TEM

Traffic Engineering Manual

JANUARY 2024

FDOT

Section 3.8

CALCULATING RAILROAD TRAFFIC SIGNAL PREEMPTION TIME

3.8.1 PURPOSE

This section describes how to determine the required preemption time for a traffic signal adjacent to a highway at-grade rail crossing with an active warning system.

3.8.2 GENERAL

This comprehensive guidance on calculating signal preemption time adheres to ***Rule 14-57.013(5), F.A.C.***

A preemption phase is required at any signalized intersection within 200 feet of a grade crossing. Set this as part of the active grade crossing traffic control device design.

For signalized intersections within 200 to 500 feet from a grade crossing, complete an engineering study to determine if preemption is needed.

Consider preemption for signalized intersections more than 500 feet from a grade crossing if traffic queues past the grade crossing or there is potential for that condition to develop.

Consult and coordinate with the appropriate railroad agency, the ***District Rail Office***, and the ***DTOE*** before implementation.

3.8.3 DEFINITIONS

Advance Preemption (AP): The length of time before activation of railroad warning devices that a highway traffic signal controller unit or assembly is notified of an approaching train.

Clear Storage Distance (CSD): The distance available for vehicle storage measured between 6 feet from the rail nearest the intersection to the intersection stop line or the normal stopping point on the highway.

Controller's Equipment Response Time to Preempt (CERTP): The time that elapses while the controller electronically registers the preempt call.

Design Vehicle (DV): The longest vehicle permitted by statute of the road authority (State or other) on a given roadway.

Design Vehicle Clearance Distance (DVCD): How far, in feet, the design vehicle must travel to enter and completely pass through the railroad crossing's minimum track clearance distance. This is the sum of the minimum track clearance distance and the total design vehicle's length. Design vehicle length can be found in ***FDM 201***.

Design Vehicle Clearance Time (DVCT): How long it takes for the design vehicle to accelerate from a stop and travel through and clear of the minimum track clearance distance.

Desired Minimum Separation Time (DMST): A time buffer between the departure of the last vehicle (the design vehicle) from the railroad crossing and the arrival of the train.

Maximum Highway Traffic Signal Preemption Time (MHTSPT): The maximum time a highway traffic signal needs after initiating the preemption sequence to finish timing the right of way transfer time, queue clearance time, and separation time.

Minimum Green Time During Right of Way Transfer (MGTRT): The minimum number of seconds any existing phase will display a green indication before the controller unit terminates the phase through its yellow change and red clearance intervals and transitions to the track clearance green interval. A 5-second interval is recommended to make the transition to the track clearance green interval as rapid as possible.

Minimum Track Clearance Distance (MTCD): The length along the highway at one or more railroad tracks, measured from the portion of the railroad crossing automatic gate arm farthest from the near rail to 6 feet beyond the tracks measured perpendicular to the far rail.

Minimum Walk Time During Right of Way Transfer (MWTRT): The minimum pedestrian WALK indication time before the preemption sequence begins. FDOT recommends a 5-second interval to make the transition to the track clearance green interval as rapid as possible.

Other Green Time During Right of Way Transfer (OGTRT): Any additional green time beyond the preempt minimum green time for the worst-case vehicle phase.

Pedestrian Clearance Time During Right of Way Transfer (PCTRT): The pedestrian clearance (i.e., flashing *DON'T WALK* indication) time for the worst-case pedestrian phase. A zero value is allowed for the most rapid transition to the track clearance green interval.

Preemption: The transfer of normal operation of a traffic control signal to a special control mode of operation.

Preempt Delay Time (PDT): The number of seconds 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 Trap: A potential hazard condition that happens when the gates do not block vehicle access to the crossing before the expiration of the track clearance green. Vehicles can continue to cross the tracks and possibly stop on the tracks. In a preempt trap, the track clearance green interval has already expired, so there will be no further opportunity to clear the tracks.

Preempt Verification and Response Time (PVRT): The number of seconds between when the controller unit receives a preempt call from the railroad's grade crossing warning equipment and the controller software begins to respond to the preempt call.

Queue Clearance Time (QCT): The time it takes the design vehicle to start up, move through, and clear the entire minimum track clearance distance when it is stopped just inside.

Queue Start-up Time (QST): Time from the beginning of the track clearance green until the design vehicle can start moving.

Red Clearance Time (RCT): The required red clearance interval time during right of way transfer before transitioning to track clearance.

Required Preemption Time (RPT): The time provided by the engineer of record to the railroad signal designer.

Right of Way Transfer Time (RTT): 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 light rail transit 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.

Separation Time (ST): The portion of maximum highway traffic signal preemption time when the minimum track clearance distance is clear of vehicles before the arrival of a train.

