Interconnection of Highway-Rail Grade Crossing Warning Systems and Highway Traffic Signals
INTRODUCTION

Welcome to this seminar on Interconnection of Highway-Rail Grade Crossing Warning Systems and Highway Traffic Signals. Over the past eight years, I have had the opportunity to present this seminar to persons from the Federal Railroad Administration, the Federal Highway Administration, numerous state Departments of Transportation, city, county and state traffic engineering and signal departments as well as many railroads. Obviously, this is a highly specialized topic, one that receives very little attention in terms of available training. However, from the perspective of safety, it requires far more attention than it normally receives. Only when a catastrophic event occurs such as the Fox River Grove crash in October of 1995 does the need for training of this type become apparent.

Following the Fox River Grove crash, I was approached by the Oklahoma Department of Transportation in 1996, inquiring if I would have an interest in assisting them with understanding interconnection and preemption. This seminar is the ongoing continuation of that effort. My background includes over 31 years of active involvement in both highway traffic signal and railroad signal application, design and maintenance.

This workbook is a compilation of information, drawings, standards, recommended practices and my ideas to assist you in following with the presentation and to provide a future reference as you need it. It has been developed as I have presented seminars and I strive to continually update it to reflect the most current information available.

Some sections have been reproduced from the Manual on Uniform Traffic Control Devices which exists in the public domain. Other sections from the AREMA Communication & Signal Manual of Recommended Practice and Institute of Transportation Engineers recommended practice for Preemption of Traffic Signals Near Railroad Grade Crossings are reproduced with permission to be used only for training and education. Use of these sections as work product requires the user to purchase a licensed copy from AREMA or ITE at their web sites listed below. It should also be noted that both publications are “living” documents which undergo continuing updates and revisions to address changing technology and practice. Therefore, the user should maintain current documents for use and reference.

Finally, I depend on you to provide me with feedback to assist in improving the content and presentation of this material. Please take a few minutes after the seminar to complete the comment form for me. If you would like, leave me your contact information if there is a specific thought or comment you want to discuss individually. If you need follow-up information or have a question my staff or I might be able to assist with, you can contact me from the information listed below.

Rick Campbell
INTRODUCTION

Additional information from standards and recommended practices used in this seminar may be obtained from the following:

Federal Highway Administration
http://mutcd.fhwa.dot.gov/

AREMA Communication & Signal Manual of Recommended Practices
American Railway Engineering and Maintenance-of-Way Association
http://www.arema.org

Preemption of Traffic Signals Near Railroad Crossings
Institute of Transportation Engineers
http://www.ite.org

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Workbook Index

7. Advance Preemption Paper Presented to AREMA
16. Highway Traffic Signals
21. 2 Phase Intersection
22. 2 Phase Intersection with Detectors
25. 2 Phase Intersection with Pedestrian Movements
26. 2 Phase Intersection with Detectors and Pedestrian Movements
27. Basic Traffic Signal Timing
28. 8 Phase Intersection
29. 8 Phase Intersection with Detectors
30. 8 Phase Sequence
31. 8 Phase Intersection with Pedestrian Movements
32. 8 Phase Intersection with Detectors and Pedestrian Movements
33. Railroad Crossing Signals
34. MUTCD Part 8A.01 - Introduction
68. 3 Track Crossing
78. Motion Sensor Crossing
81. Constant Warning Time Crossing
84. MUTCD Part 8D.07 - Traffic Control Signals at or Near Highway-Rail Grade Crossings
86. MUTCD Part 8A.01 - Definitions
100. MUTCD Part 4D.02 - Responsibility for Operation and Maintenance
101. MUTCD Part 4D.13 - Preeemption and Priority Control of Traffic Control Signals
103. MUTCD Part 4E.09 - Pedestrian Intervals and Signal Phases
Index (continued)


111. AREMA Signal Manual, Section 3.3.10 (Recommended Instructions for Determining Warning Time and Calculating Approach Distance for Highway-Rail Grade Crossing Warning Systems - Revised 2002)


123. 8 Phase Dual Ring Intersection with Pedestrian Movement and Railroad

124. 8 Phase Dual Ring Intersection with Pedestrian Movement and 2 Track Railroad

125. Railroad Preempt Phase Sequence


140. Instructions for Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings, Texas DOT

156. Vehicle Dynamics for Computing Track Clearance
   - Vehicles Accelerating from a Stopped Position
   - Distance Traveled Over Time from a Stopped Position

158. Basic Preempt Time Line

159. Preempt Time Line - Blank

160. Intersection Geometric Considerations

162. Special Considerations for Advance Preemption 1

167. Warning Label

169. Presignal Applications at Highway-Rail Grade Crossings
ADVANCE PREEMPTION

PRESENTED TO
AREMA
1998 ANNUAL MEETING
CHICAGO, ILLINOIS

PRESENTED BY
RICHARD M. CAMPBELL
PRESIDENT
RAILROAD CONTROLS LIMITED
500 SOUTH FREEWAY
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817-820-6300
For years, many Highway Traffic Signals located adjacent to Highway-Rail Grade Crossings with active warning systems have been interconnected. This interconnection is intended to “pre-empt” the normal operation of the Traffic Signal when a Train approaches the Grade Crossing, so that vehicles stopped on the tracks can receive a Green Signal to get clear of the tracks. The requirement for interconnection and preemption is

The application and operation of this “interconnection” has existed in many forms, and been identified by many different names such as preemption, interconnect, railroad circuit, railroad tie-in, railroad preemption, etc. There were even wide variations in the electrical configuration utilized.

In most cases, Railroads and Highway Departments maintained their respective portion of these circuits independently, and often referred to the same functions of the “System” by completely different names. Each party believed they were doing “the right thing”.

On October 25, 1995, a tragedy occurred in Fox River Grove, Illinois that would forever change the casual approach given to these interconnections. A METRA Commuter Train, operating on the Union Pacific Railroad, struck a school bus at the Algonquin Road Highway-Rail Grade Crossing. The force of the impact sheared the body of the bus from its chassis, and seven students perished.

As officials began to collect data and reconstruct events leading up to the crash, a very alarming fact came to light…

The Railroad Signal Personnel and Traffic Signal Personnel knew and understood the operation of their own systems, but knew virtually nothing about the other portion of the system to which it was connected! They also referred to identical functions using different terminology.

This lack of understanding was further demonstrated when most surprisingly, the particular tests performed by each group on their respective portion of the system determined that it was operating as designed!

The stage was now set for a Repeat Performance of the Fox River crash!
For many years, Association of American Railroad representatives understood the need for vital control logic, and attempted to initiate changes. It was common to find wide varieties of electrical parameters utilized, including normally open or normally closed circuits, typically all single break, with varying levels of operational voltages. A number of years ago, the National Committee (which is responsible for determining the standards published in the Manual on Uniform Traffic Control devices), adopted a standard requiring a normally closed circuit between the Traffic Signal Controller and the Grade Crossing Warning System. However, little else was done relative to the interconnect circuit itself. The National Committee also pursued changes in the Signal section of the MUTCD to further define operating sequences and characteristics of the traffic signals as a train approaches. Sadly, both groups worked at changes, but little cooperative effort was made to overcome some of the most fundamental differences.

In understanding the events leading up to the Fox River Grove crash, it is important to understand the new terminology proposed by Secretary Pena’s Task Force. This was the first official effort to establish commonality of terms and understanding of operating parameters relative to preemption.

Subsequently, in our work on AREMA Committee “D”, we have accepted and initiated implementation of this new terminology into the applicable standards. It is our understanding that the National Committee is proceeding on a parallel course.

1. **Minimum Track Clearance Distance (MTCD)** – For standard two-quadrant railroad warning devices, the minimum track clearance distance is the length along a highway at one or more railroad tracks, measured either from the railroad stop line, warning device or 4 meters (12 feet) perpendicular to the track centerline to 2 meters (6 feet) beyond the track(s) measured perpendicular to the far rail, along the centerline or edge line of the highway, as appropriate, to obtain the longer distance.

2. **Clear Storage Distance** – The distance available for vehicle storage measured between 2 meters (6 feet) from the rail nearest the intersection to the intersection STOP BAR
or the normal stopping point on the highway. At skewed crossings and intersections, the 2 meter (6 foot) distance shall be measured perpendicular to the nearest rail either along the centerline, or edge line of the highway as appropriate to obtain the shorter clear distance.

3. **Preemption** – The transfer of normal operation of traffic signals to a special control mode.

4. **Interconnection** – The electrical connection between the railroad active warning system and the traffic signal controller assembly for the purpose of preemption.

5. **Monitored Interconnected Operation** – An interconnected operation that has the capability to be monitored by the railroad and/or highway authority at a location away from the railroad-highway grade crossing.

6. **Minimum Warning Time – Through Train Movements** – The least amount of time active warning devices shall operate prior to the arrival of a train at a railroad-highway grade crossing.

7. **Right-of-Way Transfer Time** – The maximum amount of time needed for the worst case condition, prior to display of the clear track green interval. This includes any railroad or traffic signal control equipment time to react to a preemption call, and any traffic signal green, pedestrian walk and clearance, yellow change and red clearance intervals for opposing traffic.

8. **Queue Clearance Time** – The time required for the design vehicle stopped within the minimum track clearance distance to start up and move through the minimum track clearance distance. If pre-signals are present, this time should be long enough to allow the vehicle to move through the intersection, or clear the tracks if there is sufficient clear storage distance.

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

10. **Maximum Preemption Time** – The maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the timing of the Right-of-Way Transfer Time, Queue Clearance Time and Separation Time.
10. **Maximum Preemption Time** – The maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the timing of the Right-of-Way Transfer Time, Queue Clearance Time and Separation Time.

11. **Advance Preemption and Advance Preemption Time** – Notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly by railroad equipment for a period of time prior to activating the railroad active warning devices. This period of time is the difference in the Maximum Preemption Time required for highway traffic signal operation and the Minimum Warning Time needed for railroad operation and is called the Advance Preemption Time.

12. **Simultaneous Preemption** – Notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly and railroad active warning devices at the same time.

13. **Pre-Signal** – Supplemental highway traffic signal faces operated as part of the highway intersection traffic signals, located in a position that controls traffic approaching the railroad crossing and intersection.

14. **Cantilevered Signal Structure** – A cantilevered signal structure is a structure that is rigidly attached to a vertical pole and is used to provide overhead support of signal units.

15. **Design Vehicle** – The longest vehicle permitted by statute of the road authority (State or other) on that roadway.

Once an understanding exists of terminology, it is possible to understand the operating parameters of preemption sequences. In accordance with applicable sections of the MUTCD, when a traffic signal is called upon to initiate preemption and display a clear track green interval, certain intervals may not be skipped and/or shortened. This creates the very makeup of Right-of-Way Transfer Time. In other words, if the traffic signal is displaying green to the highway parallel to the railroad when a call for preemption is received, the following sequence of events must occur:

- Display of a minimum green interval to the highway. This serves to minimize the possibility of rear end crashes when a trailing motorist does not recognize and respond to a short green display. Most motorists, upon seeing a traffic signal change from red to green, do not
• Display of a minimum green interval to the highway. This serves to minimize the possibility of rear end crashes when a trailing motorist does not recognize and respond to a short green display. Most motorists, upon seeing a traffic signal change from red to green, do not anticipate a virtual immediate change to yellow as this is not normally encountered. If a perceptive motorist is ahead of a complacent motorist, the potential for a rear end crash is great.

• Termination of WALK interval, if provided. If the WALK indication is displayed to pedestrians, it is normally aborted and pedestrian clearance is permitted to begin.

• Display of Pedestrian Clearance (flashing DON’T WALK), if provided. If a WALK indication is displayed to pedestrians, it must be followed by some display of Pedestrian Clearance. The MUTCD permits the abbreviation of pedestrian clearance, but does not give guidance as to the extent or methods to determine an appropriate value. Pedestrian clearance time is permitted to include the yellow change and red clearance intervals.

• Display of yellow change interval to approaching motorists.

• Display of red clearance interval to approaching motorists.

Only after these intervals have been completed, can clear track green begin. This then begins the time interval identified as Queue Clearance Time. This interval is a function of start up and travel time for all vehicles within the Clear Storage Distance and the Minimum Track Clearance Distance.

This time interval is determined through a traffic engineering study taking into account such items as:

• Clear Storage Distance
• Minimum Track Clearance Distance
• Types of vehicles (passenger cars vs. trucks vs. busses)
• Crossing surface quality
• Vertical and horizontal alignment
• Sight distance
• Other limitations on speed
• Visual Distractions

Finally, consideration must be given to Separation Time. This is the buffer zone between the time the last vehicle clears the MTCD and the arrival of the train at the crossing. This interval is important as a motorist stopped within the MTCD may take uncontrolled offensive action including striking other vehicles or pedestrians in an
Finally, consideration must be given to Separation Time. This is the buffer zone between the time the last vehicle clears the MTCD and the arrival of the train at the crossing. This interval is important as a motorist stopped within the MTCD may take uncontrolled offensive action including striking other vehicles or pedestrians in an attempt to clear the MTCD as the train gets closer to the point of impact. A defensive motorist that simply abandons their vehicle prior to impact can also have a devastating effect of other vehicles and pedestrians in the vicinity of the crossing when impact occurs. For these reasons, Separation Time must be of sufficient duration to permit a motorist to safely exit the MTCD with an approaching train.

In many cases, these factors combined add up to a significant amount of time necessary to provide proper clearance. Further, this total time may exceed the amount of warning time provided by the grade crossing warning system!

Over the years, railroad-highway grade crossing warning systems have been designed based on a minimum warning time of 20 seconds. This time has been traced to the Handbook of the AAR dating to the 1920’s, which utilized design criteria of the 1920’s. It is based on the time it takes a truck to engage in gear and cross what we now know as the MTCD. Although much debated, the 20 second MWT remains in use to this date. However, in many cases, the 20 second MWT is not adequate resulting in the need for Advance Preemption in lieu of Simultaneous Preemption.

In March of 1998, AREMA Committee D voted to adopt an updated Part 3.3.10 to the Signal Manual. This part serves to clarify and simplify the components of intervals that comprise the Total Warning Time. Recognizing the need for advance preemption, Part 3.3.10 now identifies how advance preemption is added to the operation of the warning system.

In its most simple form, advance preemption provides the ability for the highway-rail grade crossing warning system to notify the traffic signal controller assembly of an approaching train prior to initiating operation of the grade crossing signals. In other words, additional time is provided to permit the traffic signal controller to complete the required minimum times (Right-of-Way Transfer Time) and initiate clear track green and any necessary time prior to activation of the railroad warning system. This permits an orderly transition into preemption without subjecting a motorist within the MTCD to a panic condition. Actually, from the motorist’s perspective, the traffic signal has made a routine change and provided display of a normal green indication.
prior to activation of the railroad warning system. This permits an orderly transition into preemption without subjecting a motorist within the MTCD to a panic condition. Actually, from the motorist’s perspective, the traffic signal has made a routine change and provided display of a normal green indication.

Although simple in concept, advance preemption has some far-reaching consequences if utilized improperly. As more time (APT) is factored into the notification of the traffic signal, consideration must be given to the variability of the traffic signal relative to its sequence when preemption is initiated. As part of its normal operation, the traffic signal can be anywhere in its sequence when called to preemption. In fact, the clear track green interval may actually be a standard green interval for vehicles crossing the track under normal conditions. Up to this point, all timing and assessment of the traffic signal and grade crossing warning system has been geared to the worth case time identified as Right-of-Way Transfer Time (RWTT). In this scenario, where the preemption call is received during the concurrent clear track green interval, the RWTT has become the best case as opposed to the worst case which, in actuality, becomes zero. The longer the RWTT becomes, the greater the magnitude of the problem with best case time. The most dangerous part is that it is possible, without a complete analysis, to actually enter and complete clear track green before operation of the grade crossing warning system. **The result is that any vehicle entering the MTCD is guaranteed to be trapped with no possible exit path.** This actually occurs where the best possible solution is studied and implemented with provisions for advance preemption and analysis of traffic signal worst case timing.

