decelerating, or stopping. These operations can cause traffic signals to enter and exit preemption without a train ever reaching the crossing. This can lead to driver confusion and frustration. If possible, railroad approaches for interconnected traffic signals should not extend into sidings or rail yards. TAT should be kept to a minimum at these locations to reduce the potential of having these elements in the approaches. If a switch or station is located inside the railroad approach, the ADV and XR circuits could energize at the same time. Where these elements cannot be avoided, the XR circuit shall be included in the interconnection. When the XR input is received the traffic signal shall immediately transition to track clearance green by serving the yellow and red clearance for any conflicting phases to begin clearing vehicles off the tracks as soon as possible. Queue management techniques should also be evaluated by the diagnostic team to provide queue prevention at all times and reduce the likelihood that vehicles are stopped on the tracks.

Chapter 5: Equipment Standards

Contents:

Section 1: Traffic Signal Cabinets for Railroad Interconnected Intersections

This section discusses how the railroad preemption circuits discussed in Chapter 4 should interface with TxDOT approved traffic signal cabinets. Traffic signals with railroad interconnection should use the standard TxDOT traffic signal cabinet, which is a Type P (44”W x 26”D x 55”H) that conforms to NEMA TS 2-2016 Traffic Controller Assemblies with NTCIP Requirements - Version 03.07 or latest Standards. Other NEMA cabinets may be used, but they shall accommodate the preemption related equipment and operations discussed in this chapter. The standards presented in this manual also apply to legacy style traffic signal cabinets that conform to the NEMA TS1 specification. Likewise, this preemption standard is compatible with the NEMA ATC traffic signal cabinet specification. However, the use of an ATC cabinet at locations with railroad preemption requires a design exception.

The primary input method of railroad preemption information from the railroad to the traffic signal controller is through the railroad interface which passes the information to the preemption input terminals located on the traffic signal cabinet main panel. When timing the railroad preemption warning time for the grade crossing, the standard TxDOT railroad interface sequences through multiple preemptors in the traffic signal controller while executing the preemption plan. The designer and traffic signal technician implementing the railroad preemption shall account for the use of a minimum of six preemption input terminals for railroad preemption. Six preemption input terminals may be necessary depending on the requested railroad circuitry.

Section 2: Traffic Signal Controllers for Railroad Interconnected Intersections

TxDOT traffic signals may operate on traffic signal controllers from various manufacturers in the TxDOT Districts and there will be manufacturer-specific variances in the controller configuration and programming. However, all TxDOT controllers shall meet NEMA TS2 standards. Traffic signal controllers interconnected to grade crossings for the purpose of railroad preemption shall have a minimum of six preemptors available for railroad preemption. The contractor or traffic signal technician shall assign preemptors based on the railroad circuit configuration.

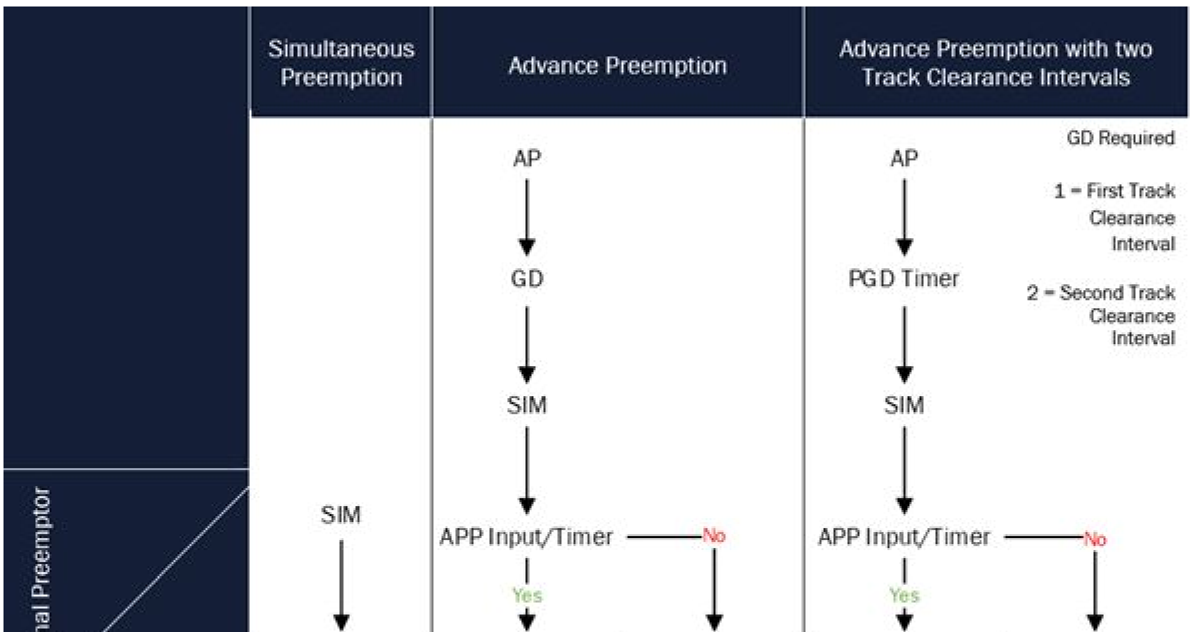
ATC Controllers

Traffic signal controllers that conform to the NEMA ATC specification provide robust logic processing features and the ability to map controller inputs that can be assigned in the logic processor. These features are required when considering the use of a passive-style railroad interface as defined in Chapter 5, Section 3.

Section 3: Interconnection Methods

Solid State Interface

The standard TxDOT railroad interface actively controls traffic signal operations during railroad preemption through its own microprocessor using multiple preemptors that are associated with the specific control plan. This manual defines such an interface as an active-style where the interface is responsible for processing all railroad inputs and directing the traffic signal controller. The preemptors shall be configured as shown in Figure 5-1 and described in Chapter 5, Section 4. The "static" configuration assigns each preemptor a specific railroad circuit and is the TxDOT standard. Some active-style interfaces use a dynamic preemptor assignment, which shuffles the preemptor assignment based on the railroad circuits requested.



Signal Preemptor / Configuration Options	1	3	4	13	14
PE1	ARF	ARF	ARF	ARF	ARF
PE2				PGD[2]	PGD[2]
PE3	SIM	SIM	SIM	SIM[1]	SIM[1]
PE4		AP	AP	AP[1]	AP[1]
PE5		APP		APP[1]	
PE6		DWL	DWL	DWL	DWL

ARF = All Red Flash GD = Gate Down DWL = Dwell/Limited Service APP = Advance Pedestrian Preemption

AP = Advance Preemption SIM = Simultaneous Preemption PGD = Pseudo Gate Down

Figure 5–1. Configuration Output Chart (Static)

Active style interfaces require several preemptors to operate. Most ATC traffic signal controllers have sufficient preemptors to accommodate these demands and Emergency Vehicle Preemption (EVP), if desired. However, depending on the traffic signal cabinet used, there may not be enough preemption terminals on the main panel to access all of the available preemptors in the controller. Preemptors 1-6 shall be reserved for railroad preemption. EVP detection/inputs may be combined, where feasible, and connected to lower priority preemption inputs. Alternatively, other inputs may be remapped for EVP.

Relay Interface Panel

This manual defines relay interface panels which only pass railroad preemption inputs through to the traffic signal controller, as passive-style interfaces. With passive-style interfaces, the traffic signal controller is responsible for processing all railroad inputs from the interface and managing the preemption operations. Off-the-shelf, passive-style interfaces are available, but can require complex logic processing in the traffic signal controller to provide the necessary preemption functionality. As a result of this, along with the possibility of equipment failure and potential human error, TxDOT does not allow passive-style railroad interface panels. The designer shall not specify use of a passive-style railroad interface panel without a design exception and verification that the interface panel can provide the output as described in Chapter 5, Section 4.

Section 4: Railroad Preemption Operation Specification

The purpose of this standard is to define the required operations for the purpose of railroad preemption.

Traffic Signal Operation

At interconnected traffic signals, the controller assembly, consisting of the traffic signal controller and cabinet, shall provide the operation detailed below relative to the preemption functionality and operation.

The controller assembly shall be provided with all hardware, software and firmware necessary to provide the operation described herein. The designer, contractor and/or traffic signal technician should closely review the functional requirements of the railroad preemption operation to assure that the equipment is capable of performing the functions as specified. In many cases, the railroad circuits have been designed to provide and support the specific functionality. As a result, no exceptions will be permitted to these requirements.

Interconnection Circuits

The following sections expand upon the railroad relays/circuits discussed in Chapter 4 and specify how these circuits shall interact with the traffic signal system. The combined circuits are specified in the preemption design and are referred to as the “Interconnection.” The designer shall request the circuits from the railroad to meet the needs of the specific grade crossing location as determined by the diagnostic team.

Advance Pedestrian Preemption (APP)

The Advance Pedestrian Preemption (APP) circuit may be included to extend the Total Approach Time (TAT) beyond what is allowed by the AREMA 50 second rule and provide pedestrian clearance. When an APP circuit is specified, it should always be in conjunction with an Advance Vehicle Preemption (AVP) circuit.

The railroad may provide this circuit to notify the traffic signal controller of an approaching train prior to AVP and prior to activation of the railroad warning devices. The time interval between this notification and the instant when the AVP circuit is activated is known as the Advance Pedestrian Preemption Time (APPT). The Advance Pedestrian Preemption (APP) circuit should be single break.

When the APP circuit is activated, the following sequence shall occur:

- Any pedestrian walk interval which has not completed its programmed value should be truncated to zero. The signal controller should immediately begin the pedestrian change interval.
- Any pedestrian change interval which has not completed its programmed value may be truncated to an alternate pedestrian change value.

- When the pedestrian change interval has completed timing, no new pedestrian service shall begin until this circuit returns to its non-activated state. If no pedestrian service is active when the APP circuit is activated, no new pedestrian service shall be allowed. Any pedestrian calls received during APP shall be stored until pedestrian service is allowed. During the APPT interval, vehicular movements shall continue to operate normally.

Advance Vehicle Preemption (AVP)

The AVP circuit is only used when APP operation is specified. This circuit notifies the traffic signal controller of an approaching train prior to activation of railroad warning devices. The period of time between this notification and the instant when the railroad warning devices are activated is known as Advance Vehicle Preemption Time (AVPT). In most cases, AVPT should be used by the traffic signal controller to terminate any active non-track clearance vehicular movements and to transition to a programmed track clearance interval to clear the track(s). The AVP circuit should be single break.

When this input is activated, the following sequence shall occur:

- Any minimum green interval which has not completed its programmed value shall be truncated to an alternate minimum green value (usually zero).
- The normal yellow change interval shall complete its programmed value. The yellow change interval shall begin once the pedestrian intervals and the minimum green interval have completed their timing.
- The normal red clearance interval shall complete its programmed value.
- The Preemption Clearance Interval shall start immediately following completion of the red clearance interval and shall continue until the gate down input is received and the minimum Preemption Clearance Interval has been served.

Advance Preemption (AP)

This circuit is used when APP operation is NOT specified. Where used, the railroad may provide this circuit to notify the traffic signal controller of an approaching train prior to activation of the railroad active warning devices. The period of time between this notification and the instant when the railroad warning devices are activated is known as Advance Preemption Time (APT). In most cases, APT is used by the traffic signal controller to terminate any active non-track clearance movements and to change to a programmed Preemption Clearance Interval to clear the track(s). The Advance Preemption circuit should be single break with supervision.

When this input is activated, the following sequence shall occur:

- Any pedestrian walk interval which has not completed its programmed value may be truncated to an alternate walk value and any remaining walk time shall be completed. When the alternate walk time has completed, the associated pedestrian change interval shall begin.
- Any pedestrian change interval which has not completed its programmed value may be truncated to an alternate pedestrian change value.

- Any minimum green interval which has not completed its programmed value shall be truncated to an alternate minimum green value.
- The normal yellow change interval shall complete its programmed value. The yellow change interval shall begin once the pedestrian intervals and the minimum green interval have completed their timing.
- The normal red clearance interval shall complete its programmed value.
- The Preemption Clearance Interval shall start immediately following completion of the red clearance interval and shall continue until the gate down input is received and the minimum Preemption Clearance Interval has been served.

Supervision (SUPR)

The supervision circuit is provided through a railroad relay back contact and monitored by the railroad interface for a fault condition in the interconnection cable. The supervision circuit is the inverse operation of the circuit being supervised. If the circuits are both energized or are both de-energized at any time, this shall indicate a vital interconnect failure and shall cause the traffic signal controller unit to transition to all-red soft flash until the fault is repaired. When the Advance Preemption circuit is specified, it should be the supervised circuit; otherwise, the Crossing Active (XR) circuit should be the supervised circuit.

Crossing Active (XR)

The railroad may provide this circuit to notify the traffic signal controller of an approaching train at the same time the railroad warning devices activate. This circuit is commonly referred to as an "XR" circuit by the railroad. It is also the circuit typically used for “Simultaneous Preemption”. The XR or equivalent circuit should be single break. The XR circuit shall be connected in such a way that the Simultaneous Preemption Relay can never be down with the XR relay up. This is commonly circuited by having the XR relay as a repeater of the preemption relay.

Where Advance Preemption is used, the traffic signal controller should enter the preemption sequence during the APPT, AVPT and/or APT period for through train moves. However, where a train restarts within the approach circuit to the crossing, the APT may be reduced or eliminated. This commonly occurs where railroad switching operations take place, where trains meet or pass, or where trains stop at stations within the approach circuit to the crossing. The railroad then has operating rules which govern the movement of trains over the crossing. However, in these instances where APT is reduced or eliminated and the Crossing Active input is activated, any remaining walk, pedestrian change or minimum green time shall be truncated to zero. Yellow change shall begin for any phases other than the Preemption Clearance Interval phases followed by the red clearance interval. The Preemption Clearance Interval shall start immediately following completion of the red clearance interval and shall continue until the gate down input is received and the minimum Preemption Clearance Interval has been served. The crossing active circuit should also be used to activate blank-out signs restricting movement towards the crossing during preemption.