Track Clearance Distance (TCD): The length along a highway at one or more railroad tracks, measured from the highway stop line, warning device, or 12 feet perpendicular to the track center line, to 6 feet beyond the track(s) measured perpendicular to the far rail, along the center line or edge line of the highway, as appropriate, to obtain the longer distance.

Track Clearance Time (TCT): Time needed to travel through the track clearance distance plus a 4-second separation time.

Vehicle-Gate Interaction: When the automatic gate descends on a stationary or slow-moving vehicle as it moves through the minimum track clearance distance.

Yellow Change Time (YCT): The required yellow change interval time during right of way transfer prior to the track clearance.

3.8.4 PROCEDURE

Engineers may calculate the maximum preemption time for highway-rail grade crossings as follows.

- Calculate the Right of Way Transfer Time.

  The components of right of way transfer time include the *preempt verification* and *response time* and *the worst-case conflicting vehicle or pedestrian time*. Calculate these through the following steps:

  Step 1: Calculate *preempt verification* and *response time* (seconds).

  Collect the preempt delay time (seconds) and the controller response time to preempt (seconds). Calculate the preempt verification and response time by adding the preempt delay time and the controller response time.

  Step 2: Calculate the *worst-case conflicting vehicle time* (seconds).

  Add the minimum green time during right of way transfer (seconds), other green time during right of way transfer (seconds), yellow change time (seconds), and red clearance time (seconds). The worst-case conflicting vehicle time is the total.

  Step 3: Calculate the *worst-case conflicting pedestrian time* (seconds).

  Add the minimum WALK time during right of way transfer, pedestrian clearance time during right of way transfer, vehicle yellow change time, and vehicle red clearance time. The worst-case conflicting pedestrian time is the total.

  Step 4: Determine the worst-case conflicting vehicle or pedestrian time.

  The worst-case conflicting vehicle or pedestrian time is whichever is longer between the worst-case conflicting vehicle time (**Step 2**) and the worst-case conflicting pedestrian time (**Step 3**).

  Step 5: Calculate the right of way transfer time.

  The right of way transfer time is the sum of the *preempt verification* and *response time* (**Step 1**) and the worst-case conflicting vehicle or pedestrian time (**Step 4**).

- Calculate the queue clearance time.

  The queue clearance time includes the time it takes the design vehicle to start moving and to accelerate through the clearance distance. Calculate this through the following steps:

  Step 1: Determine the queue start-up distance.

Measure the clear storage distance and minimum track clearance distance for the highway-rail grade crossing. Calculate the queue start-up distance, L (feet), by adding the clear storage distance with the minimum track clearance distance.

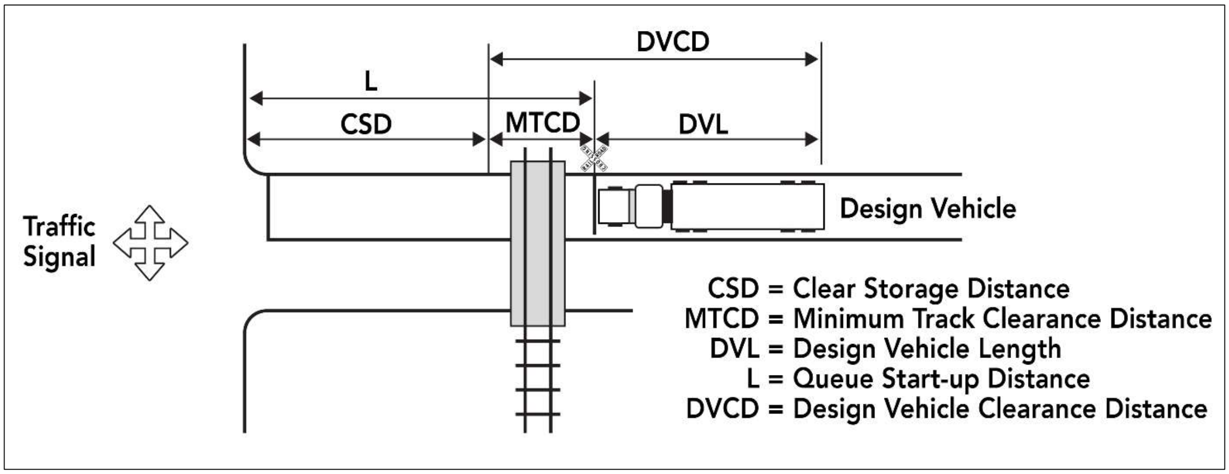
Step 2: Calculate the time the design vehicle needs to start moving.

Calculate the time the design vehicle needs to start moving, in seconds, as 2 plus the queue start-up distance, L, divided by the speed of 20 feet per second.

Step 3: Determine the design vehicle clearance distance.