The solution to this condition requires additional intelligence on the part of the traffic signal controller unit. Because the entry into clear track green can begin at any point between zero and RWTT, the traffic signal controller unit should measure the difference between actual entry time and RWTT. This value should be dynamically added to the clear track green time. The result is a uniform relationship between Queue Clearance Time, Separation Time and operation of the grade crossing warning system. However, at this point, no commercially available traffic signal controller units exist with this capability. An alternative solution exists where, through the use of additional circuitry in the traffic signal controller assembly and the grade crossing warning system, the clear track green interval can be held until the approach gate is fully horizontal. This assures that the flow of vehicles through the MTCD is blocked before clear track green can complete timing and terminate. This eliminates the possibility of terminating clear track green prior to activation of the grade crossing warning system.
assembly and the grade crossing warning system, the clear track green interval can be held until the approach gate is fully horizontal. This assures that the flow of vehicles through the MTCD is blocked before clear track green can complete timing and terminate. This eliminates the possibility of terminating clear track green prior to activation of the grade crossing warning system.

In early 1996 I was contacted by Texas DOT to see if I had any interest to provide in-house training for TXDOT staff regarding preemption. Based on the success with TXDOT and their subsequent discussions with other agencies, in the summer of 1996, I was contacted by the Oklahoma Department of Transportation. ODOT wanted to inquire if I might be interested in providing similar training regarding operation of grade crossing warning systems and highway traffic signals to a larger group. In the fall of 1996, I presented the first of what would be many seminars to come on this topic. The results were overwhelming. I was confronted with two independent groups in a single room. Railroad signal personnel and highway traffic signal personnel. With a few exceptions, neither group knew the other group. Even those with primary responsibility for maintenance and operation of their respective systems at a single location. The seminar provided the opportunity to teach each group how the other group’s equipment operated. Finally, with the knowledge of how both systems operate, it is possible to understand the two systems as one. The results have provided a forum to gain a working understanding of both systems and a method to perform some operational analysis of the entire system operation. The ultimate goal is to eliminate, through education, “Accidents That Shouldn’t Happen”.
HIGHWAY TRAFFIC SIGNALS

RCL
Railroad Controls Limited
The Morgan Traffic Signal
The first American-made automobiles were introduced to U.S. consumers shortly before the turn of the century. The Ford Motor Company was founded in 1903 and with it American consumers began to discover the adventures of the open road. In the early years of the 20th century, it was not uncommon for bicycles, animal-powered wagons and new gasoline-powered motor vehicles to share the same streets and roadways with pedestrians. Accidents were frequent. After witnessing a collision between an automobile and a horse-drawn carriage, Garrett Morgan took his turn at inventing a traffic signal. Other inventors had experimented with, marketed and even patented traffic signals, however, Garrett Morgan was one of the first to apply for and acquire a U.S. patent for an inexpensive to produce traffic signal. The patent was granted on November 20, 1923. Garrett Morgan later had the technology patented in Great Britain and Canada as well.

Garrett Morgan stated in his patent for the traffic signal, "This invention relates to traffic signals, and particularly to those which are adapted to be positioned adjacent the intersection of two or more streets and are manually operable for directing the flow of traffic... In addition, my invention contemplates the provision of a signal which may be readily and cheaply manufactured."

The Morgan traffic signal was a T-shaped pole unit that featured three positions: Stop, Go and an all-directional stop position. This “third position” halted traffic in all directions to allow pedestrians to cross streets more safely.

Garrett Morgan's hand-cranked semaphore traffic management device was in use throughout North America until all manual traffic signals were replaced by the automatic red, yellow and green-light traffic signals currently used around the world. The inventor sold the rights to his traffic signal to the General Electric Corporation for $40,000. Shortly before his death, in 1963, Garrett Morgan was awarded a citation for his traffic signal by the United States Government.
TRAFFIC SIGNAL CONTROLLER UNITS

TYPE 170
Controller Unit

TYPE 2070
Controller Unit

NEMA
Controller Unit
(ASC)

NEMA
Controller Unit
(820A)
2Ø
PHASE SEQUENCE
2Ø
PHASE SEQUENCE
Traffic Actuated Signal Development

Charles Adler, Jr. holding horn for traffic signal, n.d.
Charles Adler, Jr. Collection, ca. 1920-1980

"To Obtain Signal - Stop Blow Horn,"
traffic-actuated signal light,
Charles Adler, Jr. Collection,
ca. 1920-1980

Traffic-actuated (by the sound of a car horn) signal light
Charles Adler, Jr. Collection, ca. 1920-1980
"Charles Adler, Jr. demonstrating the operation of the signal by the passage of a car over the sound detector"
2Ø+PEDS
PHASE SEQUENCE
BASIC TRAFFIC SIGNAL TIMING

BEGINNING OF GREEN
FIXED (PROGRAMMABLE) END OF MIN. GREEN
YELLOW MAY BEGIN (IF W+PC TIME IS COMPLETE)

MINIMUM GREEN

EXT. GREEN

MAXIMUM GREEN

YELLOW MAY BEGIN (IF MIN AND W+PC ARE COMPLETE)

2 SEC

0 SEC

WALK

PEDESTRIAN CHANGE

0 7 10 25 30
PHASE SEQUENCE

8Ø

Ø1 Ø2

Ø3 Ø4

Ø5 Ø6

Ø7 Ø8
8 PHASE SEQUENCE

RING 1

1 - 2 - 3 - 4

RING 2

5 - 6 - 7 - 8
8Ø+PEDS
PHASE SEQUENCE
8Ø+PEDS
PHASE SEQUENCE
RAILROAD CROSSING SIGNALS

RCL
Railroad Controls Limited
Section 8A.01 Introduction

Support:

Traffic control for highway-rail grade crossings includes all signs, signals, markings, other warning devices, and their supports along highways approaching and at highway-rail grade crossings. The function of this traffic control is to permit reasonably safe and efficient operation of both rail and highway traffic at highway-rail grade crossings.

For purposes of installation, operation, and maintenance of traffic control devices at highway-rail grade crossings, it is recognized that the crossing of the highway and rail tracks is situated on a right-of-way available for the joint use of both highway traffic and railroad traffic.

The highway agency or authority with jurisdiction and the regulatory agency with statutory authority, if applicable, jointly determine the need and selection of devices at a highway-rail grade crossing.

In Part 8, the combination of devices selected or installed at a specific highway-rail grade crossing is referred to as a “traffic control system.”
Section 8A.02  Use of Standard Devices, Systems and Practices

Support:

Because of the large number of significant variables to be considered, no single standard system of traffic control devices is universally applicable for all highway-rail grade crossings.

Guidance:

The appropriate traffic control system should be determined by an engineering study involving both the highway agency and the railroad company.

Standard:

Traffic control devices, systems and practices shall be consistent with the design and application of the standards contained herein.

Before a new or modified highway-rail grade crossing traffic control system is installed, approval shall be obtained from the highway agency with the jurisdictional and/or statutory authority and from the railroad company.
§ 646.214 Design.

(a) General. (1) Facilities that are the responsibility of the railroad for maintenance and operation shall conform to the specifications and design standards used by the railroad in its normal practice, subject to approval by the State highway agency and FHWA.

(2) Facilities that are the responsibility of the highway agency for maintenance and operation shall conform to the specifications and design standards and guides used by the highway agency in its normal practice for Federal-aid projects.

(b) Grade crossing improvements. (1) All traffic control devices proposed shall comply with the latest edition of the Manual on Uniform Traffic Control Devices for Streets and Highways supplemented to the extent applicable by State standards.

(2) Pursuant to 23 U.S.C. 109(e), where a railroad-highway grade crossing is located within the limits of or near the terminus of a Federal-aid highway project for construction of a new highway or improvement of the existing roadway, the crossing shall not be opened for unrestricted use by traffic or the project accepted by FHWA until adequate warning devices for the crossing are installed and functioning properly.

(3)(i) Adequate warning devices, under §646.214(b)(2) or on any project where Federal-aid funds participate in the installation of the devices are to include automatic gates with flashing light signals when one or more of the following conditions exist:

(A) Multiple main line railroad tracks.

(B) Multiple tracks at or in the vicinity of the crossing which may be occupied by a train or locomotive so as to obscure the movement of another train approaching the crossing.

(C) High Speed train operation combined with limited sight distance at either single or multiple track crossings.

(D) A combination of high speeds and moderately high volumes of highway and railroad traffic.

(E) Either a high volume of vehicular traffic, high number of train movements, substantial numbers of school buses or trucks carrying hazardous materials, unusually restricted sight distance, continuing accident occurrences, or any combination of these conditions.

(F) A diagnostic team recommends them.

(ii) In individual cases where a diagnostic team justifies that gates are not appropriate, FHWA may find that the above requirements are not applicable.
(4) For crossings where the requirements of §646.214(b)(3) are not applicable, the type of warning device to be installed, whether the determination is made by a State regulatory agency, State highway agency, and/or the railroad, is subject to the approval of FHWA.

(c) Grade crossing elimination. All crossings of railroads and highways at grade shall be eliminated where there is full control of access on the highway (a freeway) regardless of the volume of railroad or highway traffic.

UNITED STATES CODE
TITLE 23 — HIGHWAYS

CHAPTER 4--HIGHWAY SAFETY

Sec. 409. Discovery and admission as evidence of certain reports and surveys

Notwithstanding any other provision of law, reports, surveys, schedules, lists, or data compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential accident sites, hazardous roadway conditions, or railway-highway crossings, pursuant to sections 130, 144, and 152 of this title or for the purpose of developing any highway safety construction improvement project which may be implemented utilizing Federal-aid highway funds shall not be subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other purposes in any action for damages arising from any occurrence at a location mentioned or addressed in such reports, surveys, schedules, lists, or data.


Amendments

1995--Pub. L. 104-59 inserted `or collected'' after `data compiled''.

1991--Pub. L. 102-240 substituted `Discovery and admission'' for `Admission'' in section catchline and `subject to discovery or admitted into evidence in a Federal or State court proceeding'' for `admitted into evidence in Federal or State court'' in text.

Effective Date of 1991 Amendment

Amendment by Pub. L. 102-240 effective Dec. 18, 1991, and applicable to funds authorized to be appropriated or made available after Sept. 30, 1991, and, with certain exceptions, not applicable to funds appropriated or made available on or before Sept. 30, 1991, see section 1100 of Pub. L. 102-240, set out as a note under section 104 of this title.
§ 646.204 Definitions.

For the purposes of this subpart, the following definitions apply:

Active warning devices means those traffic control devices activated by the approach or presence of a train, such as flashing light signals, automatic gates and similar devices, as well as manually operated devices and crossing watchmen, all of which display to motorists positive warning of the approach or presence of a train.

Company shall mean any railroad or utility company including any wholly owned or controlled subsidiary thereof.

Construction shall mean the actual physical construction to improve or eliminate a railroad-highway grade crossing or accomplish other railroad involved work.

A diagnostic team means a group of knowledgeable representatives of the parties of interest in a railroad-highway crossing or a group of crossings.

Main line railroad track means a track of a principal line of a railroad, including extensions through yards, upon which trains are operated by timetable or train order or both, or the use of which is governed by block signals or by centralized traffic control.

Passive warning devices means those types of traffic control devices, including signs, markings and other devices, located at or in advance of grade crossings to indicate the presence of a crossing but which do not change aspect upon the approach or presence of a train.

Preliminary engineering shall mean the work necessary to produce construction plans, specifications, and estimates to the degree of completeness required for undertaking construction thereunder, including locating, surveying, designing, and related work.

Railroad shall mean all rail carriers, publicly-owned, private, and common carriers, including line haul freight and passenger railroads, switching and terminal railroads and passenger carrying railroads such as rapid transit, commuter and street railroads.

Utility shall mean the lines and facilities for producing, transmitting or distributing communications, power, electricity, light, heat, gas, oil, water, steam, sewer and similar commodities.

[40 FR 16059, Apr. 9, 1975, as amended at 62 FR 45328, Aug. 27, 1997]
• The first crossing warning device similar to today’s technology consisted of a tilting crossbar and was erected in 1857 to provide warning for approaching pedestrians, horses and horse drawn wagons and carriages.

• In 1860 a red disc, red flag and at night, red lantern were added to the crossbar.

• In 1870, the first revolving red disc was used on top of a mast manufactured by the Hall Signal Company.
• The first crossbuck style signs were used in the late 1800’s including legends such as STOP – LOOK – LISTEN, LOOK OUT FOR THE LOCOMOTIVE or WATCH OUT FOR THE CARS.

• The design was intended to suggest crossed bones and death.
• Flagmen were used at busy roads to provide additional warning.

• Even in early days, flagmen were often ignored as impatient drives hurried to beat the train.

• Flagmen were ultimately used to manually operate crossing gates, usually configured for full closures like today’s four quadrant gates.

• The gate was a long arm usually blocking the entire roadway.

• The introduction of the electric track circuit allowed warning devices to be automated.
  • The first automatic bell signal was developed to scare any horse.

• One such bell was produced by a French Canadian clockmaker named David Rosseau.

• H. S. Balliet, writing in 1921 on the “Progress of Railroad Signaling in America” described Rosseau’s bells as “ingenious and perfectly functioning.”
US&S’s crossing bell, relay box and battery case, with wooden post

Bryant Zinc Company’s crossing bell and relay box on an iron post, with crossing sign

US&S’s crossing bell, relay box and battery case, with iron pipe post and crossing sign
Crossing bell and relay box on an iron post, with sign: Bryant Zinc Company

Bell and relay box on an iron post, with sign: Bryant Zinc Company

Railroad Supply Company's crossing bell and relay box on a channel iron post, with sign
• Soon after the bell was introduced, a red light for nighttime operation was added.

• A magnetically operated banner was also added creating the “Automatic Flagman” or Wig-Wag signal.
• The first flashing light signal was installed on the Central Railroad of New Jersey in 1913 at Woodbridge Avenue in Sewaren, NJ.

• It consisted of four or five lights arranged in a quadrant of a circle and when operated gave the appearance of a swinging lamp and was invented by L. S. Brach.

• The first standardized crossing signal was developed through an effort of the American Railway Association. In 1915, a task force was convened to bring order to crossing signals.

• The standard was produced in 1916 and included a crossbuck sign, black and white stripes for crossing gates when used, a circular approach sign with a cross and the letters RR, STOP signs for watchmen by day, red lights on the gates and a red light in the hand of a watchmen at night.
• The first flashing light signal consisting of two horizontally mounted, alternately flashing red lights was invented by L. S. Brach.

• It was introduced through the A.R.A. Committee on Highway Crossing Protection around 1930 under direction of A. H. Rudd, Signal Engineer of the Pennsylvania Railroad.
Model 6 Signal—The Railway's Answer To Higher Rail and Highway Speeds

SPEEDS of 80 to 120 m.p.h. are daily performances for such trains as the Hiawatha, the Twin Zephyrs, the City of Portland, the Abraham Lincoln, the Flying Yankee, the Comet, the "400" and the Rebel. These super-speed trains require the ultimate in crossing protection because these trains must be protected as well as the highway traffic. Drivers of highway vehicles depend more and more on signal indications.

Model 6 Signal will provide adequate crossing protection at low cost. It compels attention and action day and night. Model 6 combines the Standard A.R.A. Flashing Light Signal with the Federal Octagon "STOP" Sign. The "STOP" Sign is operative and rotates to the "STOP" position only when a train is approaching. At all other times it is parallel to the highway and invisible to traffic. Model 6 shows "STOP" only when a "STOP" is imperative. It provides unfailling protection 24 hours of the day.
• The first motor driven highway crossing gate was introduced in 1936 by adapting a semaphore signal mechanism to drive the gate.

• It was installed on the Illinois Central Railroad.

• The first use of the rails to carry electric current dates back to 1848.

• Franklin Pope, working with Thomas Edison, conducted an experiment in 1871 using a 42 foot section of rail, but his work was based on the open circuit principle.

• Interestingly, before producing a closed circuit track circuit, Pope was accidentally electrocuted in his home.

• The first electric track circuit based on the closed circuit principle was invented by Dr. William Robinson in 1872.