At locations without gates, this circuit should be used to terminate the Preemption Clearance Interval. Once the crossing active circuit is energized, the traffic signal has at least 20 seconds to complete the Preemption Clearance Interval and transition to limited service. If the advance preemption circuit has already energized, the signal should already be transitioning to the Preemption Clearance Interval. The Preemption Clearance Interval should extend beyond receipt of the crossing active input until the minimum Preemption Clearance Interval has been served.

Where Simultaneous Preemption is used, the traffic signal controller shall transition to the Preemption Clearance Interval as soon as possible. The following sequence shall occur:

- Any pedestrian walk interval which has not completed its programmed value should be truncated to zero.
- Any pedestrian change interval which has not completed its programmed value should be truncated to zero.
- Any minimum green interval which has not completed its programmed value should be truncated to zero.
- The normal yellow change interval shall complete its programmed value.
- The normal red clearance interval shall complete its programmed value.
- The Preemption Clearance Interval shall start immediately following completion of the red clearance interval and shall continue until the gate down input is received and the minimum Preemption Clearance Interval has been served.

Gate Down (GD)

If gates are present at the grade crossing, the railroad may provide this circuit to notify the traffic signal controller when the gate(s) controlling access over the track(s) approaching the intersection is/are almost horizontal. The traffic signal controller unit shall not leave the Preemption Clearance Interval until the gate down circuit is closed indicating that the gate(s) is/are down confirming that vehicles are physically restricted from entering the crossing area. Once the gates are down the traffic signal must finish clearing vehicles that have already entered the crossing area.. The traffic signal controller shall extend the Preemption Clearance Interval until the gate down input is activated.

The Gate Down circuit should be single break. If more than one gate controls access over the crossing approaching the intersection or if exit gates are present at the grade crossing, then all mechanisms must indicate that they are lowered prior to closing the Gate Down relay. All gates on approach to an interconnected traffic signal should be connected to the Gate Down circuit to provide the appropriate Gate Down information. In accordance with AREMA 16.30.10, the Gate Down shall be wrapped by the Island relay. This will provide a fail-safe Gate Down indication to the traffic signal controller in the event one or more of the included gates is not down and the train occupies the Island circuit.

Island Occupied (ISLD)

This circuit may be provided by the railroad if requested and will notify the traffic signal controller when a train has physically entered the limits of the grade crossing. This is referred to as the “Island”. This circuit may be used to terminate the Preemption Clearance Interval in the absence of a gate down indication as noted in the discussion of the Gate Down circuit. However, by the time the island circuit is energized, the train is already at the crossing. Consequently, a separate island circuit is only applicable in unique situations at locations where there are no gates present. The Island relay circuit should be single break.

Traffic Signal Health Circuit (TSH)

The traffic signal controller shall notify the railroad warning system whenever the traffic signal has entered conflict flash, manual flash, soft flash, manual signals off, or when commercial power and backup power system has failed (signals off) through a traffic signal health circuit. The railroad may, at their option provide a traffic signal health relay which will normally be energized by this input. Whenever the Traffic Signal Health relay is down, the operation of the railroad warning devices shall be extended by the Advance Preemption (and APP, if used) time. The Traffic Signal Health relay must remain open until the XR relay closes.

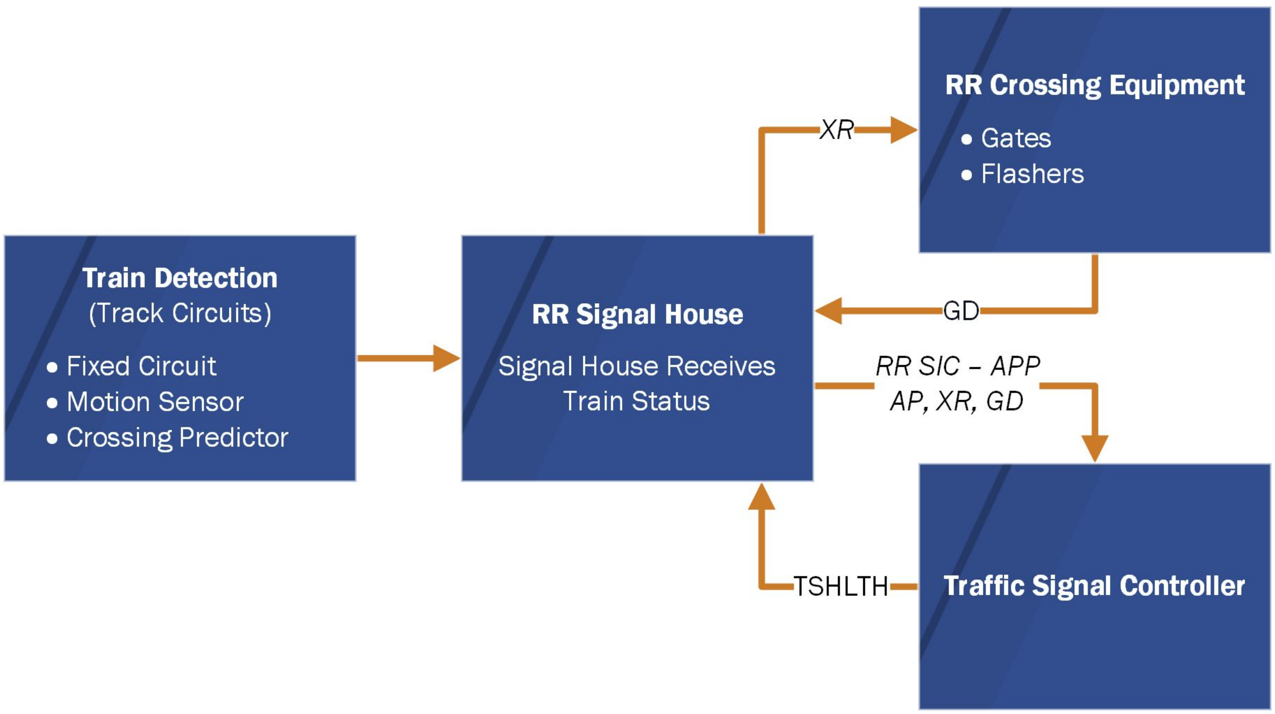


Figure 5–2. Crossing Circuit Diagram

Functional Implementation

The preemption sequencing shall be implemented through the railroad preemption system installed in the cabinet assembly. Based on the states of the interconnection inputs from the railroad warning system, the system will call pre-defined preemption plans in the controller unit as shown in Figure 5-3. Note, this is according to the static configuration where each preemptor is assigned to a specific railroad circuit.

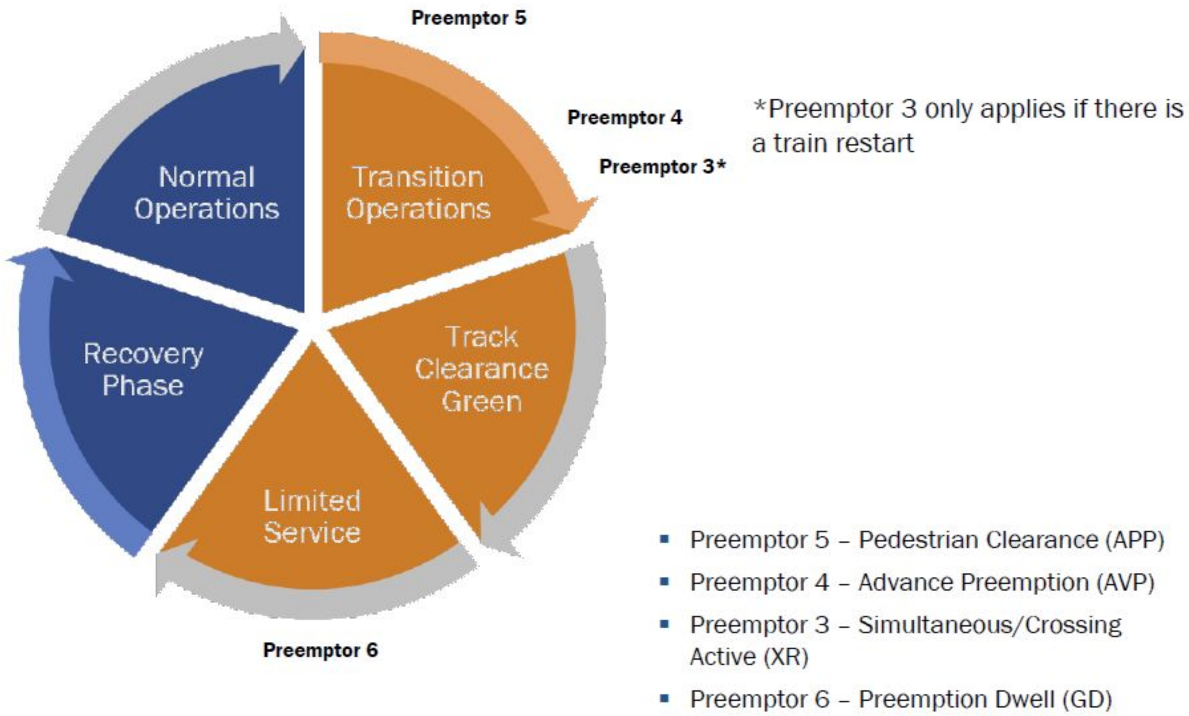


Figure 5–3. Preemptors Used in a Static Configuration

Each preemption plan must be configured for non-locking operation providing the operation described in the following statements:

Preemptor 1 – All-Red Soft Flash

When activated, this plan has priority over all other preemption plans. The controller unit shall transition to All-Red Soft Flash via the following steps:

1. A preemption delay period shall elapse prior to transition to this plan. This delay period is typically set to allow a railroad preemption system module to be changed within a short period of time without placing the intersection into flashing operation.
2. Any pedestrian walk interval which has not completed its programmed value shall be truncated to an alternate walk value and any remaining walk time shall be completed. When the alternate walk time has completed, the associated pedestrian change interval shall begin.
3. Any pedestrian change interval which has not completed its programmed value shall be truncated to an alternate pedestrian change value.
4. Any minimum green interval which has not completed its programmed value shall be truncated to an alternate minimum green value.
5. The normal yellow change interval shall complete its programmed value.
6. The normal red clearance interval shall complete its programmed value.

7. The Preemption Clearance Interval shall start immediately following completion of the red clearance interval and shall continue until the minimum Preemption Clearance Interval has been served.
8. The All-Red Flash interval shall be displayed and begin to time its programmed minimum time. Once the programmed time has completed, the sequence shall remain in All-Red Soft Flash operation until the Plan 1 input is no longer active.
9. When the Plan 1 input is no longer active, the sequence shall advance to the programmed exit phases following a programmable steady All-Red display.

Preemptor 2 – Special Applications Interval

1. Plan 2 is typically used where two Preemption Clearance Intervals are required based on site specific intersection geometry.

Preemptor 3 – Simultaneous/Crossing Active Interval

When activated, this plan has priority over lower numbered preemption plans. The controller unit shall transition to the Preemption Clearance Interval via the following steps:

1. Any pedestrian walk interval which has not completed its programmed value shall be truncated to zero.
2. Any pedestrian change interval which has not completed its programmed value shall be truncated to zero.
3. Any minimum green interval which has not completed its programmed value shall be truncated to zero.
4. The normal yellow interval shall complete its programmed value.
5. The normal red clearance interval shall complete its programmed value.
6. The Preemption Clearance Interval shall be displayed and begin to time its programmed minimum time. Once the programmed time has completed, the sequence shall remain in the Preemption Clearance Interval.
7. When the Plan 3 input is no longer active, the sequence shall advance to the programmed exit phases.

Preemptor 4 – Advance Preemption Interval

When activated, this plan has priority over lower numbered preemption plans. The controller unit shall transition to the Preemption Clearance Interval via the following steps:

1. Any pedestrian walk interval which has not completed its programmed value shall be truncated to an alternate walk value, and any remaining walk time shall be completed. When the alternate walk time has completed, the associated pedestrian change interval shall begin.

2. Any pedestrian change interval which has not completed its programmed value shall be truncated to an alternate pedestrian change value.
3. Any minimum green interval which has not completed its programmed value shall be truncated to an alternate minimum green value.
4. The normal yellow change interval shall complete its programmed value.
5. The normal red clearance interval shall complete its programmed value.
6. The Preemption Clearance Interval shall be displayed and begin to time its programmed minimum time. Once the programmed time has completed, the sequence shall remain in the Preemption Clearance Interval.
7. When the Plan 4 input is no longer active, the sequence shall advance to the programmed exit phases.

Preemptor 5 – Pedestrian Clearance Interval

When activated, this plan has priority over lower numbered preemption plans. The controller unit shall transition to the pedestrian change interval via the following steps:

1. Any pedestrian walk interval which has not completed its programmed value shall be truncated to an alternate walk value and any remaining walk time shall be completed. When the alternate walk time has completed, the associated pedestrian change interval shall begin.
2. Any pedestrian change interval which has not completed its programmed value shall be truncated to an alternate pedestrian change value.
3. As long as the Plan 5 input is active, all allowed vehicle phases shall continue to operate normally. No new pedestrian service may begin.
4. When the Plan 5 input is no longer active, the sequence shall advance to the programmed exit phases.

Preemptor 6 – Preemption Dwell Interval

When activated, this plan has priority over lower numbered preemption plans. The controller unit shall transition to the Preemption Dwell Interval via the following steps:

1. The normal yellow change interval shall complete its programmed value.
2. The normal red clearance interval shall complete its programmed value.
3. The Preemption Dwell operation shall commence operation and remain as long as the Plan 6 input is active.
4. When the Plan 6 input is no longer active, the sequence shall advance to the programmed exit phases.