Combine the minimum track clearance distance and the total design vehicle's length, as shown in ***Figure 3.8-1***.

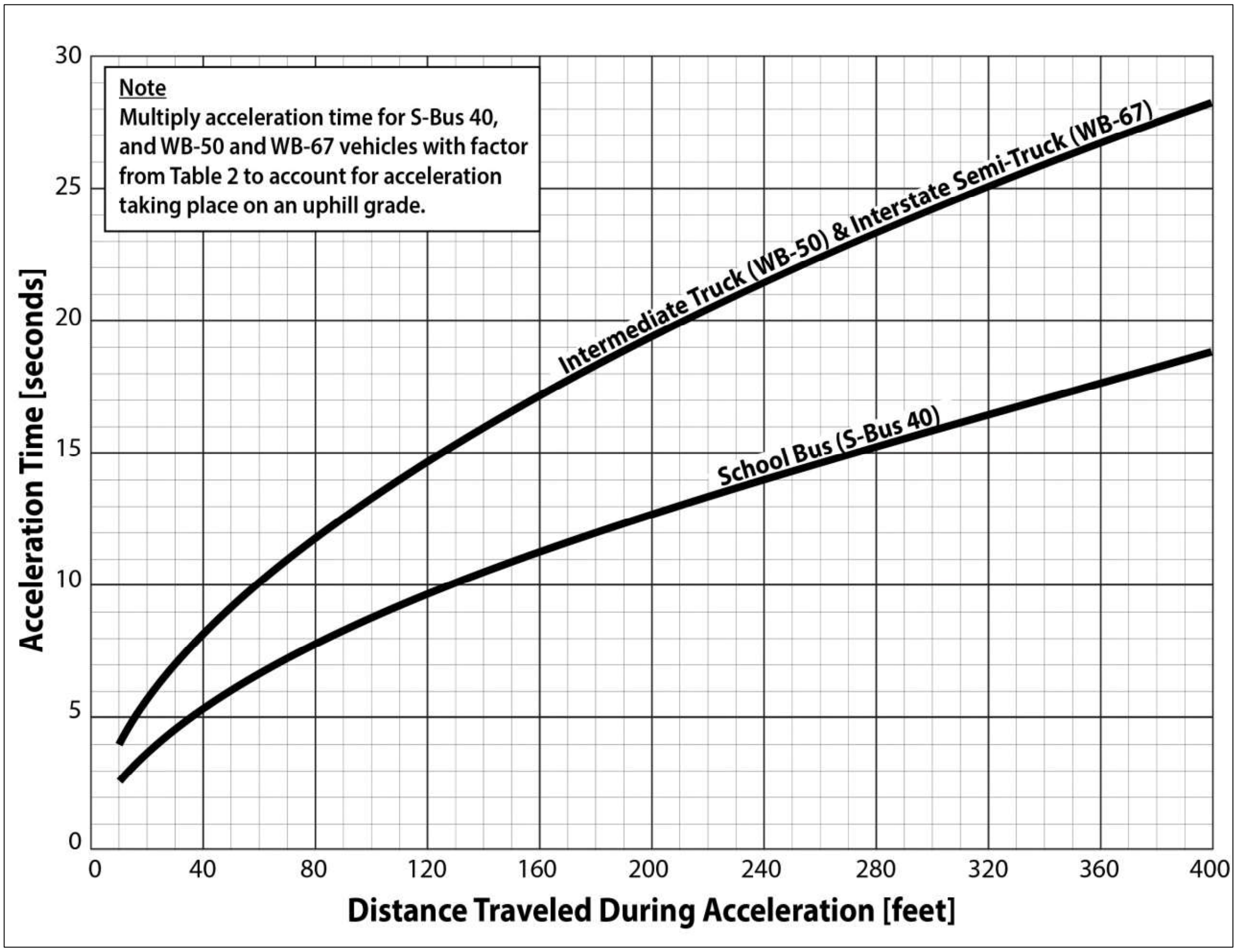
Figure 3.8-1. Geometric Data at the Highway-Rail Grade Crossing



Step 4: Calculate the time the design vehicle needs to accelerate through the design vehicle clearance distance on level terrain.

Select the design vehicle for the analysis. Use ***Figure 3.8-2*** to determine the time the design vehicle needs to accelerate through the design vehicle clearance distance on level terrain.

Figure 3.8-2. Acceleration Time Over a Fixed Distance on a Level Surface



Step 5: Calculate the time the design vehicle needs to accelerate through the design vehicle clearance distance on an uphill grade.

If the design vehicle clearance distance is on an uphill grade, calculate the approach grade factor to account for slower acceleration. Determine the approach grade factor, shown in ***Table 3.8-1***, based on design vehicle clearance distance, design vehicle, and slope grade.