• Robinson’s work occurred almost simultaneously with Pope’s, and in 1870 he demonstrated a model of his circuit based on an open circuit principle at a fair in New York City.

• Later that year, Robinson’s circuit was installed at Kinzua, PA on the Philadelphia and Erie Railroad.
Brilliant, imaginative, and immensely energetic, William Robinson lost no opportunity to advance the cause of his inventions throughout the railroad world.
• Robinson discovered the immediate safety risks associated with an open circuit, and worked to produce a closed circuit which he demonstrated in 1872 at the State Fair in Erie, Pennsylvania.

• Robinson recognized that gravity was a necessary part of the fail safe principle.

• The first insulated joints necessary for Robinson’s track circuit were made of wood.

• In 1876, fiber insulated rail joints were developed.

• Bond wires were also invented to be pushed into a hole drilled in the rail and held in place by a pin.
• In 1878, Robinson, following many successful installations of his new circuit and signal system, formed the Union Electric Signal Company.

• On May 1, 1881, George Westinghouse consolidated the Union Electric Signal Company and the Interlocking Switch and Signal Company to form what is now known as the Union Switch & Signal Company.
• On November 22, 1910, the following report was made by the Block Signal and Train Control Board to the Interstate Commerce Commission:

“Perhaps no single invention in the history of the development of railway transportation has contributed more toward the safety and dispatch in that field than the track circuit. By this invention, simple in itself, the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today,…”

• Robinson’s circuit is what we now know as the DC Track Circuit and consists of a battery and relay connected to the rails at opposite ends of the circuit.
• In later years, engineers worked to design a circuit that allowed the battery and relay to be located at the same end of the circuit.

• It was determined that in order to accomplish the goal of having the relay at the same end of the circuit, the energy source would have to utilize AC current.

• A rectifier (now known as a diode) was installed at the distant end of the circuit.

• A higher AC voltage could be applied to the rails which allowed better shunting (sensitivity) where large amounts of rust exist due to infrequent use.

• In the mid 1960’s everyone was embracing a new device that would revolutionize the world, the transistor.

• Railroad signal engineers looked for ways to improve the state of the art through the use of solid state electronics.

• The result was the Solid State Audio Frequency Overlay (AFO) track circuit.
  • The AFO track circuit was unique in that it did not require insulated joints.

• A transmitter was connected to the rails at one end of the circuit.

• A receiver was connected to the rails at the other end of the circuit.

• The fail safe operation is maintained with the AFO circuit.
• Although the AFO circuit simplified highway crossing circuits by allowing multiple approaches to overlap, it was unable to provide more information than an occupied/unoccupied condition.

• Once individual track circuits were developed, combinations of track circuit occupancy were used to provide more intelligent control.

• In highway-rail grade crossing control, circuitry was developed to allow warning devices to begin operating as a train approached a crossing, but permitted the devices to stop operating as soon as the train cleared the crossing.

• This circuit made use of “stick” relays. A stick circuit allows the train direction to be established through a crossing.
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'

INSULATED JOINT DEFINES CIRCUIT LIMITS
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'
CONVENTIONAL 3 TRACK CIRCUIT

1TR

2TR

3TR

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'

INSULATED JOINT DEFINES CIRCUIT LIMITS
CONVENTIONAL 3 TRACK CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
ERT = 2 SEC.
APPROACH TIME = 22 SEC.

APPROACH LENGTH @ 30 MPH - 968'
Flasher Relay
• In the late 1960’s, the first Solid State Motion Sensor was developed.

• It was built on principles from the AFO track circuit.

• The Motion Sensor provided a means to determine if a train was moving toward the crossing, moving away from the crossing or stopped within the approach circuit to a crossing.
MOTION SENSOR CIRCUIT

TERMINATION SHUNT DEFINES CIRCUIT LIMITS.

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT= 20 SEC.
ERT= 3 SEC.
APPROACH TIME= 23 SEC.

APPROACH LENGTH @ 30 MPH - 1012’
• Product design engineers quickly realized that, with a slight amount of additional information, a Motion Sensor could be adapted to measure train speed by measuring the rate of voltage change against a fixed distance.

• Although the calculations were performed through analog means, this formed the first Constant Warning Time system.

• With the development of the microprocessor and the reliability derived from the use of CMOS logic devices, the first HXP-1 Digital Grade Crossing Processor was developed by Harmon Electronics in the early 1970’s.
CONSTANT WARNING TIME CIRCUIT

MT = 20 SEC.
CT = 0 SEC.
MWT = 20 SEC.
MWT = 20 SEC.
BT = 5 SEC.
TOTAL WARNING TIME = 25 SEC.
APT = 0 SEC.
ERT = 5 SEC.
APPROACH TIME = 30 SEC.

APPROACH LENGTH @ 30 MPH - 1320’
• Today, microprocessors have revolutionized all facets of railroad signaling.

• Items we now take for granted such as personal computers, keyboards and displays ease user interface with increasingly complex equipment.
Section 8D.07 Traffic Control Signals at or Near Highway-Rail Grade Crossings

Guidance:

The highway agency with jurisdiction, the regulatory agency with statutory authority, if applicable and the railroad company should jointly determine the preemption operation at highway-rail grade crossings adjacent to signalized highway intersections.

When a highway-rail grade crossing is equipped with a flashing-light signal system and is located within 60m (200 ft) of an intersection or mid-block location controlled by a traffic control signal, the traffic control signal should be provided with preemption in accordance with Section 4D.13.

Coordination with the flashing-light signal system should be considered for traffic control signals located farther than 60m (200 ft) from the highway-rail grade crossing. Factors to be considered should include traffic volumes, vehicle mix, vehicle and train approach speeds, frequency of trains and queue lengths.

Standard:

If preemption is provided, the normal sequence of traffic control signal indications shall be preempted upon the approach of trains to avoid entrapment of vehicles on the highway-rail grade crossing by conflicting aspects of the traffic control signals and the highway-rail grade crossing flashing-light signals.
This preemption feature shall have an electrical circuit of the closed-circuit principle, or a supervised communication circuit between the control circuits of the highway-rail grade crossing warning system and the traffic control signal controller. The traffic control signal controller preemptor shall be activated via the supervised communication circuit or the electrical circuit that is normally energized by the control circuits of the highway-rail grade crossing warning system. The approach of a train to a highway-rail grade crossing shall de-energize the electrical circuit or activate the supervised communication circuit, which in turn shall activate the traffic control signal controller preemptor. This shall establish and maintain the preemption condition during the time the highway-rail grade crossing warning system is activated, except that when crossing gates exist, the preemption condition shall be maintained until the crossing gates are energized to start their upward movement. When multiple or successive preemptions occur, train activation shall receive first priority.
SECTION 8A.01

STANDARD:

1. **Advance Preemption**—the notification of an approaching train that is forwarded to the highway traffic signal controller unit or assembly by the railroad equipment in advance of the activation of the railroad warning devices.

2. **Advance Preemption Time**—the period of time that is the difference between the required maximum highway traffic signal preemption time and the activation of the railroad warning devices.

3. **Cantilevered Signal Structure**—a structure that is rigidly attached to a vertical pole and is used to provide overhead support of signal units.

4. **Clear Storage Distance**—the distance available for vehicle storage measured between 1.8 m (6 ft) from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway. At skewed highway-rail grade crossings and intersections, the 1.8 m (6 ft) distance shall be measured perpendicular to the nearest rail either along the centerline or edge line of the highway, as appropriate, to obtain the shorter distance. Where exit gates are used, the distance available for vehicle storage is measured from the point where the rear of the vehicle would be clear of the exit gate arm. In cases where the exit gate arm is parallel to the track(s) and is not perpendicular to the highway, the distance is measured either along the centerline or edge line of the highway, as appropriate, to obtain the shorter distance.
CLEAR STORAGE DISTANCE
(two-quadrant gate system)

Clear Storage Distance at 90 Degree Crossing

Clear Storage Distance shown in Red
CLEAR STORAGE DISTANCE
(two-quadrant gate system)

Clear Storage Distance at Skewed Crossing

Clear Storage Distance shown in Red
CLEAR STORAGE DISTANCE  
(four-quadrant gate system)

Clear Storage Distance at 90 Degree Crossing

Clear Storage Distance shown in Red
CLEAR STORAGE DISTANCE
(four-quadrant gate system)

Clear Storage Distance at Skewed Crossing

Clear Storage Distance shown in Red
5. Design Vehicle—the longest vehicle permitted by statute of the road authority (State or other) on that roadway.

6. Dynamic Envelope—the clearance required for the train and its cargo overhang due to any combination of loading, lateral motion, or suspension failure (see Figure 8A-1).

7. Dynamic Exit Gate Operating Mode—a mode of operation where the exit gate operation is based on the presence of vehicles within the minimum track clearance distance.

8. Exit Gate Clearance Time—for Four-Quadrant Gate systems, the exit gate clearance time is the amount of time provided to delay the descent of the exit gate arm(s) after entrance gate arm(s) begin to descend.

9. Exit Gate Operating Mode—for Four-Quadrant Gate systems, the mode of control used to govern the operation of the exit gate arms.

10. Flashing-Light Signals—a warning device consisting of two red signal indications arranged horizontally that are activated to flash alternately when a train is approaching or present at a highway-rail grade crossing.

11. Interconnection—the electrical connection between the railroad active warning system and the highway traffic signal controller assembly for the purpose of preemption.

12. Maximum Highway Traffic Signal Preemption Time—the maximum amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the timing of the right-of-way transfer time, queue clearance time, and separation time.
13. Minimum Track Clearance Distance—for standard two-quadrant railroad warning devices, the minimum track clearance distance is the length along a highway at one or more railroad tracks, measured either from the highway stop line, warning device, or 3.7 m (12 ft) perpendicular to the track centerline, to 1.8 m (6 ft) beyond the track(s) measured perpendicular to the far rail, along the centerline or edge line of the highway, as appropriate, to obtain the longer distance. For Four-Quadrant Gate systems, the minimum track clearance distance is the length along a highway at one or more railroad tracks, measured either from the highway stop line or entrance warning device, to the point where the rear of the vehicle would be clear of the exit gate arm. In cases where the exit gate arm is parallel to the track(s) and is not perpendicular to the highway, the distance is measured either along the centerline or edge of the highway, as appropriate, to obtain the longer distance.
MTCD (two-quadrant gate system)

Minimum Track Clearance Distance for two-quadrant gate system

MTCD shown in Red
MTCD (two-quadrant gate system)

Minimum Track Clearance Distance for two-quadrant gate system

MTCD shown in Red
MTCD (two-quadrant gate system)

Minimum Track Clearance Distance for two-quadrant gate system

MTCD shown in Red
MTCD (four-quadrant gate system)

Minimum Track Clearance Distance for four-quadrant gate system

Additional MTCD shown in Red
MTCD (four-quadrant gate system)

Minimum Track Clearance Distance for four-quadrant gate system

Additional MTCD shown in Red
14. Minimum Warning Time—Through Train Movements—the least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossing.

15. Preemption—the transfer of normal operation of highway traffic signals to a special control mode.

16. Pre-signal—supplemental highway traffic signal faces operated as part of the highway intersection traffic signals, located in a position that controls traffic approaching the highway-rail grade crossing in advance of the intersection.

17. Queue Clearance Time—the time required for the design vehicle of maximum length stopped just inside the minimum track clearance distance to start up and move through and clear the entire minimum track clearance distance. If presignals are present, this time shall be long enough to allow the vehicle to move through the intersection, or to clear the tracks if there is sufficient clear storage distance. 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 minimum track clearance distance.

18. Right-of-Way Transfer Time—the maximum amount of time needed for the worst case condition, prior to display of the track clearance green interval. This includes any railroad or highway traffic signal control equipment time to react to a preemption call, and any traffic control signal green, pedestrian walk and clearance, yellow change, and red clearance intervals for conflicting traffic.

19. Separation Time—the component of maximum highway traffic signal preemption time during which the minimum track clearance distance is clear of vehicular traffic prior to the arrival of the train.
20. Simultaneous Preemption—notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly and railroad active warning devices at the same time.

21. Timed Exit Gate Operating Mode—a mode of operation where the exit gate descent is based on a predetermined time interval.

22. Vehicle Intrusion Detection Devices—a detector or detectors used as a part of a system incorporating processing logic to detect the presence of vehicles within the minimum track clearance distance and to control the operation of the exit gates.

23. Wayside Equipment—the signals, switches, and/or control devices for railroad operations housed within one or more enclosures located along the railroad right-of-way and/or on railroad property.
Section 4D.02  Responsibility for Operation and Maintenance

Guidance:

Prior to installing any traffic control signal, the responsibility for the maintenance of the signal and all of the appurtenances, hardware, software and the timing plan(s) should be clearly established. The responsible agency should provide for the maintenance of the traffic control signal and all of its appurtenances in a competent manner.

To this end the agency should:

A. Keep every controller assembly in effective operation in accordance with its predetermined timing schedule; check the operation of the controller assembly frequently enough to ensure that it is operating in accordance with the predetermined timing schedule and ensure that a record of all timing changes is maintained and that only authorized persons make timing changes.
Section 4D.13  Preemption and Priority Control of Traffic Control Signals

Standard:

During the transition into preemption control:

A. The yellow change interval, and any red clearance interval that follows, shall not be shortened or omitted.

B. The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted.

C. The return to the previous steady green signal indication shall be permitted following a steady yellow signal indication in the same signal face, omitting the red clearance interval, if any.

During preemption control and during the transition out of preemption control:

A. The shortening or omission of any yellow change interval, and of any red clearance interval that follows, shall not be permitted.

B. A signal indication sequence from a steady yellow signal indication to a steady green signal indication shall not be permitted.
Guidance:

If a traffic control signal is installed near or within a highway-railroad grade crossing or if a highway-railroad grade crossing with active traffic control devices is within or near a signalized highway intersection, Chapter 8D should be consulted.

Section 4E.07 Countdown Pedestrian Signals

Standard:
If used, countdown pedestrian signals shall consist of Portland orange numbers that are at least 150 mm (6 in) in height on a black opaque background. The countdown pedestrian signal shall be located immediately adjacent to the associated UPRAISED HAND (symbolizing DONT WALK) pedestrian signal head indication. If used, the display of the number of remaining seconds shall begin only at the beginning of the pedestrian change interval. After the countdown displays zero, the display shall remain dark until the beginning of the next countdown. If used, the countdown pedestrian signal shall display the number of seconds remaining until the termination of the pedestrian change interval. Countdown displays shall not be used during the walk interval nor during the yellow change interval of a concurrent vehicular phase.

Guidance:
Because some technology includes the countdown pedestrian signal logic in a separate timing device that is independent of the timing in the traffic signal controller, care should be exercised by the engineer when timing changes are made to pedestrian change intervals.

If the pedestrian change interval is interrupted or shortened as a part of a transition into a preemption sequence (see Section 4E.10), the countdown pedestrian signal display should be discontinued and go dark immediately upon activation of the preemption transition.
Section 4E.10  Pedestrian Intervals and Signal Phases

Standard:

When pedestrian signal heads are used, a WALKING PERSON (symbolizing WALK) signal indication shall be displayed only when pedestrians are permitted to leave the curb or shoulder.

A pedestrian clearance time shall begin immediately following the WALKING PERSON (symbolizing WALK) signal indication. The first portion of the pedestrian clearance time shall consist of a pedestrian change interval during which a flashing UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed. The remaining portions shall consist of the yellow change interval and any red clearance interval (prior to a conflicting green being displayed), during which a flashing or steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed.

If countdown pedestrian signals are used, a steady UPRAISED HAND (symbolizing DONT WALK) signal indication shall be displayed during the yellow change interval and any red clearance interval (prior to a conflicting green being displayed) (see Section 4E.07).

At intersections equipped with pedestrian signal heads, the pedestrian signal indications shall be displayed except when the vehicular traffic control signal is being operated in the flashing mode. At those times, the pedestrian signal lenses shall not be illuminated.
Section 4E.10 Pedestrian Intervals and Signal Phases

Guidance:

Except as noted in the Option, the walk interval should be at least 7 seconds in length so that pedestrians will have adequate opportunity to leave the curb or shoulder before the pedestrian clearance time begins.