Section 5: Railroad Interconnection Standards

Active-Style Interface Specification

General

The traffic signal system shall provide a solid-state, modular interface. Optimum functionality and safety features are achieved when the modules are installed in a standalone companion input file rack with module insertion verification protection. The companion input file rack shall provide two to four slots for the preemption system modules. Unless otherwise stated, the contractor shall furnish a standalone companion input file rack with module insertion verification protection for the railroad preemption. The interface shall function as follows:

- The railroad preemption system shall operate from nominal 120 Vac power applied via the companion input file rack or the input file pins.
- Each interconnection circuit to the railroad warning system shall operate on 24 Vdc and be isolated from all traffic signal cabinet internal voltage sources, AC line, grounds or AC neutral.
- The railroad preemption system shall generate the isolated 24 Vdc supply for the interconnection circuits.
- Each input from the railroad shall be optically isolated from other inputs and not referenced to any traffic signal cabinet internal voltage sources, AC line, grounds or AC neutral.
- The railroad preemption system shall provide a Traffic Signal Health isolated output. This output shall be an isolated 12 Vdc and shall be energized when Traffic Signal Health as described below is valid. The system shall monitor the 120 Vac load switch signal bus control circuit. In addition, the system shall monitor an appropriate signal output to sense “soft flash” operation. Soft Flash is flashing operation generated by the controller unit by providing outputs to the load switches that are turned off and on to develop the specific flash pattern. These two inputs shall be referenced to 120 Vac Neutral. If the signal bus becomes de-energized or flashing operation is sensed, the system shall de-energize the Traffic Signal Health output to the railroad.
- The railroad preemption system shall provide outputs referenced to controller unit logic ground for selection of programmed functions.

Supplemental Terminals

All supplemental terminals provided as a part of the railroad preemption interface shall utilize a "cage-clamp" design, such as manufactured by WAGO Corporation or equivalent. Terminals which provide "side wipe" connections or set screws are not acceptable. Terminal shall provide a minimum of 25 slots for railroad inputs.

Preemption System Isolator Modules

Each module providing preemption outputs shall be a processor-based unit. At least one module shall incorporate an organic light-emitting diode (OLED) display to indicate unit status, inputs, outputs and system timing. Modules shall be provided with an internal power supply to operate from the 120 Vac source. The combined railroad preemption interface system, including all modules, shall provide the following functions and features:

For preemption outputs and health monitoring:

- Input for 120 Vac signal bus (load switch power).
- Input for 120 Vac flashing signal indication for soft flash sense (soft flash indication).
- 12 Vdc isolated output to drive railroad vital relay for Traffic Signal Health.
- Isolated option input for Preemption Clearance Interval(s) monitoring from traffic signal load switch outputs.
- Input isolation for Advance Preemption, Supervised, Crossing Active and Gate Down from railroad warning system.
- Isolated option for Advance Pedestrian Preemption (APP), Gate Up, Island from railroad warning system.
- Outputs (six) for the traffic signal controller unit to select preemption plans.
- Output (advance) for control of blank-out signs or other devices.
- Output (simultaneous) for control of blank-out signs or other devices.

For operation of blank-out signs:

- 120 Vac load switch circuitry for an input file rack
- 4 Isolated circuits
- Ground true input provides 120 Vac output
- LED output channel status
- Self-supplied 24 Vdc to module rack

Railroad Preemption Isolator Module Input File Rack

The input file rack provides slots for the railroad preemption system isolator modules. The input file rack shall provide module insertion verification relay protection on the processor module slot(s) to verify proper seating. An improperly seated or missing module will place a call to the traffic signal controller preemption plan programmed for flash operation.

Unless otherwise specified, the railroad bungalow shall be provided with isolated relay contacts for the interface. Solid state outputs from the railroad may be used as an option to the relay contacts as required by the railroad. The interface shall provide the circuits described as required and specified in the preemption interconnection design.

At interconnected traffic signals, the controller assembly shall provide the operation detailed below relative to the railroad preemption functionality and operation.

The controller assembly shall be provided with all hardware, software and firmware necessary to provide the operation described herein. The designer, contractor and/or traffic signal technician should closely review the functional requirements of the railroad preemption operation to assure that the equipment is capable of performing the functions as specified. In many cases, the railroad circuits have been designed to provide and support the specific functionality. As a result, no exceptions will be permitted to these requirements. The Traffic Management Section of the Traffic Operations Division (TRF-TM) should be contacted for any further clarification regarding the hardware specifications.

Railroad Preemption Cable

Cable Materials

A railroad preemption cable must be a 15-conductor cable having a polyethylene jacket. The cable jacket must be rated for 600 Vac and 75 degrees C.

The railroad preemption cable color code must conform to DMS-11110, Traffic Signal Cable, Type A cables, Table 1 and be assigned as shown in the following table:

Table 5-1. Railroad Preemption Color Code and Functional Connection

Conductor No.	Color Code	Railroad Interface Field Terminal Connections	Conductor Identification
1	Black	TSH IN 5-	Health Status DC-
2	White	-	Spare
3	Red	TSH IN 5+	Health Status DC+
4	Green	-	Spare
5	Orange	XR IN 3	Simultaneous DC-
6	Blue	TCR IN 1	Advance DC-
7	White/black stripe	-	Spare
8	Red/black stripe	GD/ISLD IN 2	Gate Down/Island
9	Green/black stripe	APP OUT 4	Advance Pedestrian Preemption
10	Orange/black stripe	XR OUT 3	Simultaneous
11	Blue/black stripe	TCR OUT 1	Advance Primary
12	Black/white stripe	-	Spare
13	Red/white stripe	GD/ISLD OUT 2	Gate Down/Island DC-
14	Green/white stripe	APP IN 4	Advance Pedestrian Preemption DC-

Table 5-1. Railroad Preemption Color Code and Functional Connection

Conductor No.	Color Code	Railroad Interface Field Terminal Connections	Conductor Identification
15	Blue/white stripe	SUPR 1	Advance Secondary

The individual conductors in the cable shall:

1. Be stranded and comply with IMSA 20-1
2. Have polyethylene insulation
3. Minimum 14 AWG

Installation Methods

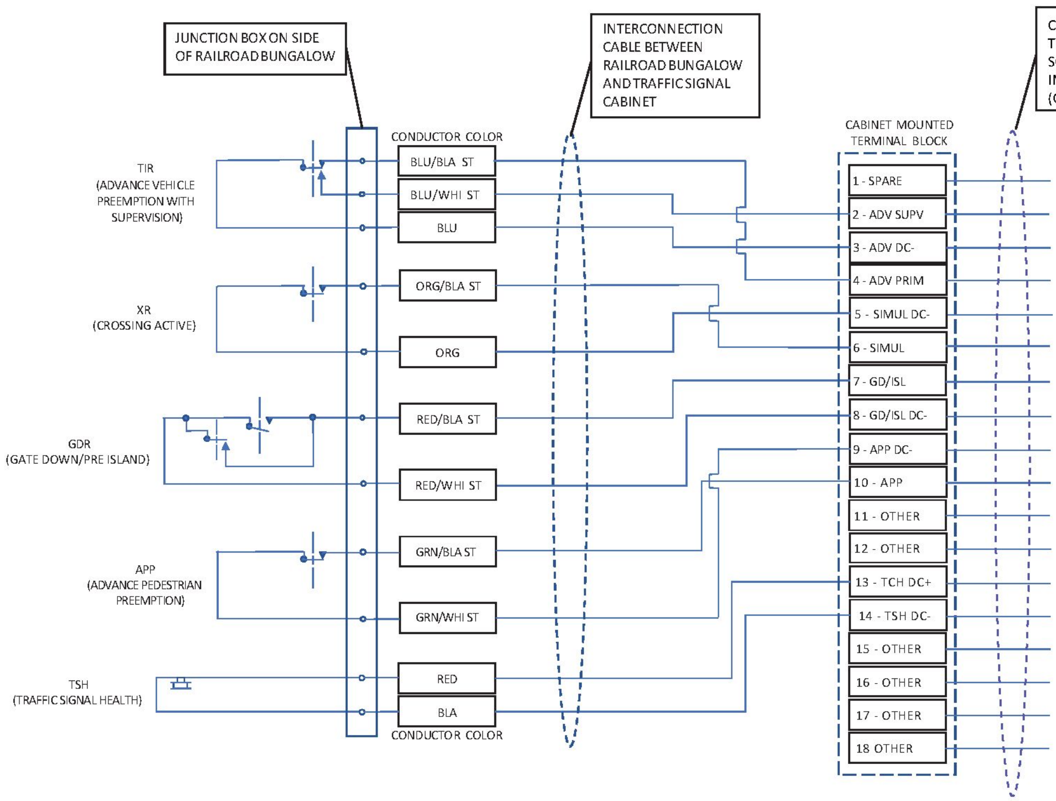
Typically, the contractor is required to install the conduit and riser up to the junction box at the railroad signal house. The railroad may install the conduit under the tracks on a project-by-project basis. This should be defined during the design phase of the project.

Do not splice railroad preemption cable from controller cabinet to railroad cabinet. Terminate individual conductors with connectors in the controller cabinet. Provide identification on both ends of the cable.

Keep all exposed conductors the same length and individually insulate spare conductors against each other.

Provide a minimum 6 feet of slack in the pull box adjacent to the railroad cabinet.

Connect the cable end in the railroad cabinet as directed by the railroad agency representative.



NOTES:

1. STANDARD PREEMPTION CABLE 15C/14AWG. NO SPLICES BETWEEN TRAFFIC SIGNAL CABINET AND RAILROAD EQUIPMENT HOUSE.
2. ALL INTERCONECTION CIRCUITS TO THE RAILROAD SHALL BE 24 VDC.
3. THE TRAFFIC SIGNAL HEALTH CIRCUIT SHALL PROVIDE 12 VDC.
4. THE RAILROAD WILL PROVIDE "DRY" RELAY CONTACTS.

Figure 5–4. Railroad Wiring Diagram

Uninterruptible Power Supply/Battery Back-up System

To maintain orderly and safe vehicle, pedestrian and bicycle movements at signalized intersections interconnected with a railroad crossing it is recommended to provide uninterrupted, operation, avoiding black out or flashing red conditions, during a railroad preemption event. The TxDOT standard is to install a uninterruptible power supply/battery back-up (UPS/BBU) system at traffic signals that are interconnected to a railroad crossing. UPS/BBU systems at interconnected traffic signals shall provide at least 4 hours of continuous operation before transitioning to all-red flash operation.

Traffic Signal Communications

The TxDOT standard is to provide communications to traffic signals that are interconnected to a railroad crossing connecting them to a local Traffic Management System. Providing communication capabilities with the traffic signal facilitates allows for the collection of traffic signal event and alarm data and management of the traffic signal controller database. Other benefits of providing a communication link could include video surveillance of the intersection and crossing to collect data and observe driver behavior.

Special Scenarios

Where there are unique roadway configurations located near to the railroad tracks, preemption operations may need to be further evaluated to provide the appropriate traffic signal operations to effectively clear the tracks. For example, if a grade crossing is located adjacent to a diamond interchange, consideration should be given to clearing the space between the roadway intersections in addition to clearing the tracks. Figure 5-3 provides an example of how this can be accomplished. Note that when programming the preemptors, the signal technician must program the phases and overlaps for correct operation.

Chapter 6: Interconnected Crossing Design

Contents:

Section 1: Overview

At interconnected grade crossings, approaching motorists need to perceive and react to a multitude of messages and indications including the railroad warning devices, signing, striping, and the traffic signal, which are all within relatively close proximity. The design of interconnected crossings can be complex. Designers must respond to physical constraints on both the railroad and highway right-of-way that require various clearances while also ensuring that all traffic controls operate properly together. This chapter explores the various design elements that can be implemented to guide motorists through the grade crossing and the adjacent signalized intersection in a safe and efficient manner. The most appropriate design elements shall be determined by the Diagnostic Team as discussed in Chapter 2.

Section 2: Queue Prevention Strategies

Queue management is critical to grade crossing safety. A lack of queue management can become a large contributor when vehicular queues routinely extend onto and/or past the grade crossing. Pre-signals and queue cutters are examples of queue prevention treatments that can provide an alternative to the traditional queue clearance. They are designed to keep the minimum track clearance distance (MTCD) clear at all times. Designers should be aware of various queue management strategies discussed in this section and understand the applicability of each to determine the most effective treatment for a given grade crossing.

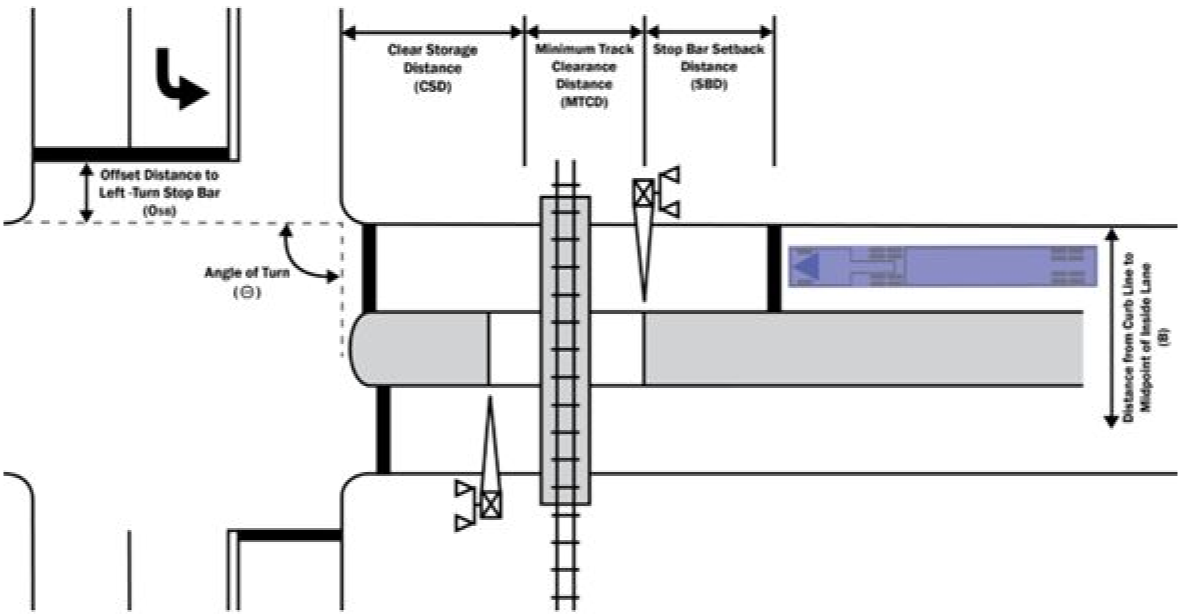


Figure 6–1. Geometric Data at a Grade Crossing

Pre-Signals

A pre-signal has traffic control signal faces that are located upstream from a signalized intersection and are operated in conjunction with the traffic control signal faces at the downstream signalized intersection in a manner that is designed to keep the area between the stop line for the upstream traffic control signal faces and the stop line for the downstream signalized intersection clear of queued vehicles. When used in conjunction with a grade crossing, the pre-signal is operated for the purpose of preventing vehicles from queuing within the Minimum Track Clearance Distance. Supplemental near-side traffic control signal faces for the downstream signalized intersection are not considered to be pre-signals.