To calculate the time needed for the design vehicle to accelerate through the design vehicle clearance distance on an uphill grade, multiply the time it needs to accelerate through the design vehicle clearance distance on level terrain by the approach grade factor.

Table 3.8-1. Factors to Account for Slower Acceleration on Uphill Grades

Acceleration Distance (feet)	Design Vehicle and Percentage Uphill Grade									
	School Bus (S-BUS 40)					Intermediate Truck (WB-50) and Interstate Semi-Truck (WB-67)				
	≤1%	2%	4%	6%	8%	0%	2%	4%	6%	8%
25	1.00	1.01	1.10	1.19	1.28	1.00	1.09	1.27	1.42	1.55
50	1.00	1.01	1.12	1.21	1.30	1.00	1.10	1.28	1.44	1.58
75	1.00	1.02	1.13	1.23	1.33	1.00	1.11	1.30	1.47	1.61
100	1.00	1.02	1.14	1.25	1.35	1.00	1.11	1.31	1.48	1.64
125	1.00	1.03	1.15	1.26	1.37	1.00	1.12	1.32	1.50	1.66
150	1.00	1.03	1.16	1.28	1.40	1.00	1.12	1.33	1.52	1.68
175	1.00	1.03	1.17	1.29	1.42	1.00	1.12	1.34	1.53	1.70
200	1.00	1.04	1.17	1.30	1.43	1.00	1.13	1.35	1.54	1.72
225	1.00	1.04	1.18	1.32	1.45	1.00	1.13	1.35	1.56	1.74
250	1.00	1.04	1.19	1.33	1.47	1.00	1.13	1.36	1.57	1.76
275	1.00	1.05	1.20	1.34	1.49	1.00	1.14	1.37	1.58	1.77
300	1.00	1.05	1.20	1.35	1.50	1.00	1.14	1.37	1.59	1.79
325	1.00	1.05	1.21	1.36	1.52	1.00	1.14	1.38	1.60	1.81
350	1.00	1.05	1.22	1.37	1.54	1.00	1.15	1.39	1.61	1.82
375	1.00	1.06	1.22	1.38	1.55	1.00	1.15	1.39	1.62	1.84
400	1.00	1.06	1.23	1.40	1.57	1.00	1.15	1.40	1.63	1.85

Step 6: Calculate the queue clearance time.

The queue clearance time is the sum of the time the design vehicle needs to start moving and the time it needs to accelerate through the design vehicle clearance distance.

- Select the desired minimum separation time (seconds).

  The separation time is added for safety reasons and to avoid driver discomfort. ITE (in an article by Marshall and Berg in February 1997) recommends a minimum separation time of 4 seconds. This value may be reduced to as low as 0 seconds if the necessary warning time is not available.

- Calculate the maximum preemption time.

To get the required preemption time, add the right of way transfer time, queue start-up time, and desired minimum separation time. If using advance preemption, check using the worst-case scenario that the preemption phase does not end before the activation of the grade crossing warning devices. Consider variability in train arrival times. Submit the calculated maximum preemption time to the ***DTOE*** and ***District Rail Office*** for approval.

- Coordinate with the appropriate railroad agency and the railroad signal designer.

  After approval by the DTOE and ***District Rail Office***, provide the required preemption time to the railroad signal designer so they can determine the required rail warning system and timings.

3.8.5 PREEMPT TRAP CHECK

A preempt trap happens when the track clearance phase ends before the active railroad grade crossing warning lights start to flash or the gates start to descend. Vehicles may cross or stop in the crossing after the end of the track clearance phase without the opportunity to clear before a train arrives. Variable actual warning time or an insufficient track clearance green interval cause preempt traps.

A preempt trap can be checked using the following procedures.

- Request the advance preemption time from the railroad.

  Use the actual value provided by the railroad. If no advance preemption time is provided, a value of 0 seconds can be used.

- Determine a multiplier for maximum advance preemption time due to train handling.

  Use field measurements. Divide the longest advance preemption time observed by the advance preemption time provided by the railroad.

  If no field observations are available or the advance preemption time is not provided, the multiplier for maximum advance preemption time 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 is typical in the vicinity of switching yards, branch lines, or anywhere low-speed switching maneuvers take place.

- Calculate maximum advance preemption time.

  Multiply advance preemption time by the multiplier for maximum advance preemption time.

- Calculate the minimum duration for the track clearance green interval.

Subtract the minimum time for a flashing-light signal before the arrival of any train from the minimum time between the gate arm reaching its horizontal position and the arrival of a train.

- Calculate the time for gates down after start of preemption.

  Add the maximum advance preemption time to the minimum duration for the track clearance green interval.

- Calculate the minimum right of way transfer time.

  Add preempt verification and response time with best-case conflicting vehicle or pedestrian time. The best-case conflicting vehicle or pedestrian time is usually 0 seconds.