Option:

If pedestrian volumes and characteristics do not require a 7-second walk interval, walk intervals as short as 4 seconds may be used.
The section for the AREMA C & S manual
Part 3.1.10
Part 16.30.10
Revision 2004
has been deleted due to copyright law.

www.arema.org
8Ø+PED
PHASE SEQUENCE
RAILROAD PREEMPT PHASE SEQUENCE
1. LOCATION DATA

<table>
<thead>
<tr>
<th>CITY</th>
<th>COUNTY</th>
<th>OPERATING AGENCY</th>
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<tr>
<td></td>
<td></td>
<td>Met/DOT DISTRICT</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>HIGHWAY INTERSECTION</th>
<th>RAILROAD COMPANY</th>
<th>RAILROAD INVENTORY NUMBER</th>
</tr>
</thead>
</table>

2. LOCATION DIAGRAM

SKETCH RAILROAD/TRAFFIC SIGNAL INTERSECTION
(Include RR approach & storage lengths, signal phasing, warning devices, pavement markings, etc.)

3. RR PREEMPTION PHASING SEQUENCE

<table>
<thead>
<tr>
<th>CRITICAL PHASES</th>
<th>TRACK CLEARANCE</th>
<th>TRACK HOLD</th>
</tr>
</thead>
</table>

4. RAILROAD DATA (PROVIDED BY RAILROAD AGENCY)

<table>
<thead>
<tr>
<th>RAILROAD CONTROLLER</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>RR WARNING DEVICE WORK CORRECTLY (flashers, gates, etc.)?</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DETECTOR TYPE</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>MAX TRAIN SPEED FOR SECTION</th>
<th>NUMBER OF TRACKS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NUMBER OF TRAINS PER DAY</th>
</tr>
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</table>

5. SIGNAL DATA

<table>
<thead>
<tr>
<th>CONTROLLER</th>
<th>ACTUATED</th>
<th>PRETIMED</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>EVP PRESENT?</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DOES RR PREEMPTION HAVE PRIORITY OVER EVP?</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>EVP CONFIRMATION LIGHTS PRESENT?</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DESCRIBE EVP OPERATION WHEN PREEMPTED BY AN APPROACHING TRAIN.</th>
</tr>
</thead>
</table>

6. REVIEW TEAM (INCLUDE TELEPHONE NUMBERS)

<table>
<thead>
<tr>
<th>HIGHWAY</th>
<th>RAILROAD</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>INSPECTION DATE</th>
</tr>
</thead>
</table>

Rev. 2/11/02 - 1
### 7. TRAFFIC SIGNAL TIMING

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>EQUIPMENT RESPONSE TIME</td>
<td>sec.</td>
</tr>
<tr>
<td>B</td>
<td>PEDESTRIAN CLEARANCE</td>
<td>sec.</td>
</tr>
<tr>
<td>C</td>
<td>MINIMUM GREEN</td>
<td>sec.</td>
</tr>
<tr>
<td>D</td>
<td>CRITICAL PHASE MOVEMENT (Whichever is greater: B or C.)</td>
<td>sec.</td>
</tr>
<tr>
<td>E</td>
<td>LEADING FLASH TIME OF AWF (Enter if present.)</td>
<td>sec.</td>
</tr>
<tr>
<td>F</td>
<td>YELLOW CHANGE INTERVAL (Do not enter if included in B.)</td>
<td>sec.</td>
</tr>
<tr>
<td>G</td>
<td>RED CLEARANCE (Do not enter if included in B.)</td>
<td>sec.</td>
</tr>
<tr>
<td>H</td>
<td>RIGHT-OF-WAY TRANSFER TIME (A + D + E + F + G)</td>
<td>sec.</td>
</tr>
<tr>
<td>I</td>
<td>DISSIPATION OF QUEUE</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>QUEUE CLEARANCE</td>
<td>sec.</td>
</tr>
<tr>
<td>K</td>
<td>TRACK CLEARANCE PHASE TIME (I or J)</td>
<td>sec.</td>
</tr>
<tr>
<td>L</td>
<td>SEPARATION TIME</td>
<td>sec.</td>
</tr>
<tr>
<td>M</td>
<td>CLEAR TRACK INTERVAL TIME (K + L)</td>
<td>sec.</td>
</tr>
<tr>
<td>N</td>
<td>MAXIMUM WARNING TIME REQUIRED FROM RAILROAD (H + M)</td>
<td>sec.</td>
</tr>
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### 8. TRAFFIC SIGNAL TIMING cont'd

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
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<tbody>
<tr>
<td>DOES RAILROAD PREEMPTION HAVE HIGHEST PRIORITY?</td>
<td>YES</td>
</tr>
<tr>
<td>IS PED CLEARANCE SHORTENED DURING PREEMPTION?</td>
<td>NO</td>
</tr>
<tr>
<td>IS MIN GREEN SHORTENED DURING PREEMPTION?</td>
<td>NO</td>
</tr>
<tr>
<td>EVP PRESENT?</td>
<td>NO</td>
</tr>
<tr>
<td>DO CONFIRMATION LIGHTS FLASH DURING RR PREEMPT?</td>
<td>NO</td>
</tr>
<tr>
<td>BACKUP POWER?</td>
<td>NO</td>
</tr>
<tr>
<td>TYPE OF BACKUP POWER</td>
<td></td>
</tr>
</tbody>
</table>

### 9. PAVEMENT MARKINGS

Describe conditions of pavement markings.

### 10. RAILROAD TIMING (Provided by Railroad Agency)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAIN DETECTION INTERVAL (must be ≥ 11)</td>
<td></td>
</tr>
<tr>
<td>FLASHER INTERVAL (must be ≥ 20 sec.)</td>
<td></td>
</tr>
<tr>
<td>WARNING TIME PROVIDED BY RAILROAD</td>
<td></td>
</tr>
</tbody>
</table>

### 11. OTHER INFORMATION

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>IS MAXIMUM WARNING TIME REQUIRED FROM RAILROAD ≤ WARNING TIME PROVIDED BY RAILROAD?</td>
<td>YES</td>
</tr>
</tbody>
</table>
Technical Memorandum
No. 00-05-T-01

MINNESOTA DEPARTMENT OF TRANSPORTATION
Program Support Group
Technical Memorandum No. 00-05-T-01
March 20, 2000

TO: Distributions 57, 612, 618, and 650

FROM: Patrick C. Hughes
Director, Program Support
Assistant Commissioner

SUBJECT: Guidelines for the Inspection and Operation of Railroad Preemption at Signalized Intersections

This Technical Memorandum replaces Technical Memorandum titled Guidelines for the Inspection and Operation of Railroad Preemption at Signalized Intersections, number 95-33-T-06. This Technical Memorandum will expire on December 31, 2005, or when this information is included in either the Minnesota Manual on Uniform Traffic Control Devices or the Minnesota Traffic Engineering Manual. This Technical Memorandum should be implemented immediately.

Introduction
This Technical Memorandum provides guidelines and recommendations for the installation, operation and inspection of traffic signals that are preempted either by trains or by Light Rail Transit (LRT) vehicles utilizing preemption. As part of this memorandum, yearly inspections will be performed and submitted to the Office of Freight, Railroads & Waterways.

Scope
The guidelines and procedures contained in this Technical Memorandum apply to Mn/DOT, and to county and city agencies through the state aid process. Mn/DOT district offices may assist local agencies in performing inspections, if requested.

The responsibility for the operation of the highway/railroad preempted traffic signals remains with the district, county or city having operational jurisdiction. Neither an inspection nor these guidelines substitute for sound engineering judgement in the operation of traffic signals.

These are general guidelines and should be used only as a guide. Other factors at each location must be considered in applying these guidelines. The Minnesota Manual on Uniform Traffic Control Devices (MMUTCD), Traffic Control Devices Handbook, Railroad-Highway Grade Crossing Handbook (FHWA-TS-86-215), and the Institute of
Transportation Engineers' Preemption of Traffic Signals at or Near Railroad Grade Crossings with Active Warning Devices should be referred to for additional guidance.

**Guidelines for Preemption**

If either of the following conditions are present, consideration should be given to interconnect the traffic signal and railroad grade crossing:

- **A** Highway traffic queues that have the potential for extending across a nearby rail crossing.
- **B** Traffic queued from a downstream railroad grade crossing that has the potential to interfere with an upstream-signalized intersection.

The 1991 version of the Minnesota Manual on Uniform Traffic Control Devices, specifies that the recommended distance between traffic signal and grade crossing for interconnection is 200 feet (65 meters). Recent research has found this distance to be inadequate. The following formulas provide a method for estimating the queue length that can be expected on the approach. If the queue length exceeds the storage between the intersection stop bar and 6 feet (2 meters) from the nearest rail, the railroad signal and the traffic signal should be interconnected.

A method for estimating queue length (with about 95 percent certainty) is as follows:

\[ L = 2qrv(1+p) \]

Where:
- \( L \) = length of queue, in feet or meters per lane;
- \( q \) = flow rate, average vehicles per lane per second;
- \( r \) = effective red time (time which the approach is red or yellow per cycle);
- \( v \) = passenger vehicle length, assume 25 feet or 7.5 meters;
- \( p \) = proportion of trucks;
- The 2 is a random arrival factor.

This formula provides a good estimate of queue lengths, where the volume to capacity (v/c) ratio for the track approach is less than 0.90. However, for v/c ratios greater than 0.90, some overflow queues could occur as a result of fluctuations in arrival rates. To compensate for this condition, it is suggested that one vehicle should be added for each percent increase in the v/c ratio over 0.90. Accordingly, in cases where the v/c ratio ranges from 0.90 to 1.00, the following formula applies:

\[ L = (2qr+x)(1+p)v \]

Where \( x = 100(v/c \text{ ratio} - 0.90) \). Thus, for a v/c ratio 0.95, \( x \) would be 5 vehicles in the above formula. This formula cannot be used if the v/c ratio greater than or equal to 1.0, then a field queue study will be needed in that case.

Queue lengths for through traffic and for left turns should both be checked to determine which queue is the most critical.
Guidelines for Design
When the determination has been made to preempt the traffic signal for a train, many items need to be considered. Some are listed here: distance between the traffic signal and the grade crossing, intersection geometry, track orientation, approach speed of train, train frequency, volume of vehicular traffic, vehicle type, pedestrian, and equipment at the intersection and grade crossing.

Short distances: Where the clear storage distance between the tracks and the highway intersection stop line is not sufficient to safely store a design vehicle like the longest, legal truck combination, or if vehicles regularly queue across the tracks, a pre-signal should be considered. An engineering study should be performed to support this recommendation. A pre-signal may also be beneficial if gates are not provided. This supplemental traffic signal should be carefully designed to avoid trapping vehicles on the tracks. Visibility-limited traffic signals at the intersection may be needed to avoid driver conflict and confusion. The "DO NOT STOP ON TRACKS" sign (R8-8) and "STOP HERE ON RED" sign (R10-6) of the MMUTCD should also be used. Certain situations where gates are not present may also require prohibiting turns on red.

Guidelines for Operation
The MMUTCD (Section 8C-6) requires that "The preemption sequence initiated when the train first enters the approach circuit, shall at once bring into effect a highway signal display which will permit traffic to clear the tracks before the train reaches the crossing. The preemption shall not cause any short vehicular clearances and all necessary vehicular clearances shall be provided. However, because of the relative hazards involved, pedestrian clearances may be abbreviated in order to provide the track clearance display as early as possible. After the track clearance phase, the highway intersection traffic control signals shall be operated to permit vehicle movements that do not cross the tracks, but shall not provide a through circular green or arrow indication for movements over the tracks".

If the traffic signal is equipped with emergency vehicle preemption, the confirmation lights shall flash for all approaches during the preempt sequence.

Traffic Signal Timing

Maximum Preemption Time
The Maximum Preemption Time is the amount of time needed following initiation of the preemption sequence for the highway traffic signals to complete the entire sequence to clear the crossing within the minimum track clearance distance, of any vehicles prior to the arrival of the train at the crossing. This is the total of the Right-of-Way Transfer Time, Track Clearance Phase Time and Separation Time. A tabulation of the calculation appears below.

Right-Of-Way Transfer Time
| Equipment Response | ___ seconds |
| Pedestrian Clearance Time | ___ seconds |
| Minimum Green on Conflicting Phase | ___ seconds |
| Leading Flash Time of AWF (if present) | ___ seconds |
| Critical Phase Movement (Longer of Pedestrian Clearance or Min Green or Leading Flash Time of AWF) | ___ seconds |
Yellow Change Interval*  ___ seconds
Red Clearance*     ___ seconds
Right-of-Way Transfer Time (Subtotal)
*if not included in the Pedestrian Clearance Time ___ seconds

Track Clearance Phase Time
Dissipation of queued vehicles, per lane ___ seconds
Queue Clearance Time ___ seconds

Track Clearance Phase Time (Dissipation or Clearance Time) ___ seconds

Separation Time (typically 4-8 seconds) ___ seconds

Maximum Preemption Time
(Sum of the Right-of-Way Transfer Time, Track Clearance Phase Time and Separation Time) ___ seconds

Railroad Timing
Railroad timing has to make sure that the Railroad Warning Time must be greater than or at least equal to the Maximum Preemption Time of traffic signal. At some locations, the Railroad Warning Time, the Train Detection Interval, and the Flasher Interval may all be the same.

Guidelines for Inspection
Existing highway/railroad preempted traffic signals shall be inspected on an annual basis. It is the responsibility of the roadway authority that has responsibility for the operation of the traffic signal to initiate the annual inspection. A copy of the completed inspection forms shall be forwarded to the Office of Freight, Railroads & Waterways on an annual basis.

The District Traffic Engineer will ensure that each location under Mn/DOT jurisdiction is inspected. Through the State Aid program, cities and counties are required to perform annual inspections.

The rail authority shall be contacted prior to inspection and a representative shall be present during each inspection. This joint inspection is critical, as the operation of railroad preemption systems is dependent on both the railroad and highway agencies.

The inspection should be done while a train passes through the area if possible.

During this inspection, a general review of the highway intersection and railroad crossing for proper signing, pavement markings, signals, sight distances, and changes in conditions should be made.

It is also advised that all traffic signals without railroad preemption need to be reviewed when traffic patterns change, see if additional traffic control/RR preemption is needed.

For information on the contents of this Technical Memorandum contact, Dayue Zhang, Assistant Traffic Signal Engineer at 651-284-3436.

Any questions regarding the publication or distribution of Technical Memorandums
should be referred to Amr Jabr, Design Standards Engineer at 651-296-4859 or Susan Berndt, Design Services Secretary at 651-296-2381.

Attachments

Highway/Railroad Interconnected Signals (Word doc) - Inspection Form (two sides).
Highway/Railroad Interconnected Signals (PDF, 189 KB) - Filled out Inspection Form Example (two sides).

GLOSSARY

Active Warning System for a Railroad Grade Crossing (Active Warning Devices) - the railroad flashing light signals with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at highway-railroad grade crossings.

Advance Preemption - notification of an approaching train is forwarded to the traffic signal controller unit by the railroad equipment for a period of time prior to the activation of railroad active warning devices.

Advanced Warning Flasher (AWF) - an advanced warning device located on main street approaches to a high speed signalized intersection, which can provide advanced warning to the motorists on the main street that the traffic signal system will be turning yellow during their approach.

Clear Storage Distance - The distance available for vehicle storage measured between 6 feet (2 meters) from the rail nearest the intersection to the intersection STOP BAR or the normal stopping point on the highway. At skewed crossings and intersections, the 6 feet (2 meters) distance will be measured perpendicular to the nearest rail either along the centerline, or edge line of the highway as appropriate to obtain the shorter clear distance.

Clear Track Green Interval - the time assigned to clear stopped vehicles from the track area on the approach to the signalized intersection (Also see Track Clearance Phase Time).