Pre-signals may be installed when the downstream traffic signal is located relatively close to the grade crossing (less than 200 feet). Figure 6-2 shows the typical layout of a pre-signal installation downstream of the grade crossing.

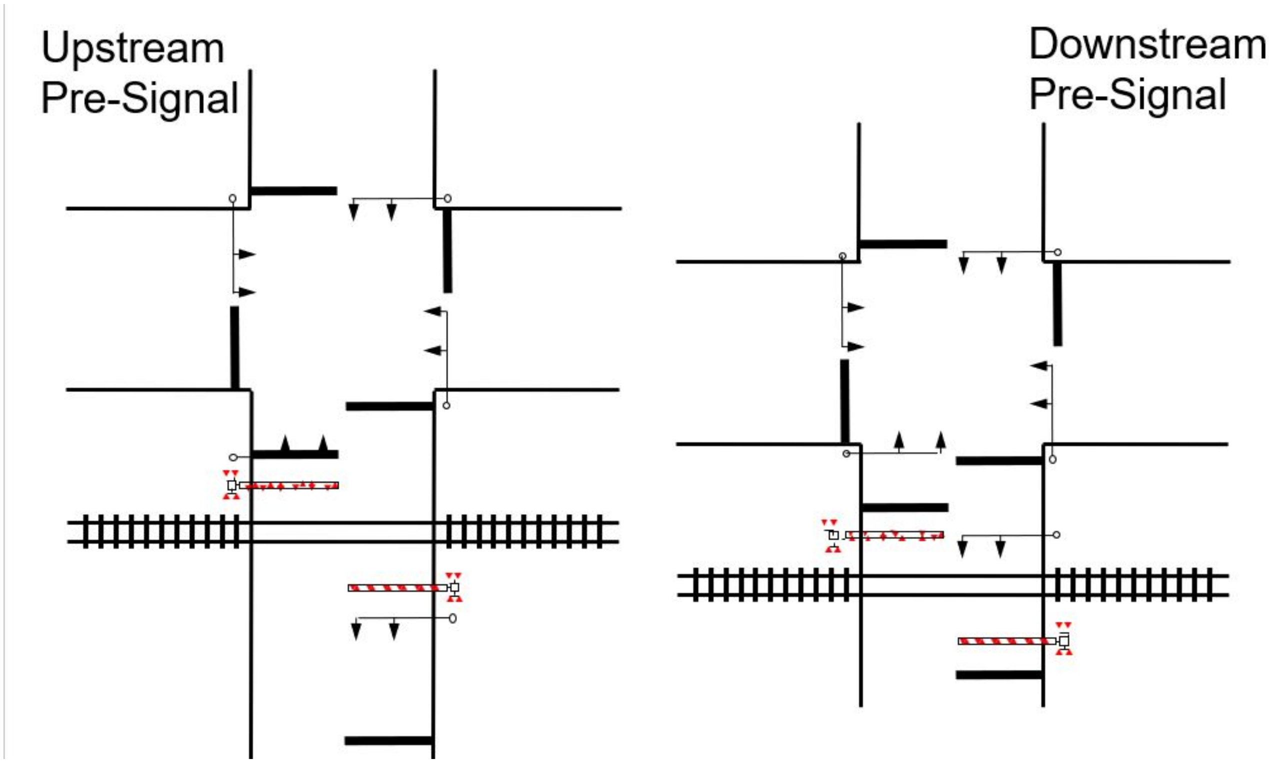


Figure 6-2. Elements of a Pre-Signal

Pre-Signal Operations

A pre-signal's phase sequencing shall be timed with an offset from the downstream traffic signal such that the pre-signal's green indication terminates prior to the downstream traffic signal's green indication in order to reduce the possibility of motorists queuing on the tracks. The distance between the crossing and the downstream intersection can affect motorist behavior. For example, if the clear storage distance (CSD) is long enough, vehicles may be able to safely queue within the CSD without intruding into either the intersection or the grade crossing. In this case, the offset between the pre-signal and the downstream signal may be timed to allow for queuing in the CSD. The pre-signal offset shall always be timed to clear the MTCD after every cycle. The pre-signal offset should be determined based on the time it takes a design vehicle traveling at the posted speed limit to traverse and clear the MTCD and CSD, if needed. The all-red clearance interval for the downstream signal should be determined based on the intersection width but should exclude the MTCD and CSD measurements as the pre-signal's all-red clearance interval will be long enough to allow vehicles to safely clear the additional distance due to the pre-signal offset.

Pre-signals operate in conjunction with the downstream traffic signal. Pre-signal faces shall display a steady circular red signal indication during railroad preemption to prohibit highway vehicles from entering the grade crossing area. During the Preemption Clearance Interval, the downstream traffic signal shall display the green signal indications for any motorists between the grade crossing and the downstream intersection. Pre-signal indications shall remain red while the grade crossing flashing-lights are activated. Figure 6-3 depicts an example of a pre-signal phasing diagram, with Ø3 and Ø8 as the pre-signal phases.

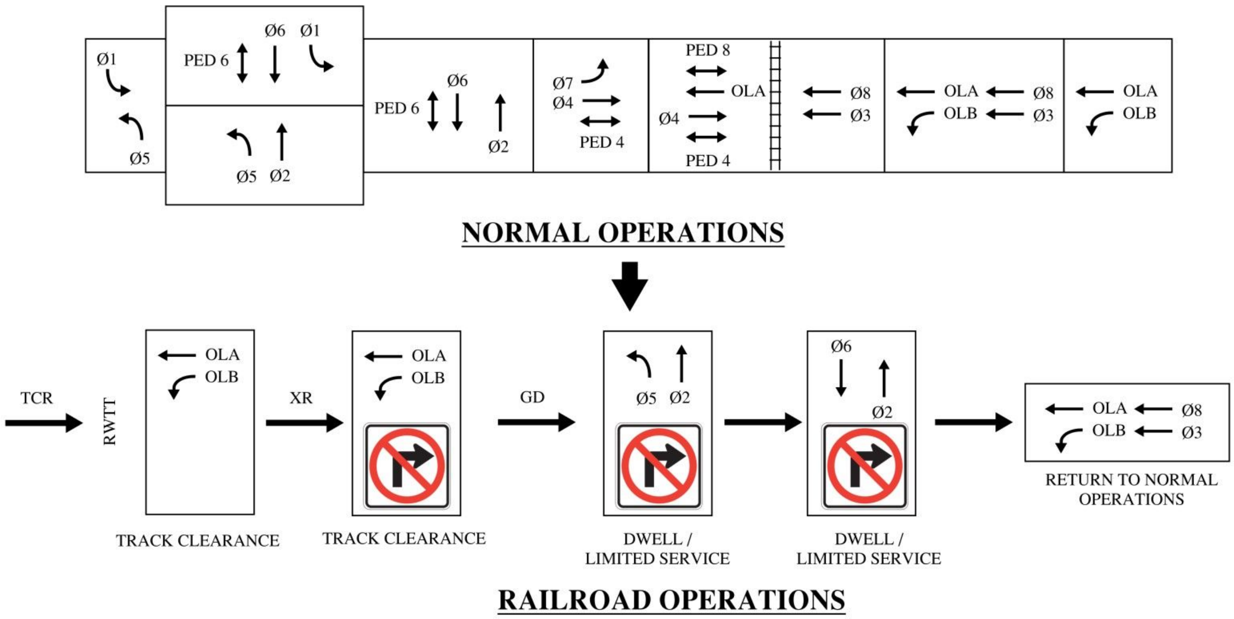


Figure 6–3. Phasing Diagram for a Pre-Signal

Pre-Signal Design Considerations

As shown in Figure 6-2, several design elements should be accounted for when considering a pre-signal installation.

Pre-signals are primary signal faces and shall comply with Sections 4D.07 and 4D.08 of TMUTCD. Pre-signal mast arms should be placed downstream of the grade crossing. A pre-signal may be installed upstream of the grade crossing as necessary to provide the most effective display to approaching motorists as determined by the Diagnostic Team. An example of where upstream placement may be necessary is when the downstream intersection is located extremely close to the grade crossing. If there is not be enough space for both the intersection's traffic signal equipment and the pre-signal, the pre-signal may be placed upstream so the proper clearances are met.

Limited visibility signal heads shall be installed at the downstream intersection such that when motorists approach the grade crossing, the pre-signal indications are the only indications visible to encourage motorists to stop upstream of the grade crossing. Motorists who have passed the railroad flashers should be able to fully view the limited visibility signal heads and be encouraged to travel through the grade crossing rather than queue on the railroad tracks. With proper design and good motorist compliance, no motorists will be queued between the grade crossing and the signalized intersection.

The use of stop lines at pre-signal locations may vary depending on the location, but it is important to clearly indicate to motorists an appropriate stopping point. When multiple stop lines are placed – for example, one at the grade crossing, and one at the intersection – it can become confusing for motorists to understand where to stop and may lead to instances where they will queue at risky locations. If the CSD can accommodate the design vehicle, stop lines may be placed at both the grade crossing and the intersection; otherwise, the intersection stop line should be shared with the grade crossing stop line. The stop line located at the grade crossing shall be accompanied by R10-6 sign(s) and supplemental traffic signal heads where possible to emphasize the appropriate stopping point. Signs and traffic signal heads located upstream of the crossing shall not obstruct visibility of any railroad warning device.

Crosswalk placement may also lead to confusing motorist perception of the proper stopping point. Crosswalks should not be placed on the same leg of the intersection as the grade crossing. If a crosswalk is installed adjacent to the grade crossing, a crosswalk design (such as a continental configuration) should be chosen that does not resemble a stop line (such as a standard configuration). Refer to TMUTCD Figure 3C-1 for crosswalk marking options.

Queue Cutter Traffic Signals

As the CSD increases, advance preemption times can become very long due to the time required to clear the MTCD and CSD. In cases where the grade crossing is located farther than 400’ from a signalized intersection, an actuated queue cutter traffic signal can provide adequate queue management at the grade crossing. Queue cutter traffic signals are independently-controlled traffic control signals (not operated in conjunction with the traffic control signal faces at a downstream signalized intersection) located at a grade crossing that control traffic in one direction only on the roadway for the purpose of keeping the MTCD clear of vehicles. A queue cutter traffic signal functions by “cutting” the queue upstream of the grade crossing by turning red before vehicles queue onto the railroad tracks. Queue cutter traffic signals should utilize queue detection downstream of the grade crossing to prevent on-track queuing. Generally, any detection type may used to detect the vehicle queue, but vital loop detection should be considered. The Diagnostic Team should discuss detection types and evaluate each grade crossing individually to determine the best solution.

Many design features of a queue cutter traffic signal are similar to a pre-signal as shown in Figure 6-4. The most notable difference is the detection zone which is essential for queue cutter traffic signal operation. Queue cutter traffic signal indications shall comply with Sections 4D.07 and 4D.08 of the TMUTCD. Queue cutter mast arms should be placed downstream of the grade crossing, where possible, as it places the stop line closer to the crossing. A queue cutter may be installed upstream of the grade crossing as necessary to provide the most effective display to approaching motorists as determined by the Diagnostic Team.

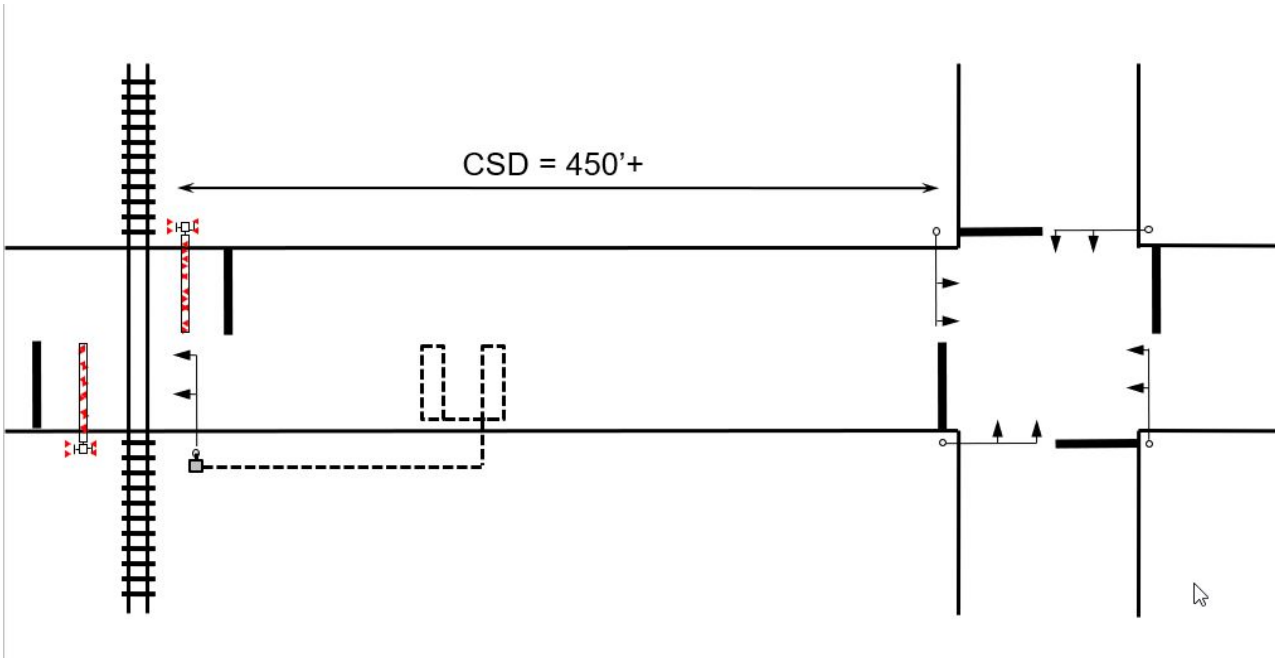


Figure 6–4. Elements of a Queue Cutter Traffic Signal

Queue Cutter Traffic Signal Operations

The queue cutter traffic signal queue detection zone should be located far enough away from the crossing to detect a growing queue, transition the queue cutter traffic signal by serving any minimum green and yellow change interval time, and then allow a design vehicle that has already passed the queue cutter traffic signal's stop line to clear the MTCD before the queue extends to the grade crossing. Once the queue cutter traffic signal displays a red signal indication, the queue cutter traffic signal shall continue to display a red indication as long as the downstream vehicle detection system continues to detect the presence of stopped vehicles.