- Calculate the minimum track clearance green interval.

  Subtract the minimum right of way transfer time from the time for gates down after preemption begins. The minimum track clearance green interval has to be as long as it takes for a car to clear the tracks after the gates are lowered to avoid a preempt trap.

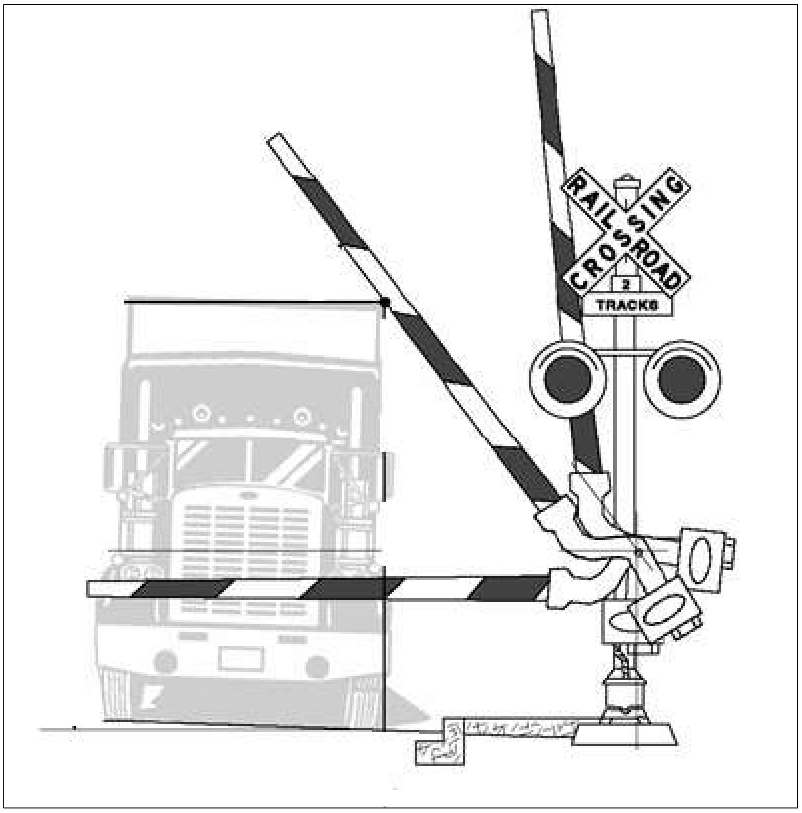
  If the actual track clearance green interval is shorter than the minimum track clearance green interval, a preempt trap will occur.

3.8.6 VEHICLE-GATE INTERACTION CHECK

Even if there is sufficient warning time and the preempt trap has been addressed, the automatic gates may still descend on slow-moving or stationary vehicles, causing panic, confusion, or other unsafe actions from drivers.

Long, high vehicles that accelerate slowly, such as tractor-trailers, are most exposed. The gates may “clip” the rear of the trailer as the vehicle crosses the track during the clear track phase. ***Figure 3.8-3*** shows the passing vehicle-descending gate - relationship. The vehicle-gate interaction can be checked as follows:

Figure 3.8-3. Relationship between Descending Gate and Passing Vehicle



- Calculate the time the design vehicle needs to clear the descending gate.

  Collect the right of way transfer time and the time the design vehicle needs to start moving from previous steps. Calculate the time the design vehicle needs to accelerate through the design vehicle length using ***Figure 3.8-2*** and ***Table 3.8-1***.

  Add the right of way transfer time, time the design vehicle needs to start moving, and time the design vehicle needs to accelerate through the minimum track clearance distance.

- Collect the flashing light duration before the gate starts to descend.

  This value typically ranges from 3 to 5 seconds and must be obtained from the railroad. The railroad's value may be verified through field observations.

- Calculate non-interaction gate descent time.