Confirmation Lights - Indicator lights mounted on the mast arms confirm that preemption is in operation, when an authorized emergency vehicle approaching an EVP-equipped signalized intersection enroute and making a call for preemption.

Critical Phase Movement - The longest of either the Pedestrian Clearance Interval, the Minimum Green Interval, or Leading Flash Time of AWF (if present).

Design Vehicle - the longest vehicle permitted by the road authority on a roadway.

Dissipation of Queued Vehicles, per lane - This is the time needed to allow all vehicles stored between the rail crossing stop line and the signalized intersection to move forward and clear the intersection. This should be used when the railroad tracks are close to the roadway. The time to clear a queue of passenger cars can be estimated by the following
formula: \( t = 4 + 2n \); where \( t \) is the time to clear the queue in seconds, \( n \) is the number of vehicles in the queue per lane. This formula assumes that all the queued vehicles can accelerate at, or close to, the rate of passenger vehicles.

**Emergency Vehicle Preemption (EVP)** - A system installed on authorized emergency vehicles and at traffic signals which allows the authorized emergency vehicles to travel through signalized intersections in a safe and timely manner. A typical system works as follows: An authorized emergency vehicle approaching a signalized intersection enroute to a call has an activated emitter (a strobe light oscillating at a specified frequency). The oscillations are detected by an EVP detector mounted on the signal mast arm. The signal controller terminates any conflicting phases to bring up the through phase for the authorized emergency vehicle. Indicator lights mounted on the mast arms indicate that preemption is in operation. An optional system can respond to vehicle sirens, using the siren as the emitter and a microphone array as the detector. This system is allowable when requested by local agencies, but only outside of the eight-county metro area. This system must be specified in the project plans and specifications, and must be pre-approved by Mn/DOT.

**Equipment Response** - The time for a traffic signal controller to respond. Less than a second for most traffic signal controllers. Check controller manufacturers.

**Flashers Interval** - Interval from the time the railroad flashers begin flashing to the time the train arrives at the crossing. This time must be equal to or greater than the minimum 20 seconds required by the MMUTCD. The MMUTCD states that, circuits controlling automatic flashing light signals shall provide for a minimum operation of 20 seconds before the arrival of any train on such track.

**Flashing Light Signal** - the signal at rail crossing display toward approaching highway traffic the aspect of two red lights in a horizontal line flashing alternately when indicating the approach or presence of a train.

**Interconnection** - in the context of this document, the electrical connection between the railroad active warning system and the traffic signal controller assembly for the purpose of preemption. **Interval** - a portion of a signal cycle during which signal indications do not change.

**Leading Flash Time of AWF** - the amount of time the Advanced Warning Flasher is operating prior to the yellow phase.

**Light Rail Transit (LRT)** - a type of electric transit railway with a "light volume" traffic capacity compared with "heavy rail." Light rail may be on exclusive, semi-exclusive or nonexclusive right-of-way, high or low platform loading, multi-car trains, single cars, automated or manually operated.

**Maximum Preemption Time** - The maximum amount of time needed following initiation of the preemption sequence for the traffic signals to complete the entire sequence and clear the minimum track clearance distance of any vehicles prior to the arrival of the train at the crossing. This is the total of Right-of-Way Transfer Time, Track Clearance Phase Time, and Separation Time. This time should equal to or greater than the Railroad Warning Time.
Minimum Green - The shortest green time allowed a phase.

Minimum Green on Conflicting Phase - The longest Minimum Green on a non-clear track phase. On many traffic signal controllers the minimum green can be shortened during preemption. A Minimum Green of less than 10 seconds should not be used on high speed approaches.

Minimum Track Clearance Distance - For standard two quadrant railroad warning devices, the minimum track clearance distance is the length along a highway at one or more railroad tracks, measured either from the railroad stop line, warning device, or 12 feet (4 meters) perpendicular to the track centerline, to 6 feet (2 meters) beyond the track(s) measured perpendicular to the far rail, along the centerline or edge line of the highway, as appropriate, to obtain the longer distance.

Pedestrian Clearance Time - the time interval provided for a pedestrian crossing in a crosswalk, after leaving the curb or shoulder, to travel to the far side of the farthest traveled lane or to a median of sufficient width for pedestrians to wait. The longest pedestrian clearance interval on the non-track clear phase should be used. Some signal controllers include the WALK as part of the preemption, check with signal controller manufacturer. The MMUTCD allows the Pedestrian Clearance to be shortened during preemption if needed. This should be considered a temporary action. If decreasing the pedestrian clearance is required, the roadway agency must work with the railroad company to increase the time to provide the proper pedestrian safety.

Preemption - the transfer of normal operation of signals to a special control mode. Signals are commonly preempted by trains or by emergency vehicles.

Pre-Signal - Supplemental highway traffic signal faces operated as part of the highway intersection traffic signals, located in a position to control traffic approaching the railroad crossing and intersection. The signal faces control vehicles in advance of the railroad tracks and their operation shall be integrated into the railroad preemption program. The signal faces may be located on either the near or far side of the railroad tracks, including mounting on the same cantilever signal structure(s) as the railroad active warning devices.

Priority Control - a means by which the right-of-way is obtained or modified.

Queue Clearance Time - the time required for the design vehicle stopped with its nose at the start of the minimum track clearance distance to start up and move far enough to clear its tail end from the minimum track clearance distance. If pre-signals are present, this time should be long enough to allow the vehicle to move through the intersection, or clear the tracks if there is sufficient clear storage distance. If the crossing is a significant distance from the intersection it may not be necessary to clear all of the vehicles through the intersection. The time interval necessary to allow a vehicle to move from the track area to a safe location can be determined by summing the values of the following: the time needed for the vehicle ahead to begin to move out of the way \( t_1 \) and the time needed for a design vehicle in a standing queue to accelerate and move off the tracks \( t_2 \).

The time before a vehicle ahead begins to move can be estimated by:
\[ t_1 = 2 + 1.4n \]

where \( t_1 \) is the time (in seconds) it takes for the vehicle to begin moving and \( n \) is the number of vehicles queued ahead of the critical vehicle \( (n = \text{distance/20 feet}) \).

The time a design vehicle takes to transverse the tracks:

\[ t_2 = \sqrt{\frac{2(L + D)}{a}} \]

where \( t_2 \) = time (seconds) required for the design vehicle to accelerate to a position of safety once the queue in front of it has begun to move;

\[ L = \text{length of the design vehicle (feet)}; \]
\[ D = \text{minimum track clearance distance (feet)}; \]
\[ a = \text{acceleration of the passenger design vehicle. (passenger design vehicle, 4.4 ft/sec}^2; \]
\[ \text{SU (Single Unit Truck) design vehicle, 2.5 ft/sec}^2; \]
\[ \text{MU (Multiple Unit Truck) design vehicle, 1.6 ft/sec}^2; \]

**Railroad Warning Time** - Interval from the time the traffic signal controller is notified that a train is approaching to the time the train arrives at the crossing. This interval must be greater than or equal to the time required by the Maximum Preemption Time.

**Red Clearance** - The longest red clearance interval on a non-clear track phase.

**Right-of-Way Transfer Time** - the sum of the Equipment Response time, Critical Phase Movement time, the Yellow Change Interval, and the Red Clearance Interval, if these last two are not included in the Pedestrian Clearance Time. This is the worst case time required before the controller can begin servicing the track clear phase.

**Separation Time** - The time during which the minimum track clearance is clear of vehicular traffic prior to the arrival of the train, typically 4 - 8 seconds. The Separation Time is particularly important when:

1. The railroad tracks are relatively far from the intersection (a long queue needs to be cleared).
2. High train speeds.
3. High percentage of trucks and buses in traffic.

**Train Detection Interval** - Interval from the time the train is first detected to the time the train arrives at the crossing. This time must be equal to or greater than the time required by the Maximum Preemption Time. Depending on the type of train detection being used the railroad flashers may not begin flashing when the train is detected.

**Track Clearance Phase Time** - Either the Dissipation of Queued Vehicles per lane or Queue Clearance Time. If the railroad crossing is a significant distance from the
intersection, it may not be necessary to clear all of the vehicles through the intersection, and Queue Clearance Time will be used.

**Yellow Change Interval** - The longest yellow change interval on a non-clear track phase.
# Texas Department of Transportation

**GUIDE FOR DETERMINING TIME REQUIREMENTS FOR TRAFFIC SIGNAL PREEMPTION AT HIGHWAY-RAIL GRADE CROSSINGS**

<table>
<thead>
<tr>
<th>City</th>
<th>District</th>
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<tbody>
<tr>
<td>County</td>
<td>Completed by</td>
</tr>
<tr>
<td>District</td>
<td>District Approval</td>
</tr>
<tr>
<td>Show North Arrow</td>
<td>Parallel Street Name</td>
</tr>
<tr>
<td>Traffic Signal</td>
<td>Crossing Street Name</td>
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<tr>
<td>Railroad</td>
<td>Railroad Contact</td>
</tr>
<tr>
<td>Crossing DOT#</td>
<td>Phone</td>
</tr>
</tbody>
</table>

## SECTION 1: RIGHT-OF-WAY TRANSFER TIME CALCULATION

### Preempt verification and response time

1. Preempt delay time (seconds) .................................................. 1. 
2. Controller response time to preempt (seconds) ......................... 2. 
3. Preempt verification and response time (seconds), add lines 1 and 2 3. 

#### Remarks

**Controller type:**

### Worst-case conflicting vehicle time

5. Minimum green time during right-of-way transfer (seconds) ........ 5. 
6. Other green time during right-of-way transfer (seconds) .............. 6. 
7. Yellow change time (seconds) ............................................... 7. 
8. Red clearance time (seconds) .............................................. 8. 

#### Remarks

### Worst-case conflicting pedestrian time

9. Worst-case conflicting pedestrian time (seconds); add lines 5 through 8 9. 
11. Minimum walk time during right-of-way transfer (seconds) ........ 11. 
12. Pedestrian clearance time during right-of-way transfer (seconds) 12. 
13. Vehicle yellow change time, if not included on line 12 (seconds) 13. 
14. Vehicle red clearance time, if not included on line 12 (seconds) 14. 

#### Remarks

### Worst-case conflicting vehicle or pedestrian time

15. Worst-case conflicting pedestrian time (seconds); add lines 11 through 14 15. 
16. Worst-case conflicting vehicle or pedestrian time (seconds); maximum of lines 9 and 15 16. 

#### Remarks

17. Right-of-way transfer time (seconds); add lines 3 and 16 .............. 17.
SECTION 2: QUEUE CLEARANCE TIME CALCULATION

18. Clear storage distance (CSD, feet) ........................................... 18.  
20. Design vehicle length (DVL, feet) ........................................... 20.  

Remarks

22. Time required for design vehicle to start moving (seconds): calculate as \(2 + (L - 20)\) .......... 22.  
24. Time for design vehicle to accelerate through the DVCD (seconds) .......... 24.  

Read from Figure 2 in Instructions.


SECTION 3: MAXIMUM PREEMPTION TIME CALCULATION

27. Queue clearance time (seconds): line 25 ................................ 27.  

Remarks


SECTION 4: SUFFICIENT WARNING TIME CHECK

30. Required minimum time, MT (seconds): per regulations ............. 30.  

Remarks

32. Minimum warning time, MWT (seconds): add lines 30 and 31 ............ 32.  
33. Advance preemption time, APT, if provided (seconds): get from railroad ... 33.  
34. Warning time provided by the railroad (seconds): add lines 32 and 33 .......... 34.  

35. Additional warning time required from railroad (seconds): subtract line 34 from line 29, round up to nearest full second, enter 0 if less than 0 .................. 35.  

If the additional warning time required (line 35) is greater than zero, additional warning time has to be requested from the railroad. Alternatively, the maximum preemption time (line 29) may be decreased after performing an engineering study to investigate the possibility of reducing the values on lines 1, 5, 6, 7, 8, 11, 12, 13 and 14.

Remarks:


SECTION 5: TRACK CLEARANCE GREEN TIME CALCULATION (OPTIONAL)

Preempt Trap Check

36. Advance preemption time (APT) provided (seconds): .......... 36. 
37. Multiplier for maximum APT due to train handling .......... 37. 
39. Minimum duration for the track clearance green interval (seconds) .......... 39. 15.0 Remarks
For zero advance preemption time
41. Preempt verification and response time (seconds): line 3 .......... 41. Remarks
42. Best-case conflicting vehicle or pedestrian time (seconds): usually 0 .......... 42. 
43. Minimum right-of-way transfer time (seconds): add lines 41 and 42 .......... 43. 
44. Minimum track clearance green time (seconds): subtract line 43 from line 40 .......... 44. 

Clearing of Clear Storage Distance

45. Time required for design vehicle to start moving (seconds), line 22 .......... 45. 
46. Design vehicle clearance distance (DVCD, feet), line 23 .......... 46. Remarks
47. Portion of CSD to clear during track clearance phase (feet) .......... 47. CSD* in Figure 3 in Instructions
49. Time required for design vehicle to accelerate through DVRD (seconds) .......... 49. Read from Figure 2 in Instructions.
50. Time to clear portion of clear storage distance (seconds): add lines 45 and 49 .......... 50. 
51. Track clearance green interval (seconds): maximum of lines 44 and 50, round up to nearest full second .......... 51. 

SECTION 6: VEHICLE-GATE INTERACTION CHECK (OPTIONAL)

52. Right-of-way transfer time (seconds): line 17 .......... 52. 
53. Time required for design vehicle to start moving (seconds), line 22 .......... 53. Read from Table 3 in Instructions.
54. Time required for design vehicle to accelerate through DVL (on line 20, seconds) .......... 54. 
55. Time required for design vehicle to clear descending gate (seconds): add lines 52 though 54 .......... 55. Remarks
56. Duration of flashing lights before gate descent start (seconds): get from railroad .......... 56. Remarks
57. Full gate descent time (seconds): get from railroad .......... 57. 
58. Proportion of non-interaction gate descent time .......... 58. Read from Figure 5 in Instructions.
60. Time available for design vehicle to clear descending gate (seconds): add lines 56 and 59 .......... 60. 
61. Advance preemption time (APT) required to avoid design vehicle-gate interaction (seconds):
subtract line 60 from line 55, round up to nearest full second, enter 0 if less than 0 .......... 61.
INSTRUCTIONS
for the
Texas Department of Transportation
GUIDE FOR DETERMINING TIME REQUIREMENTS FOR
TRAFFIC SIGNAL PREEMPTION AT HIGHWAY-RAIL GRADE CROSSINGS

USING THESE INSTRUCTIONS

The purpose of these instructions is to assist TxDOT personnel in completing the 2003 Guide For Determining Time Requirements For Traffic Signal Preemption At Highway-Rail Grade Crossings, also known as the Preemption Worksheet. The main purpose of the Preemption Worksheet is to determine if additional time (advance preemption) is required for the traffic signal to move stationary vehicles out of the crossing before the arrival of the train.

If you have any questions about completing the Preemption Worksheet, please contact the Mr. David Valdez in the Traffic Operations Division at telephone 512-416-2642 or email DVALDEZ@dot.state.tx.us. For any feedback on the Draft version of the Worksheet or Instructions, please contact Mr. Roelof Engelbrecht from the Texas Transportation Institute at 979-862-3559 or roelof@tamu.edu.

SITE DESCRIPTIVE INFORMATION:

Enter the location for the highway-rail grade crossing including the (nearest) City, the County in which the crossing is located, and the Texas Department of Transportation (TxDOT) District name. When entering the District name, do not use the dated district numbering schema; use the actual district name.

Next, enter the Date the analysis was performed, your (the analyst's) name next to "Completed by," and the status of the District Approval for this crossing.

To complete the reference schematic for this site, place a North Arrow in the provided circle to correctly orient the crossing and roadway. Record the name of the Parallel Street and the Crossing Street in the spaces provided, and remember to include any "street sign/local name for the streets as well as any state/US/Interstate designation (i.e., "FM 1826," "SH 71," "US 290," "Interstate 35 [frontage]"). You may wish to note other details on the intersection/crossing diagram as well, including the number of lanes and/or turn bays on the intersection approach crossing the tracks and any adjacent land use.