Supplemental queue detection zones should be considered when accounting for any turning movements between the grade crossing and the downstream intersection. These detectors should detect the formation of any intermediate queues to activate the queue cutter traffic signal prior to any on-track queuing occurring. Supplemental detection zones could be used to account for different platooning and arrival patterns during different times of the day and/or year.

When the queue cutter traffic signal is displaying a green signal indication and is preempted by the traffic control relay (i.e. advance preemption), the queue cutter traffic signal shall transition to preemption operations by serving any remaining minimum green followed by the yellow change interval and steady red signal indications. If the queue cutter traffic signal is preempted by the crossing active relay (i.e. simultaneous preemption), it shall immediately transition to the yellow change interval and steady red signal indications. The queue cutter shall continue to display red signal indications until the train clears the grade crossing. When there is no active preemption call and no queue is detected by the downstream detection, the queue cutter traffic signal shall finish timing any active minimum red interval, if used, and transition to green signal indications. Queue cutter traffic signal faces shall not display green signal indications when the grade crossing flashing-lights are activated both before the train arrives and after the train leaves the crossing. Figure 6-5 provides an illustration of a queue cutter traffic signal phasing diagram.

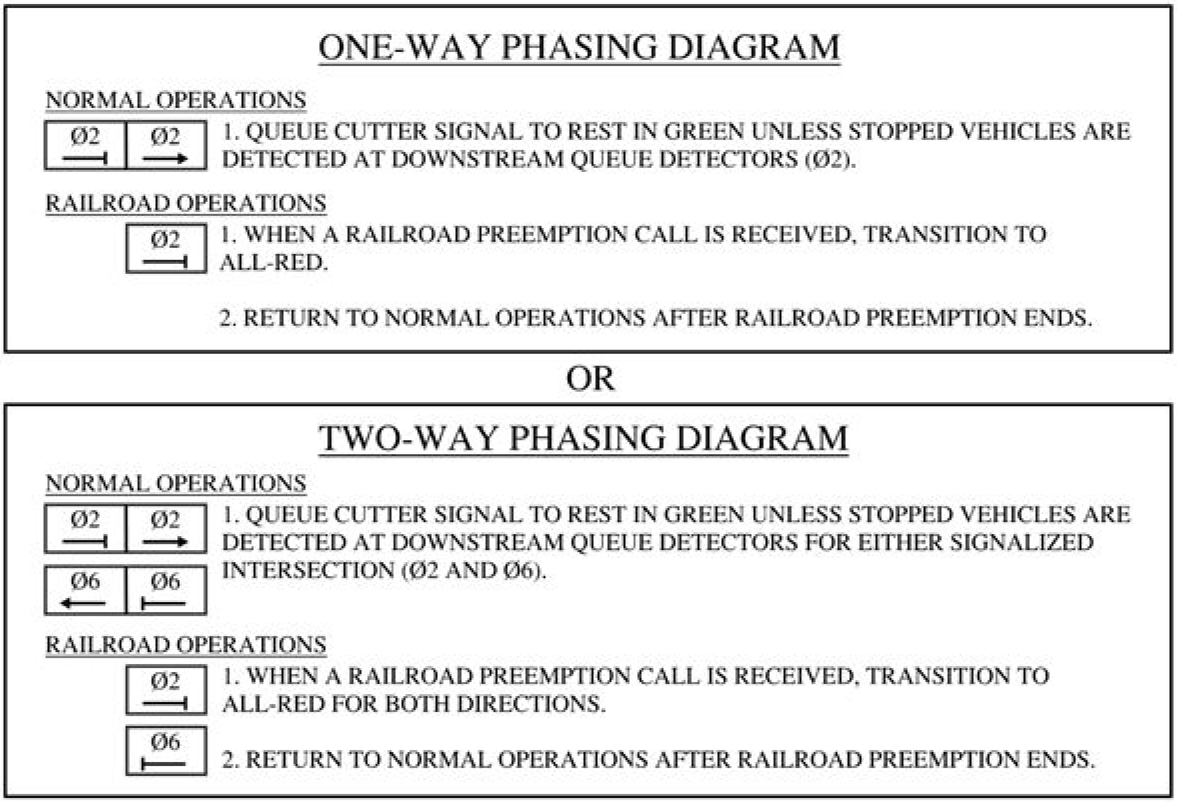


Figure 6–5. Phasing Diagram for a Queue Cutter Traffic Signal

Various types of queue detection may be used. However, the Diagnostic Team should consider the critical nature of the detection zone when recommending a detection type for a queue cutter traffic signal. The failure modes of the queue cutter traffic signal system and the downstream vehicle detection system shall be evaluated and accounted for in the design of any such system. Fail-safe design techniques shall be used in the system design, such as health monitoring and self-check operation to validate the proper functioning of the system. If the detector system fails to properly monitor its health status, then the queue cutter traffic signal shall display flashing red indications until the issue is resolved and the system functions normally.

Placement of downstream detection is key to effective operation of a queue cutter traffic signal and can be an iterative process. Placement should be measured relative to the far limit of the MTCD (i.e. 6 feet from far rail) at a distance equal to the time to detect stopped vehicles (T) plus the yellow change interval (Y), based on the 85th percentile speed. The time, T, should be based on field observations, but is typically around 4 seconds. Yellow time shall comply with TxDOT timing standards. The designer should conduct field observations of queue buildup times during the peak periods. If the observed queue buildup times are significantly less than the time required to transition the queue cutter traffic signal to red than a hybrid queue cutter/pre-signal operation should be used.

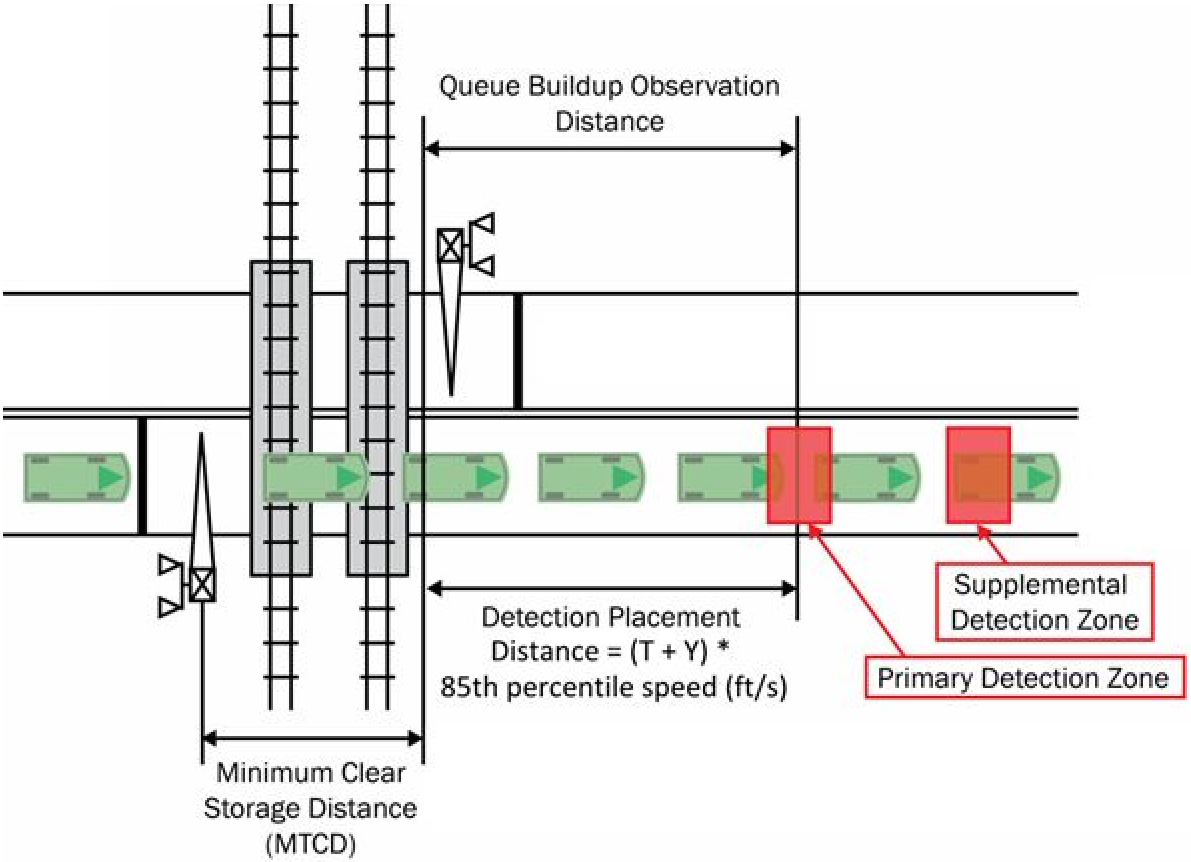


Figure 6–6. Detection Placement for Queue Cutter Traffic Signals

Hybrid or Non-Actuated Queue Cutter Traffic Signals

At certain grade crossings with variable traffic flow conditions, TMUTCD Section 8D.12 allows a variable-mode (hybrid) or non-actuated queue cutter traffic signal operation to be used in which the queue cutter traffic signal at the grade crossing may act as a pre-signal in conjunction with the downstream traffic signal during certain hours of the day, but operate independently as a queue cutter otherwise. The queue cutter traffic signal and intersection traffic signal should have separate traffic signal controllers with the queue cutter traffic signal interconnected to the railroad signal system.

For the hybrid function, the queue cutter operation is synchronized with the downstream traffic signal to optimize vehicle flow while maintaining queue prevention at the grade crossing at all times. The green signal indication at the queue cutter traffic signal should coordinate with the green indication of the downstream traffic signal to minimize stopping between the two signals while allowing for some storage between the grade crossing and the downstream intersection.

Hybrid Pre-Signals

A hybrid pre-signal may also be used in which the pre-signal signal indications and the downstream traffic signal indications are both controlled by one traffic signal controller, but may have a more dynamic signal operation than a pure pre-signal. The hybrid pre-signal may change its operations based on time of day to improve the efficiency of the intersection operations. Operation modes that could be considered include using queue detection between the grade crossing and the downstream intersection that can operate the pre-signal as a queue cutter or a pre-timed operation where the pre-signal leads the downstream traffic signal indications to manage queues by providing queue prevention at the grade crossing at all times.

Queue Management Selection

ITE provides guidance on the applicability of the aforementioned queue management strategies depending upon the clear storage distance measurement, as shown in the table below. Generally speaking, the closer a crossing is to a signalized intersection, the more likely that a pre-signal installation will be the most appropriate design choice. When the grade crossing is located further away from the intersection, a queue cutter may be deemed more fitting. However, for CSD measurements between 200’ and 400’, designers should rely on engineering judgment, the Diagnostic Team and analyze the local traffic conditions and roadway features to determine which strategy would be more effective.

Table 6-1. Queue Management Strategies

CSD	Queue Management
≤ Design Vehicle Length to 200 feet	Pre-Signal
200 feet to 400 feet	• Hybrid or Non-Actuated Queue Cutter Traffic Signal • Hybrid Pre-Signal • Review based on local traffic conditions and engineering judgment
> 400 feet	Actuated Queue Cutter

Section 3: Visibility-Limited Traffic Signal Heads

TMUTCD Section 1C.02 defines visibility-limited traffic signal heads as “a type of signal face or signal section designed (or shielded, hooded, or louvered) to restrict the visibility of a signal indication from the side, to a certain lane or lanes, or to a certain distance from the stop line”. As discussed above, visibility-limited heads shall be used at the downstream intersection for pre-signal installations; however, they may be necessary at other locations depending on the proximity of the crossing to the intersection. The distances in TMUTCD Table 4D-2 and shown in the table below shall be used to determine if downstream signal heads shall be visibility-limited to avoid indications that may be misinterpreted as conflicting near grade crossings.

Table 6-2. Distance Requiring Visibility-Limited Signal Heads at Grade Crossings

85th Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Currently, there are two different methods of limiting the visibility of traffic signal heads. One of the methods involves using programmable visibility (PV) signal heads (Figure 6-7). The lens of the signal head is masked in the field using a special type of tape that controls the visibility of the signal indication to the motorist. Another method that may be used is installing a geometrically programmed louver (Figure 6-8) over the signal lens. The louvers are mechanically adjusted with a baffle key to control the viewing angle of the signal indication. Either option may be used for intersections near grade crossings. A cutoff line for the signal indication should be shown on the design plans. Signal heads at a downstream intersection should not be visible at or upstream of the railroad warning devices. They should only be visible to vehicles in the crossing area and downstream of the crossing.