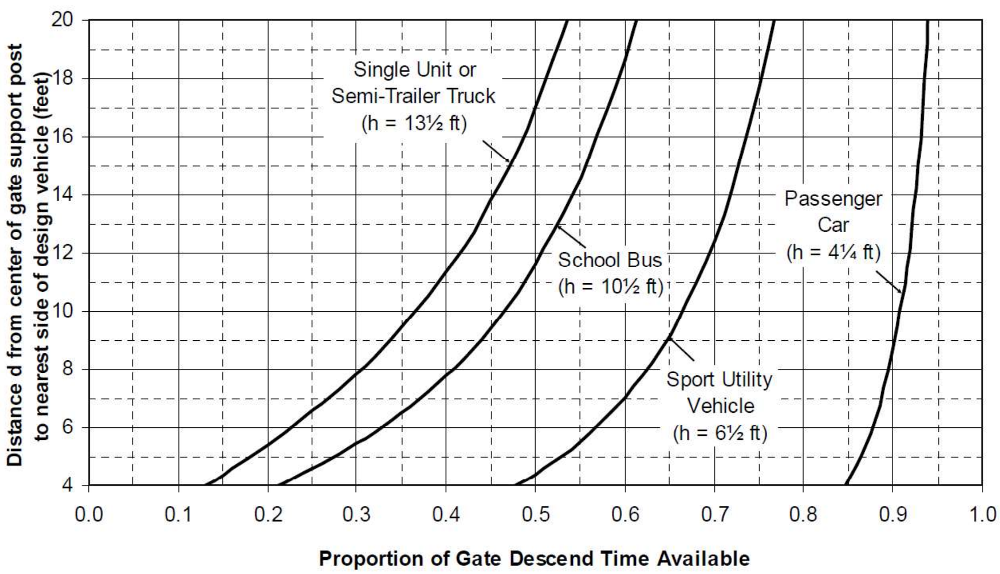
  Step 1: Collect the full gate descent time from the railroad.

  The value obtained from the railroad may be verified through field observations. In the case where multiple gates descend at different speeds, use the descent time of the gate that reaches the horizontal position first.

Step 2: 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 3.8-4***, draw a horizontal line until you reach the curve that represents the design vehicle (*h* is the vehicle height). Next, draw a vertical line down to the horizontal axis and read off the value of the proportion of non-interaction gate descent time.

Figure 3.8-4. Proportion of Gate Descent Time Available



Step 3: Calculate the non-interaction gate descent time.

Multiply the full gate descent time with the proportion of non-interaction gate descent time.

- Calculate time available for the design vehicle to clear the descending gate.

  Add the duration of flashing lights before gate descent starts with the non-interaction gate descent time.

- Vehicle-gate interaction check.

  Compare the time the design vehicle needs to clear the descending gate with the time available.

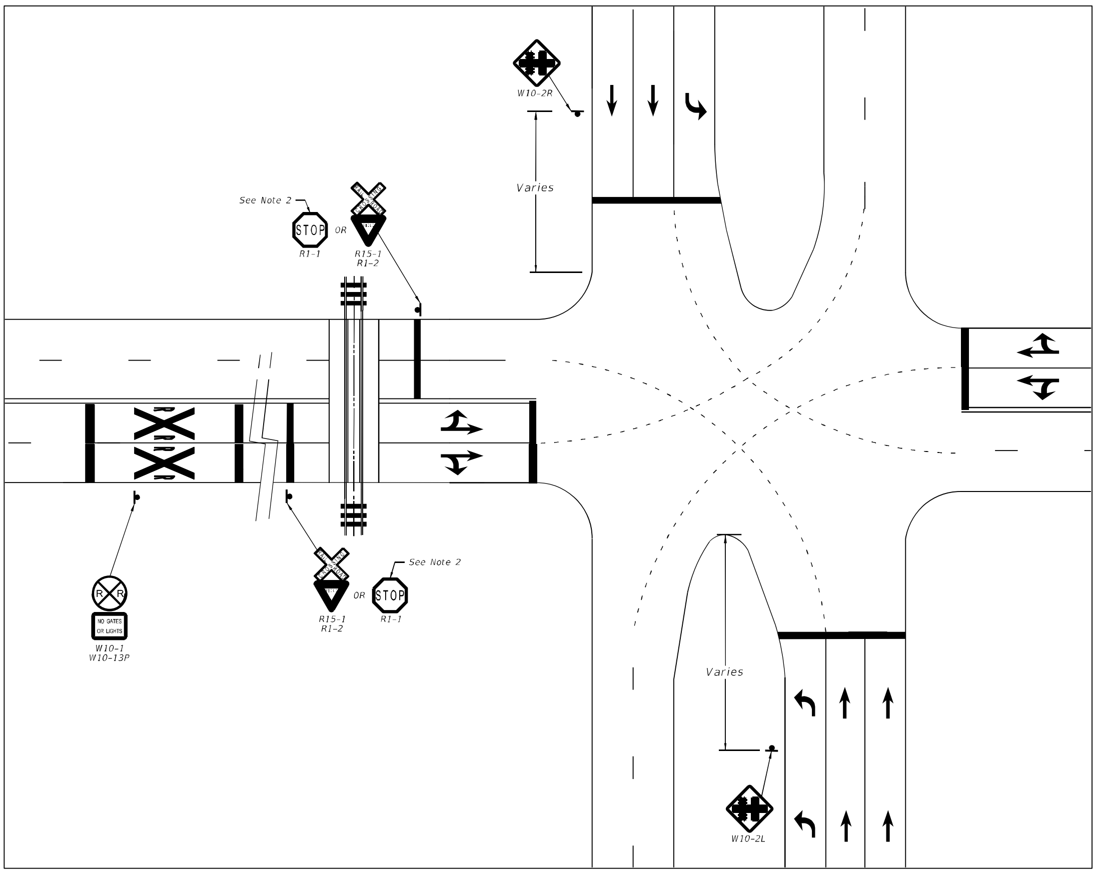
  If the time available is greater than or equal to the time needed, there will be no vehicle-gate interaction.