Enter the Railroad name, Railroad Contact person's name, and Phone number for the responsible railroad company and its equipment maintenance and operations contractor (if any). Finally, record the unique 7-character Crossing DOT# (6 numeric plus one alphanumeric characters) for the crossing.

Note that this guide for determining (warning) time requirements for traffic signal preemption requires you to input many controller unit timing/phasing values. To preserve the accuracy of these values, record all values to the next highest tenth of a second (i.e., record 5.42 seconds as 5.5 seconds).

SECTION 1: RIGHT-OF-WAY TRANSFER TIME CALCULATION

Preempt Verification and Response Time

Line 1. The preempt delay time is the amount of time, in seconds, that the traffic signal controller is programmed to wait from the initial receipt of a preempt call until the call is "verified" and considered a viable request for transfer into preemption mode. Preempt delay time is a value entered into the controller unit for purposes of preempt call validation, and may not be available on all manufacturer's controllers.
Line 2. Unlike preempt delay time (Line 1), which is a value entered into the controller, **controller response time to preempt** is the time that elapses while the controller unit electronically registers the preempt call (i.e., it is the controller’s equipment response time for the preempt call). The controller manufacturer should be consulted to find the correct value (in seconds) for use here. For future reference, you may wish to record the controller type in the **Remarks** section to the right of the controller response time to preempt value. However, note that the manufacturer’s given response time may be unique for a controller unit’s model and software generation; other models and/or software generations may have different response times.

Line 3. The sum of Line 1 and Line 2 is the **preempt verification and response time**, in seconds. It represents the number of seconds between the receipt at the controller unit of a preempt call issued by the railroad’s grade crossing warning equipment and the time the controller software actually begins to respond to the preempt call (i.e., by transitioning into preemption mode).

**Worst-Case Conflicting Vehicle Time**

Line 4. **Worst-case conflicting vehicle phase number** is the number of the controller unit phase which conflicts with the phase(s) used to clear the tracks—the track clearance phase(s)—that has the longest sum of minimum green (if provided), other (additional) green time (if provided), yellow change interval, and red clearance interval durations that may need to be serviced during the transition into preemption. Note that all of these time elements are for vehicular phases only; pedestrian phase times will be assessed in the next part of the analysis. The worst-case vehicle phase can be any phase that conflicts with the track clearance phase(s); it is not restricted to only the phases serving traffic parallel to the tracks.

Line 5. **Minimum green time during right-of-way transfer** is the number of seconds that the worst-case vehicle phase (see Line 4 discussion) must display a green indication before the controller unit will terminate the phase through its yellow change and red clearance intervals and transition to the track clearance green interval. The minimum green time during right-of-way transfer may be set to zero to allow as rapid a transition as possible to the track clearance green interval. However, local policies will govern the amount of minimum green time provided during the transition into preemption.

Line 6. If any additional green time is preserved beyond the preempt minimum green time for the worst-case vehicle phase (line 4), it should be entered here as **Other green time during right-of-way transfer**. Given the time-critical nature of the transition to the track clearance green interval during preempted operation, this value is usually zero except in unusual circumstances. One situation where other green time may be present is when a trailing green overlap is used on the worst-case vehicle phase, and the controller unit is set up to time out the trailing green overlap on entry into preemption.

Line 7. **Yellow change time** is the required yellow change interval time for the worst-case vehicle phase (line 4) given prevailing operating conditions. Yellow change time for the phase under preemption is usually the same value, in seconds, programmed for the phase under normal operating circumstances. Section 4D.13 of the Texas Manual on Uniform Traffic Control Devices (MUTCD) states that the normal yellow change interval shall not be shortened or omitted during the transition into preemption control. Guidance on setting the yellow change interval can be found in the Institute of Transportation Engineer’s Determining Vehicle Signal Change and Clearance Intervals.

Line 8. **Red clearance time** is the required red clearance interval for the worst-case vehicle phase (line 4) given prevailing operating conditions. Red clearance time for the phase under preemption is usually the same value, in seconds, programmed for the phase under normal operating circumstances. Section 4D.13 of the Texas MUTCD states that the normal red clearance interval shall not be shortened or omitted during the transition into preemption control. Guidance on setting the red clearance interval can be found in the Institute of Transportation Engineer’s Determining Vehicle Signal Change and Clearance Intervals.
Line 9. **Worst-case conflicting vehicle time** is the sum of lines 5 through 8. It will be compared with the worst-case conflicting pedestrian time to determine whether vehicle or pedestrian phase times are the most critical in their impact on warning time requirements during the transition to the track clearance green interval.

**Worst-case Conflicting Pedestrian Time**

**Line 10. Worst-case pedestrian phase number** is the pedestrian phase number (referenced as the vehicle phase number that the pedestrian phase is associated with) that has the longest sum of walk time, pedestrian clearance (i.e., flashing don't walk) times, and associated vehicle clearance times that have to be provided during the transition into preemption. The worst-case pedestrian phase is not restricted to pedestrian phases running concurrently with vehicle phases that serve traffic parallel to the tracks. The vehicle phase associated with the worst-case pedestrian phase may even be one of the track clearance phases if the pedestrian phase is not serviced concurrently with the associated track clearance phase.

**Line 11. Minimum walk time during right-of-way transfer** (seconds) is the minimum pedestrian walk time for the worst-case pedestrian phase (line 10). The Texas MUTCD permits the shortening (i.e., truncation) or complete omission of the pedestrian walk interval. A zero value allows for the most rapid transition to the track clearance green interval. However, the minimum pedestrian walk time is typically set based on local policies, which may or may not allow truncation and/or omission.

**Line 12. Pedestrian clearance time during right-of-way transfer** (seconds) is the clearance (i.e., flashing don't walk) time for the worst-case pedestrian phase. The Texas MUTCD permits the shortening (i.e., truncation) or complete omission of the pedestrian clearance interval. A zero value allows for the most rapid transition to the track clearance green interval. However, the pedestrian clearance time is typically set based on local policies, which may or may not allow truncation and/or omission.

**Line 13.** Enter a **Yellow change time** if the pedestrian clearance interval does not time simultaneously with the yellow change interval of the vehicular phase associated with your worst-case pedestrian phase; enter zero if does. Local policies will determine if this is allowed. Simultaneous timing of the pedestrian clearance interval and the yellow change interval (i.e., a zero value on line 13) allows for the most rapid transition to the track clearance green interval. If a non-zero value is entered, make sure to enter the yellow change time of the vehicular phase associated with your worst-case pedestrian phase. This value may not be the same value you enter on Line 7, since the worst-case pedestrian phase may not be the same as the worst-case vehicular phase.

**Line 14.** Enter a **Red clearance time** if the pedestrian clearance interval does not time simultaneously with the red clearance interval of the vehicular phase associated with your worst-case pedestrian phase; enter zero if does. Local policies will determine if this is allowed. Also, note that not all traffic signal controllers allow simultaneous timing of the pedestrian clearance interval and the red clearance interval. Simultaneous timing of the pedestrian clearance interval and the red clearance interval (i.e., a zero value on line 14) allows for the most rapid transition to the track clearance green interval. If a non-zero value is entered, make sure to enter the red clearance time of the vehicular phase associated with your worst-case pedestrian phase. This value may not be the same value you enter on Line 8, since the worst-case pedestrian phase may not be the same as the worst-case vehicular phase.

**Line 15.** Add lines 11 through 14 to calculate your **Worst-case conflicting pedestrian time**. This value will be compared to the worst-case conflicting vehicle time to determine whether vehicle or pedestrian phase times are the most critical in their impact on warning time requirements during the transition to the track clearance green interval.

**Worst-case Conflicting Vehicle or Pedestrian Time**

**Line 16.** Record the **Worst-case conflicting vehicle or pedestrian time** (in seconds) by comparing lines 9 and 15 and writing the larger of the two as the entry for line 16.
Line 17. Calculate the **Right-of-way transfer time** by adding lines 3 and 16. The right-of-way transfer time is the maximum amount of time needed for the worst case condition, prior to display of the track clearance green interval.

![Diagram of queue clearance distances]

**Figure 1** Queue clearance distances.

**SECTION 2: QUEUE CLEARANCE TIME CALCULATION**

**Line 18.** Record the **Clear storage distance** (CSD in Figure 1), in feet, as the shortest distance along the crossing street between the edge of the grade crossing nearest the signalized intersection—identified by a line parallel to the rail 6 feet (2 m) from the rail nearest to the intersection—and the edge of the street or shoulder of street that parallels the tracks. If the normal stopping point on the crossing street is significant different from the edge or shoulder of parallel street, measure the distance to the normal stopping point. For angled (i.e., non-perpendicular) railroad crossings, always measure the distance along the inside (centerline) edge of the leftmost lane or the distance along the outside (shoulder) edge of the rightmost lane, as appropriate, to determine the shortest clear storage distance and record that value.

**Line 19.** **Minimum track clearance distance** (MTCD in Figure 1), in feet, is the length along the highway at one or more railroad tracks, measured from the railroad crossing stop line, warning device, or 12 feet (4 m) perpendicular to the track centerline—whichever is further away from the tracks, to 6 feet (2 m) beyond the tracks measured perpendicular to the rail. For angled (i.e., non-perpendicular) railroad crossings, always measure the distance along the inside (centerline) edge of the leftmost lane or the distance along the outside (shoulder) edge of the rightmost lane, as appropriate, to determine the longest minimum track clearance distance and record that value.

**Line 20.** **Design vehicle length** (DVL in Figure 1), in feet, is the length of the design vehicle, the longest vehicle permitted by road authority statute on the subject roadway. In the **Remarks** section to the right of the data entry box for Line 20, note the design vehicle type for ease of reference. Some design vehicles from the AASHTO Green Book (A Policy on Geometric Design of Highways and Streets) are given in Table 1. Note that Texas legal size and weight limits for non-permit vehicles allow a maximum semitrailer length of 59 feet, resulting in a design vehicle length of 79.5 feet when combined with a conventional long-haul tractor.

<table>
<thead>
<tr>
<th>Design Vehicle Type</th>
<th>Symbol</th>
<th>Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>P</td>
<td>19</td>
</tr>
<tr>
<td>Single Unit Truck</td>
<td>SU</td>
<td>30</td>
</tr>
<tr>
<td>Large School Bus</td>
<td>S-BUS 40</td>
<td>40</td>
</tr>
<tr>
<td>Intermediate Semi-Trailer</td>
<td>WB-50</td>
<td>55</td>
</tr>
</tbody>
</table>

*Table 1. AASHTO Design vehicle lengths and heights.*
Line 21. **Queue start-up distance** (L in Figure 1), in feet, is the maximum length over which a queue of vehicles stopped for a red signal indication at an intersection downstream of the crossing must get in motion so that the design vehicle can move out of the railroad crossing prior to the train’s arrival. Queue start-up distance is the sum of the clear storage distance (Line 18) and minimum track clearance distance (Line 19).

Line 22. **Time required for the design vehicle to start moving** (seconds) is the time elapsed between the start of the track clearance green interval and the time the design vehicle, which is located at the edge of the railroad crossing on the opposite side from the signalized intersection, begins to move. This elapsed time is based on a “shock wave” speed of 20 feet per second and a 2 second start-up time (the additional time for the first driver to recognize the signal is green and move his/her foot from the brake to the accelerator). The time required for the design vehicle to start moving is calculated, in seconds, as 2 plus the queue start-up distance, L (Line 21) divided by the wave speed of 20 feet per second. The time required for the design vehicle to start moving is a conservative value taking into account the worst-case vehicle mix in the queue in front of the design vehicle as well as a limited level of drive inattentiveness. This value may be overridden by local observation, but care must be taken to identify the worst-case (longest) time required for the design vehicle to start moving.

Line 23. **Design vehicle clearance distance** (DVCD in Figure 1) is the length, in feet, which the design vehicle must travel in order to enter and completely pass through the railroad crossing’s minimum track clearance distance (MTCD). It is the sum of the minimum track clearance distance (Line 19) and the design vehicle’s length (Line 20).

Line 24. The **Time for design vehicle to accelerate through the design vehicle clearance distance (DVCD)** is the amount of time required for the design vehicle to accelerate from a stop and travel the complete design vehicle clearance distance. This time value, in seconds, can be found through local observation or by using by Figure 2. If local observation is used, take care to identify the worst-case (longest) time required for the design vehicle to accelerate through the DVCD. If Figure 2 is used to estimate the time for the design vehicle to accelerate through the DVCD, locate the DVCD from Line 23 on the horizontal axis of Figure 2 and then draw a line straight up until that line intersects the acceleration time performance curve for your design vehicle. Then, draw a horizontal line from this point to the left until it intersects the vertical axis, and record the appropriate acceleration time. Round up to the next higher tenth of a second. For example, with a DVCD of 80 feet and a WB-50 semi-trailer design vehicle on a level surface, the time required for the design vehicle to accelerate through the DVCD will be 12.2 seconds.

If your design vehicle is a WB-50 semi-trailer, large school bus (S-BUS 40), or single unit (SU) vehicle, you may need to apply a correction factor to estimate the effect of grade on the acceleration of the vehicle. Determine the average grade over a distance equal to the design vehicle clearance distance (DVCD), centered around the minimum track clearance distance (MTCD). If the grade is 1% uphill (+1%) or greater, multiply the acceleration time obtained from Figure 2 with the factor obtained from Table 2 and round up to the next higher tenth of a second to get an estimate of the acceleration time on the grade. For example, with a DVCD of 80 feet and a WB-50 semi-trailer design vehicle on a 4% uphill, the (interpolated) factor from Table 2 is 1.30. Therefore, the estimated time required for the design vehicle to accelerate through the DVCD will be $12.2 \times 1.30 = 15.86$ seconds, or 15.9 seconds rounded up to the next higher tenth of a second.

If you selected a design vehicle different from those listed in Figure 2 and Table 2, you may still be able to use Figure 2 and Table 2 if you can match your design vehicle to the weight, weight-to-power ratio, and power application characteristics of the design vehicles in Figure 2 and Table 2. The WB-50 curve and grade factors are based on an 80,000 lb vehicle with a weight-to-power ratio of 400 lb/kip accelerating at 85% of its maximum power on level grades and at 100% of its maximum power on uphill grades, and may therefore be representative of any heavy tractor-trailer combination with the same characteristics. The school bus curve and grade factors are based on a 27,000 lb vehicle with a weight-to-power ratio of 160 lb/kip accelerating at 70% of its maximum power on level grades and at 85% of its maximum power on uphill grades. The SU curve and grade factors are based on a 34,000 lb vehicle with a weight-to-power ratio of 200 lb/kip accelerating at 75% of its maximum power on level grades and at 90% of its maximum power on uphill grades.
Figure 2 Acceleration time over a fixed distance on a level surface.

Note
Multiply acceleration time for SU, S-BUS 40, and WB-50 vehicles with factor from Table 2 to account for acceleration taking place on an uphill grade.

Legend
SU = Single Unit Truck
S-BUS 40 = Large school bus
WB-50 = Intermediate Semitrailer
Table 2. Factors to account for slower acceleration on uphill grades. Multiply the appropriate factor (depending on the design vehicle, grade, and acceleration distance) with the acceleration time in Figure 2 to obtain the estimated acceleration time on the grade.