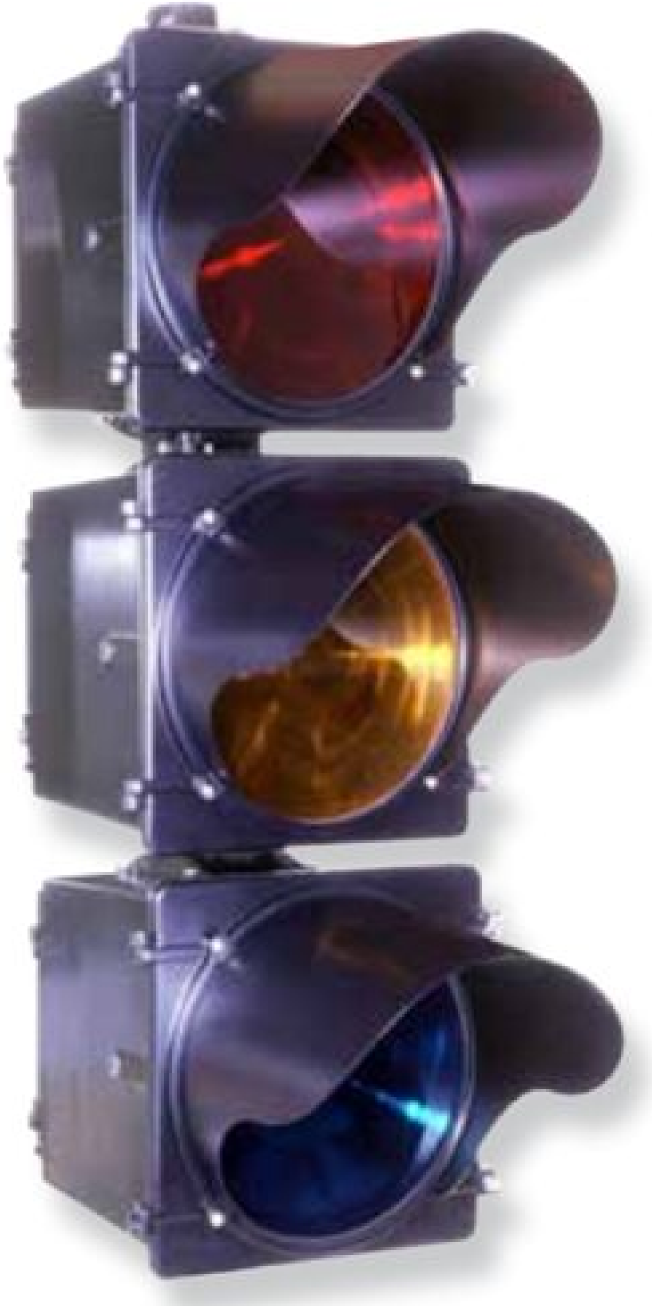


Figure 6–7. Programmable Visibility Signal Head

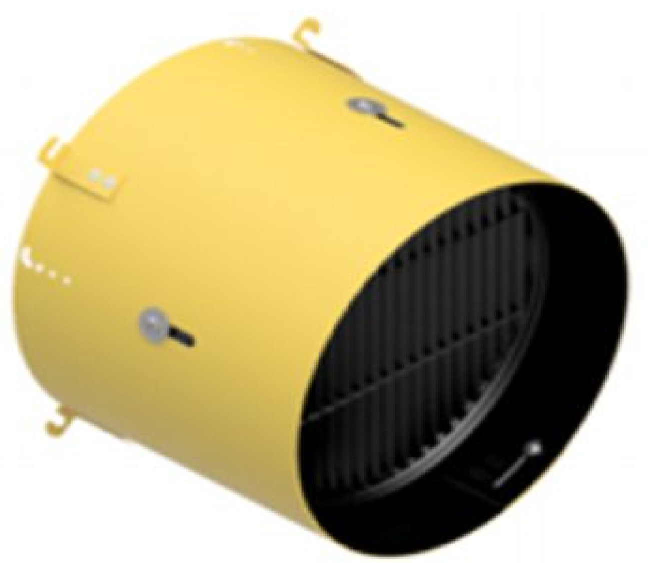


Figure 6–8. Geometrically Programmed Louvers

Section 4: Blank-Out Signs

At an interconnected signalized intersection that is located within 100 feet of a grade crossing, all existing permissive turning movements toward the grade crossing should be prohibited during the signal preemption sequences.

A blank-out or changeable message sign should be used to prohibit said turning movements towards the grade crossing during preemption operations. The blank-out sign should display its message when activated during a preemption event upon receipt of the crossing active notification; when inactive, the sign should display a blank face. The blank-out sign may also be activated during normal operations to prevent on track queuing.

Typical examples of blank-out signs are shown in Figures 6-9 and 6-10, this legend emphasizes that the turn restriction is associated with the presence of an approaching train and should be included when these signs are used exclusively during preemption. A blank-out sign should be mounted at both the near and far sides of the intersection where clear visibility is provided to approaching motorists at all times. Near and far side signs provide for duplicity in the event of one of the signs malfunctioning. At intersections with permissive only left-turns towards the tracks, an R3-2 sign shall be provided to the right of the signal head controlling left-turn movements.

Figure 6–9. R3-1a Blank-out Sign with TRAIN Legend

Figure 6–10. R3-2a Blank-out Sign with TRAIN Legend

Section 5: Other Interconnected Devices

Train Blank-Out Signs for Pedestrians

Pedestrian blank-out signs may be installed along sidewalk approaches as supplementary warning devices to the highway-related active traffic control devices to improve pedestrian safety. Pedestrian blank-out signs can be effective measures at grade crossings with high pedestrian volumes, high train speeds or frequency, extremely wide crossings, complex highway-rail crossing geometry, school zones, inadequate sight distance, and/or multiple railroad tracks. These blank-out signs should be placed such that they are clearly visible to pedestrians along the sidewalk approaches while not intruding into users' path of travel.

Figure 6–13. W10-7 Blank-out Sign

An example of a blank-out sign that may be used at grade crossings is shown in Figure 6-13, although alternative signs may be selected depending on the intended message to pedestrians. Blank-out signs used to enhance pedestrian safety should be train-activated through an interconnection cable to the railroad signal house similar to an interconnected traffic signal; however, the operation of a blank-out sign is much simpler and may not require a traffic signal controller.

Active Advance Warning Signs

Active advance warning signs (AAWS) shall consist of two 12-inch yellow warning beacons mounted in an assembly with the Advance Warning Sign (W10-1) and activated by detection of an approaching train. The beacons shall be flashed in accordance with TMUTCD Section 4S.01. AAWSs may be supplemented with a message, either active or passive, that indicates the purpose of the device, such as “PREPARE TO STOP WHEN FLASHING”. If used, the AAWS shall remain activated until preemption is complete. AAWS shall operate in a fail-safe mode and default to flashing in the event of an interconnection failure.

A train-activated AAWS should be considered at crossing locations where the railroad signals cannot be seen until an approaching motorist has passed the decision point, which is the distance from the crossing from which a safe stop can be made. The design of an AAWS should include a request for advance preemption or simultaneous preemption as determined by the Diagnostic Team. If advance preemption is used, the advance preemption time should be equivalent to the yellow change time calculated based on the speed of the roadway.

A back-up power supply should be included in case of a power outage or failure. A dysfunctional AAWS cannot alert approaching motorists of the activated railroad signal equipment and could lead to a collision. If a back-up power supply cannot be provided, a passive message such as “RAILROAD SIGNAL AHEAD” may be used to provide a full-time warning message.

The AAWS should be placed at the location where the advance warning sign would normally be placed and should be dependent on vehicle speed and the roadway geometry features. The AAWS may also be cantilevered or installed on both sides of the roadway to enhance motorists’ visibility at grade crossings with unusual geometry or site conditions.

Section 6: Traffic Signal Plans for Railroad Interconnection

Chapter 7, Section 5 of the TxDOT Rail-Highway Operations Manual details how “Exhibit A” plan sets should be developed and carried forward to PS&E design. Designers should be familiar with the railroad authority’s design standards and be able to include the appropriate details on the plans.

For projects involving traffic signal preemption, the follow details shall be provided:

- Existing and proposed railroad warning equipment, including the railroad gate mechanisms, cantilevers, flashers, railroad signal house, grade crossing surface, and all relevant offsets (centerline of track, edge of roadway, etc.)
- Existing and proposed traffic signal equipment, including the traffic signal poles, signal head configurations, traffic signal cabinet, traffic signal controller type and software used, and railroad preemption interface
- Correct timing including equipment response time, advance preemption time, clearance time, minimum time, and buffer time. Any traffic signal timings shown shall match timings in preemption form (TxDOT Form 2304)
- Phasing diagram for normal operations
- Phasing diagram for preemption operations specifying the right-of-way transfer time, track clearance phases, dwell/hold/limited service phases, and exit/return phases
- Railroad signal interconnect cable wiring diagram – providing details on which railroad relays are being proposed
- Details on how the various railroad relays affect traffic signal operations
- Completed Railroad Interconnection Worksheet in Appendix A (See Chapter 4 for details)
- Adequate motorist visibility of both highway traffic signal heads and railroad signal equipment at all times
- Battery back-up supply for traffic signal system
    - Per TMUTCD Section 4F.19, “traffic signals with railroad preemption or coordinated with flashing-light signal systems should be provided with a back-up power supply”.
    - In the event of a power outage or another interference, the battery back-up supply will enable the traffic signal to continue running properly and transitioning to preemption operations safely until any issues are resolved. Typically, the battery back-up supply is installed as a stand-alone piece of equipment, but it may also be side-mounted on the traffic signal cabinet. When designing at interconnected crossings, there is typically a variety of traffic signal equipment, railroad warning equipment, and signage that must be installed within close proximity with one another. Designers should be aware of and be able to accommodate the following design constraints:
- Traffic Signal Head Visibility – The roadway needs to be designed such that all the necessary signage, traffic signals, and railroad warning devices are visible to the motorist at an adequate distance to allow time for them to perceive and react safely. It is important to note that from a

motorist's point of view on the road, it can be difficult to perceive a large quantity of indications while also reacting quickly without compromising safety. This issue is magnified when warning flashers, traffic signals, and signs are placed in such a way that they may potentially block one another. In order to provide adequate visibility, designers should denote vertical mounting heights and horizontal offsets for all appropriate traffic control devices in the plans. All equipment locations and construction notes on the design plans should be detailed enough to ensure that the contractor can install all equipment without any visibility conflicts. This may lead to higher/lower mounting heights, larger offsets, and other placement variations when designing near grade crossings.

  - For visibility-limited traffic signal heads, the cutoff line at which motorists can fully view the signal heads should be noted on the plans so that contractors are aware of how the signal heads need to be programmed and/or adjusted.

- Above and Underground Utilities – Designers should note the presence of any existing utilities, both above and below ground, that may impact any proposed improvements at the grade crossing. Designers shall coordinate with the railroad authority in the event that utility work must take place within the railroad right-of-way and follow their standard practice and safety and right of entry requirements accordingly.
- Pedestrian Path – the pedestrian path of travel should be designed to follow ADA standards and remain clear of any railroad warning devices and/or traffic signal equipment at all times. Pedestrian approaches should direct pedestrians around the back of railroad gate mechanisms such that they may safely exit the grade crossing during a preemption event without being restricted by the descending railroad gate arms.

Section 7: Traffic Signal Phasing

Traffic signal phasing during normal and preemption operations shall be clearly defined on the design plans. Figure 6-14 presents a generic railroad preemption sequence. Each piece of this sequence should be represented on the plans.

Figure 6–14. Generic Railroad Preemption Sequence

The right-of-way transfer time (RWTT) is used to transition the traffic signal from any conflicting pedestrian and vehicular phases to the Preemption Clearance Interval. This includes the minimum green, pedestrian clearance, yellow change, and red clearance time intervals.

The Preemption Clearance Interval is then started to begin clearing any motorists queued on or approaching the tracks. The Preemption Clearance Interval must be long enough to allow a motorist to perceive and react to the green indication and travel safely through the MTCD. If the CSD is not long enough to allow a design vehicle to safely queue in, then the Preemption Clearance Interval should also allow vehicles to travel through the CSD.

Once the Preemption Clearance Interval is completed, the normal yellow change and red clearance intervals will cycle through their respective durations prior to the traffic signal entering limited service, or dwell/hold intervals. Once preemption is complete, the traffic signal transitions back to normal operations. Typically, this transition consists of returning to green indications for vehicular movements that are crossing the tracks as they have been delayed the longest. However, various factors such as traffic volumes, the time of day, and special events may dictate which phase the traffic signal will prioritize serving.

If another preemption call is placed while the traffic signal is still transitioning back to normal operations from the previous preemption event, then it is imperative that both the grade crossing warning equipment and traffic signal are capable of re-entering preemption operations efficiently and continue to provide Preemption Clearance Interval.

Chapter 7: Construction and Implementation

Contents:

Section 1: Roles and Responsibilities

The project development of an interconnected crossing shall follow the flow chart shown in Chapter 2, Section 1 of the [TxDOT Rail-Highway Operations Manual](#) with the Railroad Division (RRD) being involved throughout the process. RRD shall ultimately be responsible for drafting the Construction and Maintenance (C&M) Agreement as defined in Chapter 2, Section 4 of the TxDOT Rail-Highway Operations Manual. As it relates specifically to interconnected crossings, the C&M agreement defines the terms of construction and maintenance of the crossing and provides a Force Account for TxDOT to reimburse the railroad for the appropriate project expenses. For interconnected crossings, some railroads may hire Railroad traffic consultants to provide preemption project review and Railroad cutover support. Consultant costs should be accounted for in the railroad Force Account.

Once the C&M Agreement is finalized and a contractor is selected, the TxDOT District Railroad Coordinator shall schedule a railroad coordination meeting as defined in Chapter 9, Section 2 of the TxDOT Rail-Highway Operations Manual providing appropriate notice to all parties. The individuals presented in Table 7-1 should be present at the meeting and are referred to as the Cutover Team.

Table 7-1. Interconnected Crossing Construction Roles and Responsibilities

Title	Role/Responsibility
TxDOT District Railroad Coordinator	Coordinates railroad construction activities, controller testing and cutover.
TxDOT Railroad Division Representative	Provides guidance related to railroad interconnection implementation process. This individual should be invited to any maintenance meetings but is not required to attend.
TxDOT Railroad Investigator	Notified of proposed changes to interconnected crossings and upcoming cutovers. May participate in cutovers and diagnostic reviews, if necessary.
TxDOT Area Engineer	Monitors and coordinates inspection of contractor and railroad work.
TxDOT Project Manager	Monitors overall project activities related to scope, schedule, and budget.
Prime Contractor	Performs project construction activities.
Subcontractors	Supports the Prime Contractor in specialized activities, often including traffic signal work.
TxDOT or Local Government Traffic Signal Representative	Provides support for signal timing and programming. Approves shop drawings for the traffic signal cabinet and railroad interface. Supports final traffic signal interconnection and cutover with the railroad. Completes Form 2625 to document completion of the cutover.
Railroad Project Manager	Monitors railroad project activities. Coordinates the status of railroad construction work with the TxDOT District Railroad Coordinator.