  If the time available is less than the time needed, provide advance preemption time to avoid vehicle-gate interaction.

3.8.7 EXAMPLE

This example illustrates the step-by-step procedure for calculating the preemption time for a highway-rail grade crossing. The crossing shown in ***Figure 3.8-5*** is within 200 feet of an existing signalized intersection, and requires a preemption phase.

Figure 3.8-5. Intersection for Preemption Time Calculation



- Calculate the Right of way Transfer Time.

  Step 1: Calculate the preempt verification and response time.

  The preempt delay time is 0 seconds. The controller response time to preempt provided by the controller manufacturer is 0 seconds. The preempt verification and response time is 0 seconds, which is calculated by adding the preempt delay time and controller response time.

  Step 2: Calculate the worst-case conflicting vehicle time.

  The worst-case conflicting vehicle phase number is *Phase 8* for this intersection. The minimum green time during right of way transfer is 5 seconds. The other green time during right of way transfer is 1 second. The yellow change time for *Phase 8* is 4 seconds, and red clearance time for *Phase 8* is 1 second. The worst-case conflicting vehicle time is 11 seconds.

Step 3: Calculate the worst-case conflicting pedestrian time.

The worst-case conflicting pedestrian phase number is *Phase 8* for this intersection. The minimum walk time during right of way transfer is 5 seconds. The pedestrian clearance time during right of way transfer is 0 seconds. The vehicle yellow change time is 4 seconds, and vehicle red clearance time is 1 second. The worst-case conflicting pedestrian time is 10 seconds.

Step 4: Determine the worst-case conflicting vehicle or pedestrian time.

The worst-case conflicting vehicle or pedestrian time is 11 seconds based on results from **Steps 2** and **3**.

Step 5: Calculate the right of way transfer time.

The right of way transfer time is 11 seconds based on results from **Steps 1** and **4**.

- Calculate the queue clearance time.

Step 1: Determine the queue start-up distance.

The measured clearance storage distance is 54 feet. The measured minimum track clearance distance is 55 feet. The queue start-up distance is 109 feet.

Step 2: Calculate the time the design vehicle needs to start moving.

$2+109\div20=8$ seconds

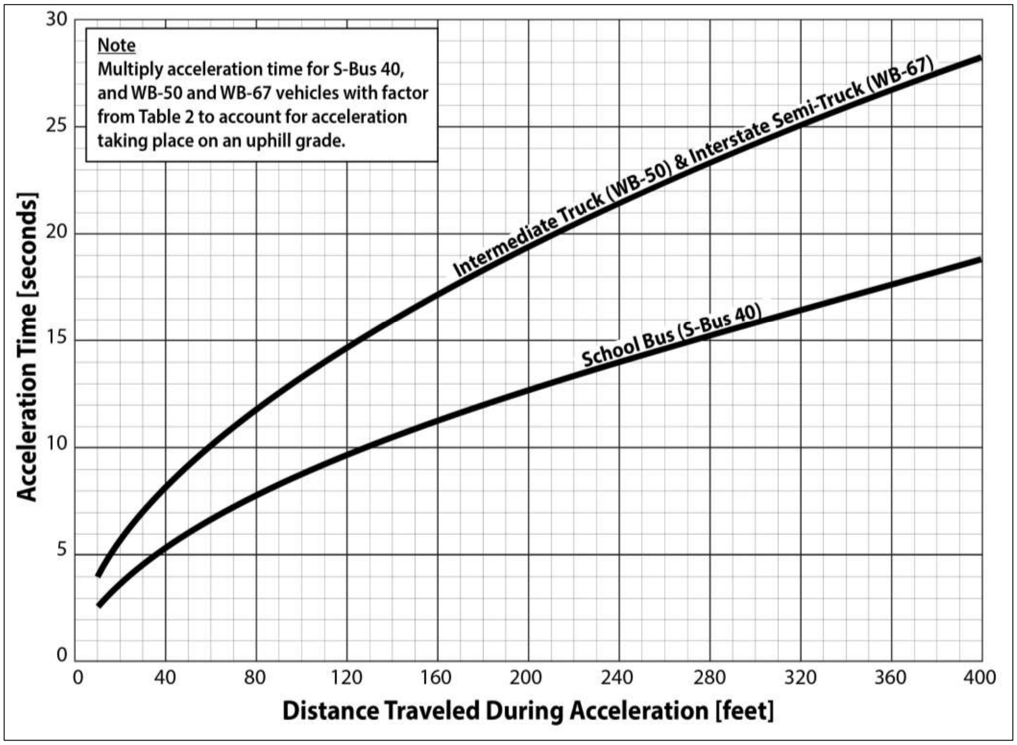
Step 3: Determine the design vehicle clearance distance.