<table>
<thead>
<tr>
<th>Acceleration Distance (ft)</th>
<th>Design Vehicle and Percentage Uphill Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single Unit Truck (SU)</td>
</tr>
<tr>
<td></td>
<td>0-2% 4% 6% 8%</td>
</tr>
<tr>
<td>25</td>
<td>1.00 1.06 1.13 1.19</td>
</tr>
<tr>
<td>50</td>
<td>1.00 1.09 1.17 1.25</td>
</tr>
<tr>
<td>75</td>
<td>1.00 1.10 1.19 1.29</td>
</tr>
<tr>
<td>100</td>
<td>1.00 1.11 1.21 1.32</td>
</tr>
<tr>
<td>125</td>
<td>1.00 1.12 1.23 1.34</td>
</tr>
<tr>
<td>150</td>
<td>1.00 1.12 1.24 1.37</td>
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<tr>
<td>175</td>
<td>1.00 1.13 1.25 1.38</td>
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<td>200</td>
<td>1.00 1.13 1.26 1.40</td>
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<td>225</td>
<td>1.00 1.14 1.27 1.42</td>
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<td>250</td>
<td>1.00 1.14 1.28 1.43</td>
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<td>275</td>
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<td>300</td>
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<tr>
<td>325</td>
<td>1.00 1.15 1.30 1.47</td>
</tr>
<tr>
<td>350</td>
<td>1.00 1.15 1.31 1.48</td>
</tr>
<tr>
<td>375</td>
<td>1.00 1.15 1.31 1.49</td>
</tr>
<tr>
<td>400</td>
<td>1.00 1.15 1.32 1.50</td>
</tr>
</tbody>
</table>

For design vehicle clearance distances greater than 400 feet, use Equation 1 to estimate the time for the design vehicle to accelerate through the design vehicle clearance distance or any other distance:

\[
T = e^{\frac{2}{b} \ln \left( \frac{d}{X} \right)}
\]

where

- \( T \) = time to accelerate through distance \( X \), in seconds;
- \( X \) = distance over which acceleration takes place, in feet;
- \( e \) = 2.17828, the natural logarithm function;
- \( a, b, c, \) and \( d \) = calibration parameters from Table 3.

Note: To interpolate between grades, do not interpolate the parameters in Table 3. The correct way to interpolate is to calculate the acceleration time \( T \) using Equation 1 for the two nearest grades and then interpolate between the two acceleration times.

**Line 25. Queue clearance time** is the total amount of time required (after the signal has turned green for the approach crossing the tracks) to begin moving a queue of vehicles through the queue start-up distance (L, Line 21) and then move the design vehicle from a stopped position at the far side of the crossing completely through the minimum track clearance distance (MTC, Line 19). This value is the sum of the time required for design vehicle to start moving (Line 22) and the time for design vehicle to accelerate through the design vehicle clearance distance (Line 24).
Table 3. Parameters to estimate vehicle acceleration times over distances greater than 400 feet using Equation 1.

<table>
<thead>
<tr>
<th>Design Vehicle</th>
<th>Grade</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Passenger Car</td>
<td>Level</td>
<td>7.75</td>
<td>3.252</td>
<td>5.679</td>
<td>2.153</td>
</tr>
<tr>
<td>Left Turning Passenger Car</td>
<td>Level</td>
<td>10.29</td>
<td>5.832</td>
<td>3.114</td>
<td>5.060</td>
</tr>
<tr>
<td>Single Unit Truck (SU)</td>
<td>Level to 2%</td>
<td>8.16</td>
<td>3.624</td>
<td>5.070</td>
<td>2.018</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>10.39</td>
<td>4.865</td>
<td>4.560</td>
<td>1.739</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>9.52</td>
<td>4.542</td>
<td>4.393</td>
<td>1.700</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>9.38</td>
<td>4.597</td>
<td>4.165</td>
<td>1.668</td>
</tr>
<tr>
<td>Large School Bus (S-BUS 40)</td>
<td>Level to 1%</td>
<td>10.02</td>
<td>4.108</td>
<td>5.95</td>
<td>0.885</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>11.51</td>
<td>5.254</td>
<td>4.801</td>
<td>1.300</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>10.79</td>
<td>5.042</td>
<td>4.577</td>
<td>1.266</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>10.61</td>
<td>5.101</td>
<td>4.329</td>
<td>1.253</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>11.84</td>
<td>6.198</td>
<td>3.652</td>
<td>1.554</td>
</tr>
<tr>
<td>Intermediate Semi-Trailer (WB-50)</td>
<td>Level</td>
<td>17.75</td>
<td>7.984</td>
<td>4.940</td>
<td>0.481</td>
</tr>
<tr>
<td></td>
<td>2%</td>
<td>10.26</td>
<td>4.026</td>
<td>6.500</td>
<td>0.249</td>
</tr>
<tr>
<td></td>
<td>4%</td>
<td>9.39</td>
<td>3.635</td>
<td>6.670</td>
<td>0.193</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>9.38</td>
<td>3.732</td>
<td>6.310</td>
<td>0.188</td>
</tr>
<tr>
<td></td>
<td>8%</td>
<td>10.31</td>
<td>4.515</td>
<td>5.219</td>
<td>0.265</td>
</tr>
</tbody>
</table>

SECTION 3: MAXIMUM PREEMPTION TIME CALCULATION

Line 26. **Right-of-way transfer time**, in seconds, recorded on Line 17. The right-of-way transfer time is the maximum amount of time needed for the worst case condition, prior to display of the track clearance green interval.

Line 27. **Queue clearance time**, in seconds, recorded on Line 25. Queue clearance time starts simultaneously with the track clearance green interval (i.e. after right-of-way transfer), and is the time required for the design vehicle stopped just inside the minimum track clearance distance to start up and move completely out of the minimum track clearance distance.

Line 28. **Desired minimum separation time** is a time “buffer” between the departure of the last vehicle (the design vehicle) from the railroad crossing (as defined by the minimum track clearance distance) and the arrival of the train. Separation time is added for safety reasons and to avoid driver discomfort. If no separation time is provided, a vehicle could potentially leave the crossing at exactly the same time the train arrives, which would certainly lead to severe driver discomfort and potential unsafe behavior. The recommended value of four (4) seconds is a based on the minimum recommended value found in the Institute of Transportation Engineer’s ITE Journal (in an article by Marshall and Berg in February 1997).

Line 29. **Maximum preemption time** is the total amount of time required after the preempt is initiated by the railroad warning equipment to complete right-of-way transfer to the track clearance green interval, initiate the track clearance phase(s), move the design vehicle out of the crossing’s minimum track clearance distance, and provide a separation time “buffer” before the train arrives at the crossing. It is the sum of the right-of-way transfer time (Line 26), the queue clearance time (Line 27), and the desired minimum separation time (Line 28).

SECTION 4: SUFFICIENT WARNING TIME CHECK

Line 30. **Minimum time** (seconds) is the least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossing. Section 8D.06 of the Texas MUTCD requires that flashing-light signals shall operate for at least 20 seconds before the arrival of any train, except on tracks where all trains operate at less than 32 km/h (20 mph) and where flagging is performed by an employee on the ground.
**Line 31. Clearance time** (seconds), typically known as CT, is the additional time that may be provided by the railroad to account for longer crossing time at wide (i.e., multi-track crossings) or skewed-angle crossings. You must obtain the clearance time from the railroad responsible for the railroad crossing. In cases where the minimum track clearance distance (Line 19) exceeds 35 feet, the railroads' AREMA Manual requires clearance time of one second be provided for each additional 10 feet, or portions thereof, over 35 feet. Additional clearance time may also be provided to account for site-specific needs.

Examples of extra clearance time include cases where additional time is provided for simultaneous preemption (where the preemption notification is sent to the signal controller unit simultaneously with the activation of the railroad crossing's active warning devices), instead of providing advance preemption time.

**Line 32. Minimum warning time** (seconds) is the sum of the minimum time (Line 30) and the clearance time (Line 31). This value is the actual minimum time that active warning devices can be expected to operate at the crossing prior to the arrival of the train under normal, through-train conditions. The term “through-train” refers to the case where trains do not stop or start moving while near or at the crossing. Note that the minimum warning time does not include buffer time (BT). Buffer time is added by the railroad to ensure that the minimum warning time is always provided despite inherent variations in warning times; however, it is not consistently provided and cannot be relied upon by the traffic engineer for signal preemption and/or warning time calculations.

**Line 33. Advance preemption time** (seconds), if provided, is the period of time that the notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly prior to activating the railroad active warning devices. Only enter advance preemption time if you can verify from the railroad that advance preemption time is already being provided for your site. If you are determining whether or not you need advance preemption time, enter zero for the advance preemption time in Line 33.

**Line 34. Warning time provided by the railroad** is the sum of the minimum warning time (Line 32) and the advance preemption time (Line 33), in seconds. This value should be verified with the railroad, and should not include buffer time (BT).

**Line 35. Additional warning time required from railroad** is the additional time needed (if any), in seconds, that is required to provide safe preemption in the worst case (the maximum preemption time on Line 29), given the warning time provided by the railroad (Line 34). The additional warning time required is calculated by subtracting the warning time provided by the railroad (Line 34) from the maximum preemption time (Line 29). The result of the subtraction is equal or less than zero, it means that sufficient warning time is available, and you should enter zero (0) on Line 35. However, keep in mind that highly negative (-10 or less) subtraction results may indicate the potential for operational problems due to insufficient track clearance green time. Section 5 of the worksheet contains a methodology for calculating sufficient track clearance green time.

If the additional warning time is greater than zero (0), it means that the warning time provided by the railroad is insufficient, and additional warning time has to be requested from the railroad to ensure safe operation. The railroad can provide additional warning time either by providing additional clearance time (CT) (Line 30), or by providing or increasing advance preemption time (Line 33).

As an alternative, it may be possible to reduce the maximum preemption time (Line 29). To reduce the maximum preemption time, you can reduce either the preempt delay time (Line 1), if this is possible; reduce preempt minimum green time (Line 5) or other green time (Line 6), as long as you do not violate local policies for signal timing; or reduce yellow change time (Line 7) or red clearance time (Line 8) as long as adequate and appropriate yellow change and red clearance intervals are provided as per the Texas MUTCD Section 4D. 10 and applicable guidelines such as the Institute of Transportation Engineers' Determining Vehicle Signal Change and Clearance Intervals.

If pedestrian rather than vehicular phasing controls warning time requirements for preemption, it may be possible to reduce the minimum walk time (Line 11) and/or pedestrian clearance time (Line 12) as long as you do not violate local policies for signal timing. You can also let the pedestrian clearance time (flashing don't walk) time simultaneous with vehicular yellow change and red clearance and so reduce the values on Line 13 (yellow change time) and Line 14 (red clearance time) to zero (0). If local policies do
not currently allow simultaneous clearance for pedestrian and vehicular phasing, you may want to consider allowing this type of operation to reduce your worst-case conflicting pedestrian time.

Once you have made all of the possible adjustments to the warning time, recompute the totals in Lines 3, 9, 15, 16, 17, 26, 29, and 35. If Line 36 remains greater than zero, then you will have to request additional warning time from the railroad, as described above, to ensure safe preemption of the adjacent signalized intersection.

SECTION 5: TRACK CLEARANCE GREEN TIME CALCULATION (OPTIONAL)

Note: This section is optional and is used to calculate the duration of the track clearance green interval. If this worksheet is only used to determine if additional warning time has to be requested from the railroad, this section need not be completed.

The objective of the section is to calculate the duration of the track clearance green interval to ensure safe and efficient operations at the crossing and adjacent traffic signal.

The Preempt Trap Check section (lines 36 to 44) focuses on safety by calculating the minimum duration of the track clearance green interval to ensure that the track clearance green does not terminate before the gates block access to the crossing. If the gates do not block access to the crossing before the expiration of the track clearance green, it is possible that vehicles can continue to cross the tracks and possibly stop on the tracks. However, the track clearance green interval has already expired and there will be no further opportunity to clear. This potentially hazardous condition is called the “preempt trap” and is described in more detail in TxDOT Project Bulletin 1752-9: The Preempt Trap: How to Make Sure You Do Not Have One.

The Clearing of Clear Storage Distance section (lines 45 to 50) focuses on efficiency by calculating duration of the track clearance green interval that is needed to clear the clear storage distance (CSD in Figure 1), or a specific portion thereof.

Preempt Trap Check

Line 36. Advance preemption time provided is the duration (in seconds) the preempt sequence is active in the highway traffic signal controller before the activation of the railroad active warning devices. If Line 35 is zero (i.e. no additional warning time is required from the railroad), the value on Line 33 can be used. In other cases, use the actual value of the advance preemption time (APT) provided by the railroad. If no APT is provided, enter zero on Line 36.

Line 37. Multiplier for maximum APT due to train handling is a value that relates the maximum duration of the advance preemption time (APT) to the minimum value guaranteed by the railroad. Although the railroad guarantees a minimum duration for the APT, it is probable that in most cases the actual duration of the APT will be longer than the guaranteed duration. This variability in APT occurs due to “train handling”, which is a term that describes the acceleration and deceleration of trains on their approach to the crossing. If a train accelerates or decelerates while approaching to the crossing, the railroad warning system cannot estimate the arrival time of the train at the crossing accurately, resulting in variation in the actual duration of APT provided. This variation needs to be taken into account to ensure safe operation.

To make sure that the preempt trap does not occur we need to determine the maximum value of the APT so that a sufficiently long track clearance green interval can be provided to ensure that the gates block access to the crossing before the track clearance green ends. The maximum APT can be estimated by multiplying the advance preemption time provided (and guaranteed) by the railroad (Line 36) with the multiplier for maximum APT due to train handling. This value is only significant if the value for APT on Line 36 is non-zero. If APT is zero, continue to line 38.
In the case where APT is provided, the difference between the minimum and maximum values of APT is termed excess APT. Excess APT usually occurs when the train decelerates on the approach to the crossing, or where train handling affects the accuracy of the estimated time of train arrival at the crossing so that the preempt sequence is activated earlier than expected. The amount of excess APT is increased by the following conditions:

- Increased variation in train speeds, since more trains will be speeding up and slowing down;
- Lower train speeds, since a fixed deceleration rate has a greater effect on travel time at low speeds than at higher speeds; and
- Longer warning times, because more time is available for the train to decelerate on the approach to the crossing.

The multiplier for maximum APT can be determined from field measurements as the largest advance preemption time observed (or the 95th percentile, if enough observations are available) divided by the value on Line 36. If no field observations are available, the multiplier for maximum APT can be estimated as 1.60 if warning time variability is high or 1.25 if warning time variability is low. High warning time variability can typically be expected in the vicinity of switching yards, branch lines, or anywhere low-speed switching maneuvers takes place. According to Section 16.30.10 of the AREMA Signal Manual the railroad can provide a “timer for constant time between APT and CWT.” The effect of such a “not to exceed” timer is to eliminate excess APT, and if provided, the multiplier on Line 37 can be set to 1.0.

**Line 38. Maximum APT** is largest value (in seconds) of the advance preemption time that can typically be expected, which corresponds to the earliest possible time the preemption sequence in the traffic signal controller will be activated before the activation of the railroad grade crossing warning system (flashing lights and gates). It is the calculated by multiplying the APT provided by the railroad (Line 36) with the multiplier for maximum APT due to train handling (Line 37).

**Line 39. Minimum duration for the track clearance green** is the minimum duration (in seconds) of the track clearance green interval to ensure that the gates block access to the crossing before the track clearance green expires in the case where no advance preemption time is provided. It is necessary to block access to the crossing before the track clearance green expires to ensure that vehicles do not enter the crossing after the expiration of the track clearance green and so be subject to the preempt trap (described in the introduction to Section 5).

The 15 seconds minimum duration for the track clearance green interval is calculated from Federal regulations and requirements of the Texas MUTCD. Section 8D.06 of the Texas MUTCD requires that flashing-light signals shall operate for at least 20 seconds before the arrival of any train (with certain exceptions), while Section 8D.04 requires that the gate arm shall reach its horizontal position at least 5 seconds before the arrival of the train. For simultaneous (non-advance) preemption, the preemption sequence starts at the same time as the flashing-light signals, so to ensure that the preempt trap does not occur, a track clearance green interval of at least 15 seconds is required.

**Line 40. Gates down after start of preemption** is the maximum duration (in seconds) from when the preempt is activated in the highway traffic signal controller until the gates reach a horizontal position. Calculate this value by adding the maximum advance preemption time on Line 38 to the minimum duration for the track clearance green interval on Line 39.

**Line 41. Preempt verification and response time,** recorded on Line 3, is the number of seconds between the receipt at the controller unit of a preempt call issued by the railroad’s grade crossing warning equipment and the time the controller software actually begins to respond to the preempt call.