Table 7-1. Interconnected Crossing Construction Roles and Responsibilities

Title	Role/Responsibility
Railroad Traffic Consultant (if applicable)	Supports the Railroad Project Manager. Responsibilities may include reviewing traffic signal timing, railroad interconnect wiring, traffic signal cabinet wiring, and railroad interface wiring; coordinating with the Railroad Signal Construction Manager; and facilitating cutover with TxDOT and the railroad.
Railroad Signal Construction Representative	Responsible for railroad signal construction activities.

Having the appropriate representation early on defines roles and responsibilities for project construction and ultimately leads to a smoother cutover process. Refer to Chapter 9, Section 2 of the TxDOT Rail-Highway Operations Manual for general information related to coordinating construction work with a railroad component.

As construction at the grade crossing nears completion, the TxDOT District Railroad Coordinator shall coordinate with Cutover Team to schedule the controller testing and cutover dates. Sections 2 and 3 within this chapter describe the controller testing and cutover processes. The process to prepare for cutover should start four months prior to the anticipated cutover date with TxDOT providing the following to the railroad for review:

- Current Design Plans
- Traffic Signal Controller Timing
- Traffic Signal Cabinet Wiring Diagrams
- Railroad Interface Wiring Diagrams
- Define Responsibilities and Roles for actual conduit and preemption cable installation.

On the day of the cutover or once the cutover is completed, the TxDOT District Railroad Coordinator shall coordinate final inspection with the railroad to verify all equipment was installed per the design plans and that the interconnection is functioning as designed. Any issues that may arise should be noted and resolved prior to closing the project and submitting invoices.

Section 2: Controller Testing Related to Preemption

The purpose of the controller testing is to allow TxDOT and the railroad an opportunity to test the traffic signal system and verify that the preemption programming is operating as designed while in a controlled environment. Controller testing may take place at the signal shop or the manufacturer's facilities as needed. The testing should occur 2-4 weeks prior to the planned cutover but may occur as late as a day before if proposed operations are standard. Representatives from both TxDOT and the railroad, as well as any consultants as needed, should be present for the controller testing.

During controller testing, the Traffic Signal Representative shall complete Sections 1-3 and 5 of Form 2625 to verify traffic signal operations. A note should be added to the beginning of Section 4 stating the form is for controller testing. Section 4 cannot be filled out without railroad participation. Controller testing shall follow the testing procedures defined in the Form 2625 Instructions except the obstructed gate down test (Box 49) which will need to be simulated by removing the input to the controller. Boxes 50 and 51 cannot be completed during controller testing.

A controller testing packet may also be prepared by the railroad and/or the railroad traffic consultant for all participants. The controller testing should evaluate all potential railroad relay inputs, any potential fault conditions, and any potential errors in the traffic signal preemption timing or programming. Both the expected and the actual response of the systems should be noted for each scenario. If the actual response does not match the expected response, the participants shall adjust the preemption timing and/or programming as necessary to match and document any changes. TxDOT should schedule additional testing, if necessary, to demonstrate that the overall system will perform as intended.

The failure states and their programmed responses should be fully assessed during the controller testing. If any equipment malfunctions, the failure state assists in ensuring the safety of any users at an interconnected crossing while providing some traffic flow. Some generic failure states and responses are outlined below. Refer to Chapter 5, Section 4 for more details regarding standard preemption operations:

- Crossing Relay (XR) Failure – truncate the walk and pedestrian clearance phases, if active. Then transition to Preemption Clearance Interval (PCI) until minimum time is reached, and then to all-red flash. If a maximum preemption timer is not programmed, the controller will remain in PCI until the issue is resolved (Preemptor 3).

- Gate-Down (GD)/Island (ISLR) Relay Failure (Form 2625, Box 48) – if a pedestrian phase is active, then the traffic signal will truncate the walk and pedestrian clearance phases. The signal will then transition to PCI until maximum interval is reached, and then to all-red flash. If a maximum preemption timer is not programmed, the controller will remain in PCI until the issue is resolved. Note, in most cases, the island relay will terminate PCI and transition the traffic signal to the dwell phases. This failure would only occur if there were an issue with the island circuit. (Preemptor 4)

- Supervised Relay Failure (Form 2625, Box 49) – if a pedestrian phase is active, then the traffic signal will truncate the walk and pedestrian clearance phase. The signal will transition to PCI until minimum interval is reached and the GD input is received, and then enter and remain in limited-service operation. (Preemptor 1)

The controller testing shall also verify the expected traffic signal controller response to a preemption call and how the traffic signal transitions to preemption operations. Refer to Chapter 5, Section 4 for standard preemption operations and the Form 2625 Instructions for testing procedures. In most scenarios in which a malfunction occurs, the traffic signal controller would be expected to truncate any active walk and pedestrian clearance intervals then transition the active vehicular phase to yellow, red clearance, and PCI. After the PCI completes, the traffic signal will transition to all-red flash until any issues are resolved. The preemptor should be programmed for monitor flash to allow for network notifications.

Section 3: Cutover Process Standard Work

Once the controller testing is complete, TxDOT should confirm the cutover date with the railroad. The Cutover Team, as defined in Section 1 of this chapter, should be present for the cutover. The traffic signal cutover process is conducted at the grade crossing to physically install and verify the interconnection between the traffic signal and railroad signal systems. The District Traffic Signal Representative shall complete Form 2625 to verify operations and document completion of the cutover and submit it to TRF_Preemption_Inspection@txdot.gov. The Form 2625 used for the cutover should reflect any adjustments made during the controller testing. The railroad may also have their own cutover packet.

Consistency between the technical details specified in the design plans and the construction work should be verified and documented. Members of the Cutover Team should conduct the following tasks prior to the start of the cutover, if possible:

- Hold a safety briefing with the railroad. During this briefing, members of the Cutover Team should review the goal of the cutover meeting as well as the responsibilities of each participant.
- Walk each intersection approach to verify that signs, markings, traffic signals and RR warning equipment are per plan and are functioning/visible as intended.
- Verify the railroad interconnect cable is landed in the traffic signal cabinet as defined in Chapter 5, Section 5.
- Talk to railroad representatives to understand if there are any outstanding issues on their side and confirm the railroad signal interconnect cable is landed in the railroad signal house.
- Photograph and review completed construction per the design plans:
    - Advance warning signs and markings
    - Stop line and regulatory signs
    - Traffic signal indications and locations
    - Lighting
    - RR flashers and gates
    - Pedestrian features and channelization
    - Detection features (e.g., queue loops)

Proper traffic control and roadway flagging are necessary to provide adequate safety for the participants and the public. Railroad flagging may also become necessary if planned construction activities have a potential for equipment or workers to foul the tracks. Depending on the size of the roadway, uniformed police officers may be required to safely maintain traffic operations during the cutover process. TxDOT shall provide the signal interconnect cable from the traffic signal cabinet to a pull box near to the railroad signal house. The railroad will typically make the final connection to the junction box and into the railroad relay contacts, often in a demarcation box on the outside of the railroad signal house. The TxDOT District Railroad Coordinator should coordinate with the railroad to ensure that enough conduit is provided to make the final connection prior to the cutover and to verify the need for railroad flagging.

During the cutover, the railroad and TxDOT shall test and record the traffic signal controller's response to various relay states from the railroad signal house and the signal operations when a preemption event occurs. The testing plan used from the controller testing should be used to record the expected and actual signal controller responses throughout the cutover. Members of the Cutover Team should conduct observations using live-train events if possible. Members of the Cutover Team should check both the transition of the traffic signal into and out of railroad preemption operations.

If the actual controller response does not match the expected response, then any adjustments and troubleshooting should be conducted to ensure all equipment is functioning properly. The Traffic Signal Representative shall also test the battery back-up system to confirm proper functionality.

Members of the Cutover Team should verify the following information/details during the cutover:

- Conductor colors used for each circuit based on the information provided in Chapter 5, Section 5.
- Signal interconnect cable connections with the traffic signal controller, railroad interface, and railroad signal house, as applicable
- Maximum right-of-way transfer time and minimum Preemption Clearance Interval intervals are consistent with design plans

Once the interconnection is verified to operate as designed, the railroad will place interconnected warning labels in the traffic signal cabinet and railroad signal house, such as the label shown in Figure 7-1. The labels should include the following information for any maintenance personnel entering either enclosure in the future:

- 24-hour contact information for both TxDOT and the railroad if any issues arise at the grade crossing
- Type of interconnection to the adjacent grade crossing
- Date of interconnection installation

WARNING!

Highway-Rail Grade Crossing Warning System and Highway Traffic Signals are Interconnected.

BEFORE MODIFICATION is made to any operation which connects to or controls the timing of an active railroad warning system and/or timing and phasing of a traffic signal the appropriate party(ies) shall be notified and, if necessary, a joint inspection conducted.

U.S. DOT/AAR Crossing Number: ______________________

1. Highway Agency:______________________

   Phone Number:______________________

2.. Railroad: ______________________

   Phone Number: ______________________

3. Other: ______________________

   Phone Number: ______________________

U.S. Department of Transportation
Federal Railroad Administration
Federal Highway Administration
Federal Transit Administration
National Highway Traffic Safety Administration

Figure 7–1. FHWA/FRA Interconnected Warning Label

If any traffic signal items of immediate safety concern are noted during the cutover, they should be corrected prior to leaving the site. The purpose of the cutover is to leave the site with the traffic signal and railroad signal systems operating as designed. However, should any issues arise, that cannot be addressed immediately, the Cutover Team shall not leave the site until the team implements a safe, temporary operating condition agreeable to all parties. TxDOT shall refine the traffic signal timing and/or controller programming, if necessary, based on the testing results. Any other identified issues for less critical items may be assigned as action items and prioritized during the post-cutover process.

Upon completion of the cutover the Traffic Signal Representative shall complete Form 2625 and distribute to the Cutover Team. Per the TxDOT Rail-Highway Operations Manual in Chapter 9, Section 2, the District Railroad Coordinator shall draft a Completion Letter to the railroad and update the Texas Railroad Information Management System.

Chapter 8: Inspection and Maintenance Considerations

Contents:

Section 1: Regular Maintenance and Testing

The TxDOT Rail-Highway Operations Manual states that TxDOT (or the local highway authority) and the railroad shall assume both separate and joint maintenance responsibilities at highway-rail grade crossings. Both TxDOT (or the local highway authority) and the railroad should inform one another of any planned changes at and/or near an interconnected grade crossing, including any changes made to the traffic signal controller and cabinet or railroad interface panel.

Unless defined otherwise in a Construction and Maintenance (C&M) Agreement, the railroad maintains features lying within the railroad right-of-way, such as the crossing surface, railroad warning equipment, vegetation, and railroad circuitry. TxDOT or the local highway authority maintains the roadway approaches up to the grade crossing, signing and striping (excluding crossbuck signs), and the adjacent traffic signal and its operations. Both entities are generally responsible for any ditches, pipes, culverts, and conduits within railroad right-of-way and the traffic signal interconnection between the traffic signal cabinet and the railroad signal house. The District Railroad Coordinator and Railroad Investigator should also periodically visit each grade crossing location within TxDOT's jurisdiction and conduct an inspection for any missing or damaged equipment.

TMUTCD Section 4A.10 states that the responsibility for the maintenance of the traffic signal and all of the appurtenances, hardware, software, and timing plan(s) should be clearly established. TxDOT or the highway authority should provide the appropriate maintenance of the traffic signal in a competent manner. This is especially important where the traffic signal is interconnected to the railroad warning system because the safety of the overall system depends on appropriate responses from the traffic signal controller.

FRA's Code of Federal Regulations (CFR) defines specific intervals at which the railroad must test various elements of the railroad warning system. The sections that are directly applicable to railroad warning systems with interconnection to traffic signals are detailed in Table 8-1.

Table 8-1. Railroad Maintenance Responsibilities

CFR Regulation	Requirements
49 CFR 234.257 – Warning System Operations	The railroad tests each highway-rail crossing warning system to determine that it functions as intended when it is placed in service. They also **test at least once a month and as modifications are made**. The railroad also tests warning bells or other stationary audible warning devices shall be tested when installed to determine that they function as intended. They also test **at least once a month and as modifications are made**.
49 CFR 234.259 – Warning Time	The railroad tests each highway-rail crossing warning system to determine that it functions as intended when it is placed in service. The system is also tested **at least once a month and as modifications are made.**
49 CFR 234.261 – Highway Traffic Signal Preemption	The railroad tests each highway-rail crossing warning system to determine that it functions as intended when it is placed in service. The system is also tested **at least once a month and as modifications are made.**
49 CFR 234.263 – Relays	The railroad tests each relay related to traffic signal preemption **at least once every four years**. Other types of relays are tested more frequently.