The minimum track clearance distance is 55 feet and the design vehicle length is 48 feet. The design vehicle clearance distance is 103 feet based on minimum track clearance distance and design vehicle length.

Step 4: Calculate the time the design vehicle needs to accelerate through the design vehicle clearance distance on level terrain.

The design vehicle is WB 50 & WB-67. The time the design vehicle needs accelerate through the design vehicle clearance distance on level terrain is 14 seconds based on ***Figure 3.8-6***.

Figure 3.8-6. Calculation of Time for Design Vehicle to Accelerate through the Design Vehicle Clearance Distance on Level Terrain



Step 5: Calculate the time the design vehicle needs to accelerate through the design vehicle clearance distance on an uphill grade.

The terrain for the selected intersection is level, so there is no need to calculate acceleration time for an uphill grade.

Step 6: Calculate the queue clearance time.

The time the design vehicle needs to start moving (**Step 2**) is 8 seconds, and the time it needs to accelerate through the design vehicle clearance distance on level terrain (**Step 4**) is 14 seconds. The queue clearance time is 22 seconds based on results in **Steps 2** and **4**.

- Select the desired minimum separation time.

  The minimum separation time is 4 seconds, based on ITE's recommendation.

- Calculate the maximum preemption time.

  The right of way transfer time is 11 seconds. The queue clearance time is 22 seconds. The desired minimum separation time is 4 seconds. The maximum preemption time is 37 seconds.

The final calculated maximum preemption time is 37 seconds for this intersection.

Section 3.9

INSTALLING RETROREFLECTIVE SIGNAL BACKPLATES ON EXISTING STRUCTURES

3.9.1 PURPOSE

This section describes how to retrofit existing signal structures on the State Highway System with retroreflective signal backplates. Follow the guidelines in this section for installing flexible retroreflective backplates (FRBs) on existing mast arm and span wire structures at signalized intersections without backplates.

3.9.2 BACKGROUND

Retroreflective signal backplates improve the contrast between the traffic signal indications and their surroundings, making them easier to see during both day and night conditions and during power outages.

Installing retroreflective signal backplates can enhance safety at intersections. They have a crash modification factor in FHWA's ***Crash Modification Factor (CMF) Clearinghouse***.

All new or reconstructed traffic signal structures for all approaches are required to have rigid retroreflective backplates.

Some existing signal support structures have unknown structural capacity limits and retrofitting their signal heads with rigid retroreflective backplates would result in needing structural analysis. Research and structural evaluations using FRBs have shown negligible wind loading impacts to mast arm and span wire support structures, making them suitable for signal retrofits.

3.9.3 DEFINITIONS

Flexible Retroreflective Backplate (FRB): A signal backplate that allows portions of the panels to fold back when subjected to high winds and return to their original position when the wind subsides.

Mast Arm: A structure that is rigidly attached to a vertical pole and used to provide overhead support for highway traffic signal faces or grade crossing signal units.

Rigid Retroreflective Backplate: A signal backplate that remains fixed in one position when subjected to wind loading.

Signal Face: An assembly of one or more signal sections that controls one or more traffic movements on a single approach.

Signal Head: An assembly of one or more signal faces that controls traffic movements on one or more approaches.

3.9.4 PROCEDURE

For existing mast arm and span wire structures, the use of FRBs listed on the ***Department's Approved Product List (APL)*** is exempt from the ***FDM 261*** structural capacity analysis requirements. This exemption applies only when the elements to be added to an existing signal structure are FRBs.

The ***District Traffic Operations Offices*** track and document locations and implementation dates within the signalized assets by district found in ***eTraffic.***

All other signal hardware, features, and attachments proposed for retrofitting existing traffic signal structures must undergo structural analysis in accordance with ***FDM 261*** to determine if structural capacity is adequate. Examples of signal hardware, features and attachments requiring structural analysis include, but are not limited to:

- Rigid retroreflective backplates (RRBs)
- Signal heads
- Overhead street name signs
- Static signs
- Blank-out signs

Perform any required structural analysis of existing traffic signal structures in accordance with ***FDM 261***. Refer to the ***FDOT Structures Manual, Volume 3, Section 18.3*** for additional information regarding the analysis of existing structures. The ***FDOT*** Structures Manual recommends installing FRBs to alleviate loading capacity.