**Line 42. Best-case conflicting vehicle or pedestrian time** (in seconds) is the minimum time from when the preemption starts to time in the controller (i.e. after verification and response) until the track clearance green interval can start timing. In most cases, this value is zero, since the controller may already be in the track clearance phase(s) when the preemption starts timing, and therefore the track clearance green interval can start timing immediately. The best-case conflicting vehicle or pedestrian time may be greater than zero if the track clearance green interval contains phases that are not in normal operation (and conflicts with the normal phases), or where another phase or interval **always** has to terminate before the track clearance green interval can start timing.
Line 43. **Minimum right-of-way transfer time** is the minimum amount of time needed for the best case condition, prior to display of the track clearance green interval. Calculate the minimum right-of-way transfer time by adding lines 41 and 42.

Line 44. Calculate the **Minimum track clearance green time** by subtracting Line 43 from Line 40. This yields the minimum time that the track clearance green interval has to be active to avoid the preempt trap.

**Clearing of Clear Storage Distance**

![Diagram of clearing of clear storage distance](image)

**Figure 3** Relocation distances during the track clearance green interval.

Line 45. **Time required for design vehicle to start moving**, recorded on Line 22, is the number of seconds that elapses between the start of the track clearance green interval and the time the design vehicle, which is located at the edge of the railroad crossing on the opposite side from the signalized intersection, begins to move.

Line 46. **Design vehicle clearance distance** (DVCD in Figure 3) is the length, in feet, which the design vehicle must travel in order to enter and completely pass through the railroad crossing’s minimum track clearance distance (MTCD). This is the same value as recorded on Line 23.

Line 47. **Portion of CSD to clear during track clearance**, (CSD* in Figure 3) is the portion of the clear storage distance (CSD), in feet, that must be cleared of vehicles before the track clearance green interval ends. For intersections with a CSD greater than approximately 150 feet it is desirable—but not necessary—to clear the full CSD during the track clearance green interval. In other words, it is desirable to set Line 47 to the full value of CSD (Line 18). If the full CSD is not cleared, however, vehicles will be stopped in the CSD during the preempt dwell period, and if not serviced during the preempt dwell period, will be subject to unnecessary delays which may result in unsafe behavior. For CSD values less than 150 feet the full CSD is typically cleared to avoid the driver task of crossing the tracks followed immediately by the decision to stop or go when presented by a yellow signal as the track clearance green interval terminates.

Line 48. **Design vehicle relocation distance** (DVRD in Figure 3) is the distance, in feet, that the design vehicle must accelerate through during the track clearance green interval. It is the sum of the design vehicle clearance distance (Line 46) and the portion of CSD to clear during the track clearance green interval (Line 47).
**Line 49.** The **Time required for design vehicle to accelerate through DVRD** is the amount of time required for the design vehicle to accelerate from a stop and travel the complete design vehicle relocation distance (DVRD). This time value, in seconds, can be found by locating your design vehicle relocation distance from Line 48 on the horizontal axis of Figure 2 and then drawing a line straight up until that line intersects the acceleration time performance curve for your design vehicle. For a WB-50 semi-trailer, large school bus (S-BUS 40), or single unit (SU) vehicle, multiply the acceleration time with a correction factor obtained from Table 2 to estimate the effect of grade on the acceleration of the vehicle. Use the average grade over the design vehicle relocation distance. For design vehicle relocation distances greater than 400 feet, use Equation 1 with the appropriate parameters listed in Table 3.

**Line 50.** **Time to clear portion of clear storage distance**, in seconds, is the total amount of time required (after the signal has turned green for the approach crossing the tracks) to begin moving a queue of vehicles through the queue start-up distance (L in Figure 3) and then move the design vehicle from a stopped position at the far side of the crossing completely through the portion of clear storage distance that must be cleared (CSD* in Figure 3). This value is the sum of the time required for design vehicle to start moving (Line 45) and the time for the design vehicle to accelerate through the design vehicle relocation distance, DVRD (Line 49).

**Line 51.** The **Track clearance green interval** is the time required, in seconds, for the track clearance green interval to avoid the occurrence of the preemption trap and to provide enough time for the design vehicle to clear the portion of the clear storage distance specified on Line 47. The track clearance green interval time is the maximum of the minimum track clearance green time (Line 44) and the time required to clear a portion of clear storage distance (Line 50).

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### SECTION 6: VEHICLE-GATE INTERACTION CHECK (OPTIONAL)

**Note:** This section is optional and is used to calculate the required advance preemption time to avoid the automatic gates descending on a stationary or slow moving design vehicle as it moves through the minimum track clearance distance (MTCD). If this worksheet is only used to determine if additional warning time has to be requested from the railroad to ensure that vehicles have enough time to clear the crossing before the arrival of the train, this section need **not** be completed.

**Line 52.** **Right-of-way transfer time**, in seconds, recorded on Line 17, is the maximum amount of time needed for the worst case condition, prior to display of the track clearance green interval.

**Line 53.** **Time required for design vehicle to start moving**, recorded on Line 22, is the time (in seconds) elapsed between the start of the track clearance green interval and the time the design vehicle, which is located at the edge of the railroad crossing on the opposite side from the signalized intersection, begins to move.

**Line 54.** **Time required for design vehicle to accelerate through the design vehicle length, DVL**, is the time required for the design vehicle to accelerate through its own length. The design vehicle length is recorded on Line 20. This time value, in seconds, can be read from Figure 2 and Table 2 or looked up in Table 4 for standard design vehicles. For a WB-50 semi-trailer, large school bus, or single unit (SU) truck use the average grade over the design vehicle length at the far side of the crossing.

**Line 55.** **Time required for design vehicle to clear the descending gates**, in seconds, is the sum of the right-of-way transfer time on Line 52, the time required for design vehicle to start moving on Line 53, and the time required for design vehicle to accelerate through the design vehicle length on Line 54.

**Line 56.** **Duration of flashing lights before gate descent start**, in seconds, is the time the railroad warning lights flash before the gates start to descend. This value typically ranges from 3 to 5 seconds and must be obtained from the railroad. The value obtained from the railroad may be verified using field observation.
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**Line 55.** Time required for design vehicle to clear the descending gates, in seconds, is the sum of the right-of-way transfer time on Line 52, the time required for design vehicle to start moving on Line 53, and the time required for design vehicle to accelerate through the design vehicle length on Line 54.

**Line 56.** Duration of flashing lights before gate descent start, in seconds, is the time the railroad warning lights flash before the gates start to descend. This value typically ranges from 3 to 5 seconds and must be obtained from the railroad. The value obtained from the railroad may be verified using field observation.

**Line 57.** Full gate descent time, in seconds, is the time it takes for the gates to descend to a horizontal position after they start their descent. This value must be obtained from the railroad and may be verified using field observation. In the case where multiple gates descend at different speeds, use the descent time of the gate that reaches the horizontal position first.

**Line 58.** The Proportion of non-interaction gate descent time is the decimal proportion of the full gate descent time on Line 57 during which the gate will not interact with (i.e. not hit) the design vehicle if it is located under the gate. This value depends on the design vehicle height, h, and the distance from the center of the gate mechanism to the nearest side of the design vehicle, d, as shown in Figure 4. Figure 5 can be used to determine the proportion of non-interaction gate descent time. Select the distance from the center of the gate mechanism to the nearest side of the design vehicle, d, on the vertical axis of Figure 5, draw a horizontal line until you reach the curve that represents the design vehicle, and then draw a vertical line down to the horizontal axis and read off the value of the proportion of non-interaction gate descent time.

**Line 59.** Non-interaction gate descent time is time (in seconds) during gate descent that the gate will not interact with (i.e. not hit) the design vehicle if it is located under the gate. In other words, it is the time that expires after the gate starts to descend until it hits the design vehicle if it is located under the gate. This value is calculated by multiplying the full gate descent time on Line 57 with the proportion of non-interaction gate descent time on Line 58.
Figure 4 Gate interaction with the design vehicle.

Figure 5 Proportion of gate descent time available as a function of the design vehicle height and the distance from the center of the gate mechanism to the nearest side of the design vehicle.
Line 60. **Time available for design vehicle to clear descending gate**, in seconds, is the time, after the railroad warning lights start to flash, that is available for the design vehicle to clear the descending gate before the gate hits the vehicle. It is the sum of the duration of the flashing lights before gate descent start (Line 56) and the non-interaction gate descent time (Line 59).

Line 61. **Advance preemption time required to avoid design vehicle-gate interaction**, in seconds, is calculated by subtracting the time available for the design vehicle to clear descending gate (Line 60) from the time required for the design vehicle to clear descending gate (Line 55). The result is the amount of advance preemption time that is required to avoid the gates descending on a stationary or slow-moving design vehicle. If the result of the subtraction is equal to or less than zero, it means that sufficient time is available, and you should enter zero (0) on Line 61. If the result is greater than the amount of advance preemption time provided by the railroad, as given on Line 36, there is a possibility that the gates could descend on a stationary or slow-moving design vehicle. To avoid this situation, additional advance preemption time should be requested from the railroad.

It should be kept in mind that on its own, gates descending on a vehicle is not a critical safety failure, because enough time still exists to clear the crossing before the arrival of the train, if the advance preemption time on Line 36 is provided. Therefore, local policies may vary on whether additional advance preemption time (over and above that on Line 36) should be requested solely for the purpose of prohibiting gates descending on vehicles.

If additional advance preemption time is provided to avoid design vehicle-gate interaction, Line 33 of this Worksheet has to updated, and Lines 34 and 35 recomputed. Section 5 also needs to be recomputed to calculate the track clearance green time.

**REFERENCES**

The following references were used in the development of the 2003 Guide For Determining Time Requirements For Traffic Signal Preemption At Highway-Rail Grade Crossings and these accompanying Instructions.


### Vehicles Dynamics for Computing Track Clearance Phase Detection

#### Vehicles Dynamics when Accelerating from a Stopped Position

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Methodology from: Modeling Queued Driver Behavior At Signalized Junctions  
By Jim Bonneson  
Transportation Research Record. 1992 (1365) pp99-107

Numbers from:  
1. Acceleration Characteristics of Starting Vehicles  
By Gary Long, University of Florida  
TRB 2000 Preprint Paper No. 00-0980  
2. School Bus Acceleration and Sight Distance  
J.L. Gattis, S.H. Nelson, and J.D. Tubbs  
Paper Submission to ASCE

Assumptions:  
1 seconds initial perception-reaction time (Bonneson’s tau)  
The following saturation flows and vehicle queue spacing:

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### Vehicles Dynamics when Accelerating from a Stopped Position

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Methodology from: Modeling Queued Driver Behavior At Signalized Junctions
By Jim Bonneson
Transportation Research Record. 1992 (1365) pp99-107

Numbers from:
1. Acceleration Characteristics of Starting Vehicles
   By Gary Long, University of Florida
   TRB 2000 Preprint Paper No. 00-0980
2. School Bus Acceleration and Sight Distance
   J.L. Gattis, S.H. Nelson, and J.D. Tubbs
   Paper Submission to ASCE
Basic Preempt Time Line
Preempt Time Line

Train Arrival at Crossing

40 30 20 10 0

[Graph showing time line with marks at 0, 10, 20, 30, and 40]
Special Geometric Conditions
Must Always be Considered
Burbank, CA
San Fernando Road and Buena Vista Street

2300 North Buena Vista Street

52°
Automatic gate

50 feet

2400 North San Fernando Boulevard
MUTCD

Section 8B.06 Turn Restrictions During Preemption

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

- Option:
  A blank-out or changeable message sign and/or appropriate highway traffic signal indication or other similar type sign may be used to prohibit turning movements toward the highway-rail grade crossing during preemption. The R3-1a and R3-2a signs shown in Figure 8B-3 may be used for this purpose.
Burbank, CA
Driver Perspective
View Looking East
Burbank, CA
Driver View of Railroad Warning Devices
VEHICLES MAKING LEFT TURN DURING
LEFT TURN PHASE - NO PREEMPTION

APPROACHING TRAIN / SIMULTANEOUS
PREEMPTION REQUEST
LEFT TURN PHASE TERMINATES
VEHICLE AHEAD OF TRACTOR-TRAILER
STOPS FOR DESCENDING GATE

TRACTOR-TRAILER BLOCKS PATH
FOR VEHICLES EXITING MTCD
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
Presignal Applications at Highway-Rail Grade Crossings

- MUTCD Application of Presignals
- Institute of Transportation Engineers
- When is a Presignal not a Presignal
Standard:

If a pre-signal is installed at an interconnected highway-rail grade crossing near a signalized intersection, a STOP HERE ON RED (R10-6) sign shall be installed near the pre-signal or at the stop line if used. If there is a nearby signalized intersection with insufficient clear storage distance for a design vehicle, or the highway-rail grade crossing does not have gates, a NO TURN ON RED (R10-11) sign shall be installed for the approach that crosses the railroad track.
Other MUTCD Parts Relating Indirectly to Presignals

Part 4  Highway Traffic Signals
Section 4D.15  Size, Number and Location of Signal Faces by Approach

Standard:

The signal faces for each approach to an intersection or a midblock location shall be provided as follows:

A. A minimum of two signal faces shall be provided for the major movement on the approach, even if the major movement is a turning movement.

   1. A signal face installed to satisfy the distance requirements as described in Paragraphs B and C in the first Standard of this Section, and at least one and preferably both of the signal faces required by Paragraph A in this Standard shall be located:

      (a) Not less than 12 m (40 ft) beyond the stop line.
Presignal Upstream
Presignal Downstream
Presignal Downstream-
Minimum CSD
Near Side of Intersection
PREEMPTION OF TRAFFIC SIGNALS NEAR RAILROAD CROSSINGS

Pre-signal mast arm poles can be located upstream or downstream from the railroad crossing. In all cases, pre-signal poles must be located to maintain visibility of the railroad flashing lights. If an existing railroad cantilever exists and upstream pre-signals are used, they should be mounted on the cantilever if permitted by the railroad or regulatory agency.
Indiana & Ohio Railroad

Galbraith Road
Presignal
Indiana & Ohio Railroad

Galbraith Road
Presignal
Indiana & Ohio Railroad
Galbraith Road
Presignal
Pre-signals or queue-cutter signals should also be used wherever railroad warning devices consist only of flashing light signals. However, this can result in conflicting signal indications between the flashing red lights at the crossing and a display of track clearance green beyond the crossing. To eliminate this conflict, the installation of gates may be necessary.
PREEMPTION OF TRAFFIC SIGNALS NEAR RAILROAD CROSSINGS

Pre-Signal Phasing and Operation

The pre-signal intervals should be progressively timed with the downstream signal intervals to provide a delay adequate to clear vehicles from the track area and the downstream intersection. Vehicles that are required to make a mandatory stop such as school buses, vehicles hauling hazardous materials, etc., should be considered when determining the delay time to ensure that they will not be stopped within the minimum track clearance distance (see Appendix C).
PREEMPTION OF TRAFFIC SIGNALS NEAR RAILROAD CROSSINGS

Pre-Signal Phasing and Operation

Where the clear storage distance is inadequate to store a design vehicle clear of the minimum track clearance distance and crossing gates are present, consideration should be given to installation of vehicle detection within the clear storage distance to prevent vehicles from being trapped within the minimum track clearance distance by extending the clear track green interval.
Mustang Court Grapevine, TX
FWWR
When is a Presignal not a Presignal?

When it’s a Queue-Cutter Signal!

- Looks like a presignal.
- Located at the crossing like a presignal.
- When Clear Storage Distance is greater than 120’.
When is a Presignal not a Presignal?

Queue Cutter Signal

- Interconnected for simultaneous preemption.
- May or may not function as a part of the downstream intersection signals.
- Utilizes downstream vehicle detection to change to red to prevent standing vehicles within MTCOD.
PREEMPTION OF TRAFFIC SIGNALS NEAR RAILROAD CROSSINGS

If the clear storage distance is greater than 120 ft (37 m), any traffic signal heads located at a railroad crossing should be considered to be a separate mid-block crossing (a “queue-cutter” signal), and not a pre-signal. However, coordination with the intersection signals may still be appropriate.
Queue Cutter Signal
and
Downstream Detector
Questions?