NOTE:**The Federal Railroad Administration (FRA) Safety Advisory 2010-02 recommends that the railroad conduct a joint inspection with TxDOT or the highway authority at least once a year to verify that the interconnection is functioning properly.**

FRA Technical Bulletin S-12-01 provides guidance on the inspection process of highway-traffic signal preemption interconnections at grade crossings. The District Traffic Engineer or qualified delegate shall participate in the annual testing with the railroad as well as inspections conducted by TxDOT Railroad Investigators. Any previously prepared testing plans, such as finalized cutover documentation, should be referenced and used again for maintenance testing of the signal system to determine the expected responses of the system. Refer to Chapter 7 for the standard elements that should be provided in cutover documents. Annual testing of an interconnected traffic signal should include verification of the following and be documented by completing Form 2625:

- Yellow trap condition during preemption, as described in Chapter 2, is resolved or documented (Form 2625, Box 18).
- Preempt delay time matches what is shown on preemption form (Form 2304, Line 13; Form 2625, Box 21).
- If delay time is used, memory is set to non-locking so the controller does not accept false calls from the railroad company.
- Minimum green time during preemption right-of-way transfer matches what is shown on preemption form (Line 16, Box 22).
- Yellow change and red clearance times during preemption right-of-way transfer, after track clearance green, and after transition out of preemption, are not less than what is programmed for normal operation of the signal for any phase (when signal is not under preemption) per TMUTCD Section 4D.27; Box 24 & 25.
- Yellow change and red clearance times during preemption right-of-way transfer match what is shown on the preemption form (Lines 18 and 19; Box 24 & 25).
- Pedestrian walk time matches preemption form (Line 21; Box 26).
- Pedestrian clearance time matches preemption form (Line 22; Box 27).
- Guaranteed minimum times do not exceed any of the above right-of-way transfer parameters.
- Track clearance green time matches what is shown on preemption form (Line 40; Box 28).
- Track clearance, dwell/limited cycle, and exit phases are programmed properly in the controller per the cutover documentation.
- Preemption form and traffic signal layout design sheets are available in the cabinet (Box 4 & 5).
- A warning label is present in the housing indicating the presence of the interconnection and that the cabling shall not be tampered or disconnected (Box 6).
- Battery back-up system is connected and functioning properly (Box 7 & 51).
- Interconnection cable and conduit are functional.

- If there is any recording/monitoring equipment installed, verify that said equipment is operating and collecting data properly

In addition to reviewing traffic signal programming and physical equipment the highway representative should observe the following operations:

- Railroad warning and highway traffic signal indications are visible to motorists at all times except where limited visibility signal heads intentional restrict visibility from certain areas such as from the railroad stop line in the case of a pre-signal.
- The traffic signal controller received the preemption call sent by the railroad warning equipment (physical signal interconnect cable should be checked).
- Preemption Clearance Interval is displayed for at least the minimum time as designed
- Preemption Clearance Interval is sufficiently long enough to clear vehicles from the minimum track clearance distance (MTCD).
- Preemption Clearance Interval does not terminate prior to the gates being nearly horizontal.
- Vehicular movements towards the grade crossing are prohibited via traffic signal operations and/or activated blank-out signs. Blank-out signs activate when the railroad warning devices start flashing.
- Pedestrian safety is maintained throughout preemption operations at both the grade crossing and the traffic signal.
- At locations where a pre-signal is installed, the signal heads downstream of the pre-signal terminate after the pre-signal and are not visible from the railroad stop line. The pre-signal heads should also be red while the railroad lights are active.
- At locations where queue cutters are installed, the traffic signal controller appropriately responds to downstream queuing.
- Transition out of preemption operations when the railroad gate arms begin to ascend and return to normal operations once railroad lights have stopped flashing.

If any issues are identified, both parties should coordinate and assess what improvements should be made in the short-term and long-term to better protect grade crossing users. Any modifications to the signal timings shall be documented in the logbook in the traffic signal controller.

Traffic signal maintenance personnel should reference the interconnected warning label located in the traffic signal cabinet for the appropriate contact information for the railroad and the highway authority. If the contact information has changed, traffic signal maintenance personnel should update the label accordingly and coordinate with the railroad to update the corresponding label in the railroad signal house. Any changes to either the railroad warning or highway traffic signal system that affect preemption operations shall require joint coordination.

In the event of an interconnection failure, TxDOT should coordinate with the appropriate railroad to establish alternative traffic control measures at the grade crossing and intersection if needed, which can include all-red flashing operations at the traffic signal, providing roadway flaggers to direct vehicles through the grade crossing, providing railroad flaggers to notify roadway flaggers of approaching trains, placing slow orders on train activity, or temporarily closing the grade crossing until the issue is resolved. Wherever possible, the issue should be resolved within 24-48 hours to minimize disruption to train and vehicle traffic flow. If the issue cannot be resolved immediately, TxDOT personnel should provide signage to appropriately warn motorists.

During construction and/or maintenance activities, railroad warning signals and highway traffic signals should always be clearly visible to the motorists. The signal interconnect between the railroad signal house and traffic signal cabinet should also be maintained throughout every construction phase unless other provisions are made to control traffic over the grade crossing.

Section 2: Railroad Notification Procedure

When there is any operational failure at the grade crossing – as related to the traffic signal or railroad warning signal equipment– or changes made to traffic signal components related to railroad preemption (e.g. traffic signal controller, railroad preemption interface, etc.) within the cabinet, the phone number on the blue Emergency Notification System (ENS) sign at the grade crossing shall be called to notify the railroad of an issue prior to any changes being made. If the technician has questions regarding a specific component, they should contact their supervisor.

Figure 8–1. Emergency Notification System (ENS) sign

Section 3: Troubleshooting

Routine inspection process includes checking that the circuit plans are up-to-date and that the preemption timing operates as designed. Highway Agency personnel verify that the maximum right-of-way transfer time (RWTT) and minimum Preemption Clearance Interval (PCI) are accurate per the design plans during annual joint inspections. If any recording and/or monitoring equipment is installed at the grade crossing, the collected data is also evaluated for any operational anomalies.

Outside of the annual joint inspection cycle, traffic signal maintenance personnel should closely observe the highway traffic signal operations when making any changes at the traffic signal. They should observe operations during a live preemption event, if possible, to verify the traffic signal system is functioning properly referring to the inspection list included in Section 1 of this chapter for annual joint inspections.

If any issues are noted outside of the annual joint inspection, traffic signal maintenance personnel shall notify the District Traffic Engineer immediately. Prior to fixing the problem, traffic signal maintenance personnel and the District Traffic Engineer should consider whether action may be required by the railroad. If there is any doubt about action needed from the railroad, further coordination with the District Traffic Engineer and the railroad company shall be required. In some cases, coordination may be as simple as calling the number on the ENS sign to notify the railroad of anticipated time to fix the issue. More complex problems may require a new inspection of the interconnected traffic signal system. If the issue is identified and can be resolved short-term, qualified traffic signal maintenance personnel should correct any known issues as quickly as possible. The District Traffic Engineer should contact the Railroad Division for assistance as needed.

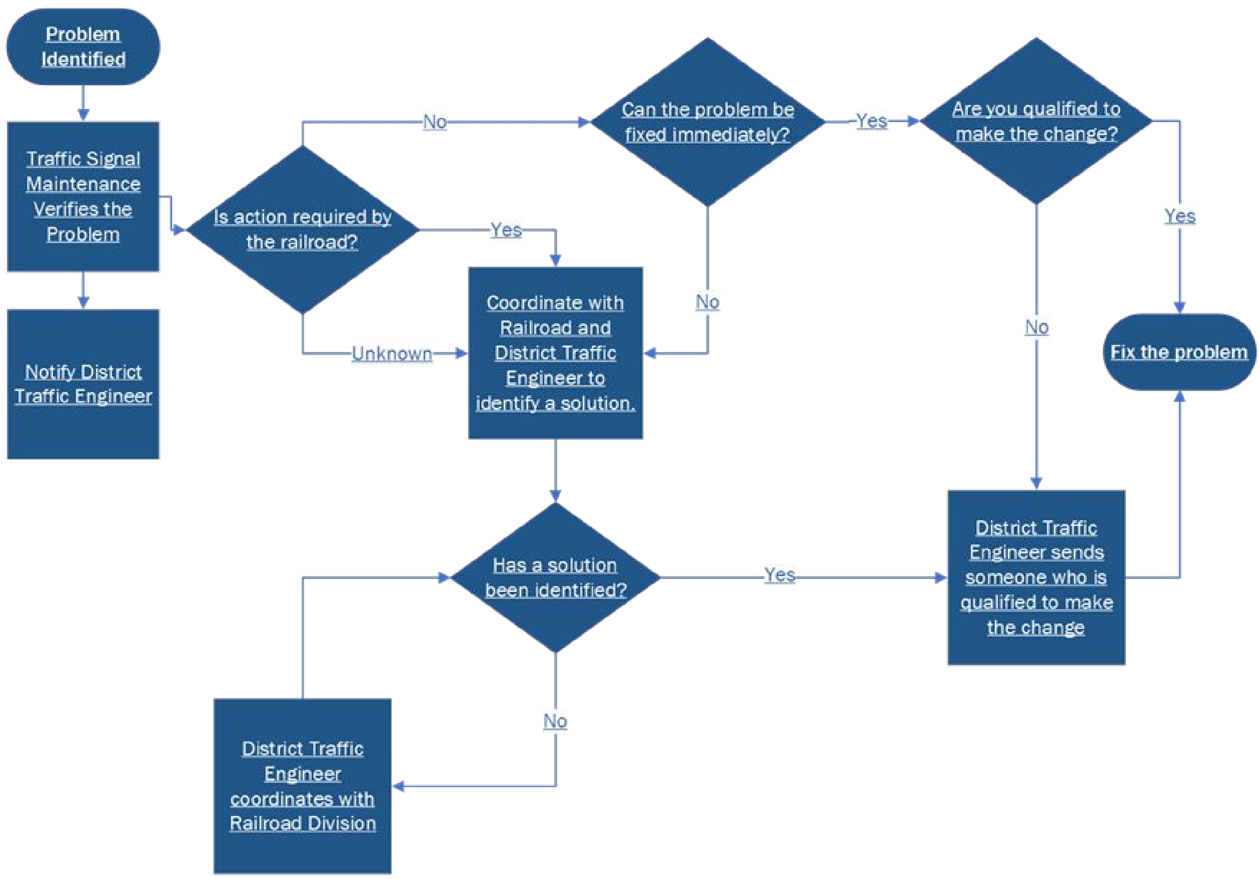


Figure 8–2. Escalation Process for Operational Failures at Interconnected Traffic Signals

Section 4: Changes Requiring Re-evaluation of Preemption Timing

Major changes such as new construction, significant queue increases, significant traffic or railroad speed changes, changes to left-turn phasing, reoccurring traffic incidents, etc. should be coordinated with the District Railroad Coordinator and the Railroad Division to initiate coordination with the appropriate railroad and re-evaluation of preemption timing. Traffic signal timing adjustments are expected and may occur with changes in traffic flows, roadway speed limits, and corridor optimization, etc. Many adjustments do not require re-evaluation of preemption timing as long as the preemption settings are not changed. When changes affect any of the following parameters, re-evaluation of preemption timing shall be required:

- Changes to the Minimum Green Time, unless those changes are overridden during preemption in the preemptor settings. See Chapter 5 for preemptor programming information. (TxDOT Form 2304, Line 16/71)
- Changes to the Pedestrian Walk Time. Confirm this time is overridden by the preemptor programming. Typically, it should be zero. See Chapter 5 for preemptor programming information. (TxDOT Form 2304, Line 21/72)
- Changes to the Pedestrian Clearance Interval, unless those changes are overridden during preemption in the preemptor settings. See Chapter 5 for preemptor programming information. (TxDOT Form 2304, Line 22/73)
- Changes to Yellow Change time. TMUTCD does not allow shortening of Yellow Change time during preemption. (TxDOT Form 2304, Lines 18/74)
- Changes to Red Clearance time. TMUTCD does not allow shortening of Red Clearance time during preemption. (TxDOT Form 2304, Lines 19/75)
- Changes to Guaranteed Minimum Times. In certain controllers the guaranteed minimum times will override preemption timing if the times programmed during preemption violate the guaranteed minimum time.
- Changes to the preemptor programming.
- Changes to logic statements.

When such changes occur, the preemption timing should be re-evaluated to ensure the following:

- If pedestrian movements are affected or added with any changes, preemption timing may need to be adjusted to include a pedestrian clearance interval.
- Yellow Change and Red Clearance intervals are kept constant between normal and preemption operations.
- Required right-of-way transfer time is not increased.
- An updated Form 2304 is documented and coordinated with the associated railroad.
- Total Approach Time is adjusted accordingly based on changes to the traffic signal timing per the updated Form 2304.

TxDOT should also be mindful of temporary traffic control being implemented near the grade crossing, especially detours, and carefully consider the potential impacts of on-track queuing. If needed, proposed traffic control should be coordinated with the appropriate railroad. Running traffic counterflow at grade crossings with flashing-lights and/or gates is not allowed unless otherwise approved by the railroad company.

Appendix A: Railroad Interconnection Worksheet

Complete this form following the diagnostic inspection to confirm proposed railroad interconnection:

Grade Crossing Information:

Roadway Data:
District: ______________________
City: ______________________
County: ______________________
Crossing Street Name: ______________________
Parallel Street Name: ______________________
Maintaining Agency: ______________________

Railroad Data:
Railroad: ______________________
DOT #: ______________________
RR Subdivision: ______________________
Mile Post: ______________________

Circuits to be Requested from the Railroad

1) Is a Crossing Active (XR) circuit requested? ☐ Yes ☐ No

If "Yes": a) What is the Additional Warning Time? (if needed) _________ Seconds
b) What is your requested circuit configuration? ☐ Single Break ☐ Double Break ☐ Supervised

2) Is an Advance Preemption circuit requested? ☐ Yes ☐ No

If "Yes": a) What is the requested Advance Preemption Time (APT)? _________ Seconds
b) What is your requested circuit configuration? ☐ Single Break ☐ Double Break ☐ Supervised

3) Is a Gate Down circuit requested? ☐ Yes ☐ No
If "Yes": What is your requested circuit configuration? ☐ Single Break ☐ Double Break ☐ Supervised

4) Is additional time for Advance Pedestrian Preemption requested? ☐ Yes ☐ No

If "Yes": a) What is the requested Advance Pedestrain Preemption Time (APPT)? _________ Seconds
b) What is your requested circuit configuration? ☐ Single Break ☐ Double Break ☐ Supervised

5) Is a Traffic Signal Health circuit requested? ☐ Yes ☐ No
** Note: A Traffic Signal Health circuit is required when requesting Advance Preemption.*

6) Indicate the interconnection wire size & number of conductors: _________ AWG _________ Conductors
** Note: Wire size and number of conductors other than defined in the TxDOT Preemption Manual requires a design exception.*

7) Who will install the interconnection conduit? ☐ Agency ☐ Railroad

Conduit Size __________ Conduit Material __________

8) What is the railroad interface? Specify manufacturer/type. ☐ Active ☐ Passive

____

Completed by: ______________________________________ Date: ____________________

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