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 *2017 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 Mr. David Valdez in the Traffic Operations Division at telephone 512-416-2642 or email David.Valdez@txdot.gov or Mark Johnson by phone at 512-416-3247 or email Mark.J.Johnson@txdot.gov.

All values shown in red boxes on the Preemption Worksheet require user inputs. Otherwise, the form auto-calculates all values.

After approval by the District, a copy of the Preemption Worksheet, along with the traffic signal design sheets and the phasing diagrams for normal and preempted operation, shall be placed in the traffic signal cabinet.

Note that the Preemption Worksheet may not suffice in all types of road/rail geometries. For example, a separate analysis is required in situations where the rail crosses 2 legs of the intersection or when the rail crosses the roadway through the center of an intersection.

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 **CSJ** (Control Section Job) of the project, if applicable.

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. Finally, record the unique 7-character **Crossing DOT#** (6 numeric plus one alphanumeric characters) for the crossing.

SECTION 1: GEOMETRIC DATA & DEFAULTS

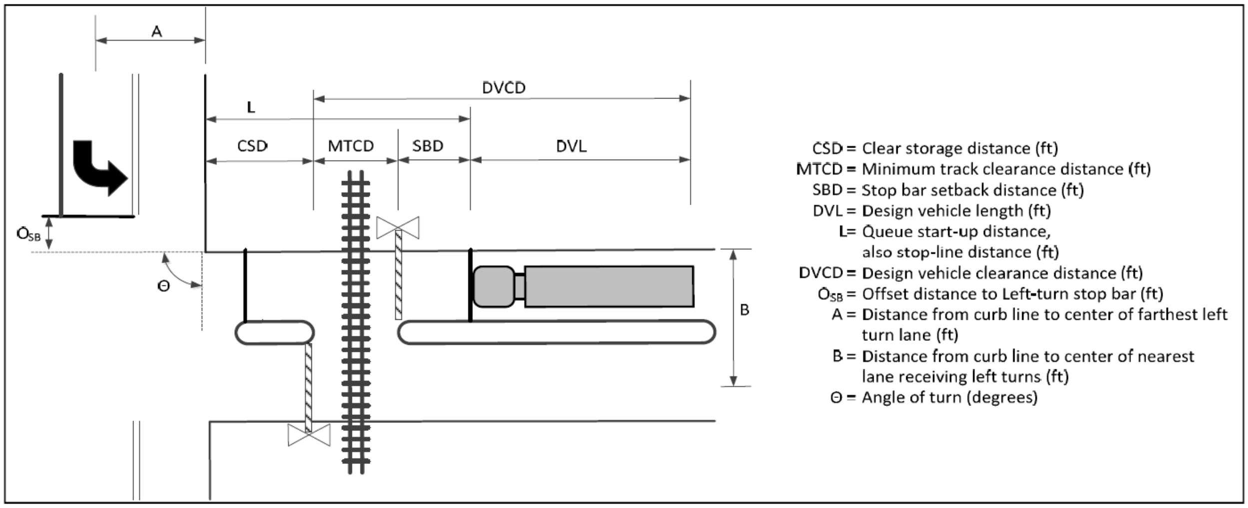

Figure 1. Geometric Data at the Grade Crossing.

GEOMETRIC DATA FOR CROSSING

Line 1. 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 significantly 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 <u>shortest</u> clear storage distance and record that value.

Line 2. 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 portion of the railroad crossing automatic gate arm farthest from the near rail to 6 feet (2 m) beyond the tracks measured perpendicular to the far 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 <u>longest</u> minimum track clearance distance and record that value. Where flashing light signals are used without automatic gates or where passive traffic control devices are used, the MTCD is measured from the railroad stop line.

Line 3. Stop bar setback distance (SBD in Figure 1) is the distance from the railroad warning device to the stop bar installed on the lanes approaching the crossing. If no stop bar is present, a value of zero (0) should be entered in the worksheet. The default value is 8’ as per *Texas Manual on Uniform Traffic Control Devices (TMUTCD)* Section 8B.28, Para. 3.

Line 4. Width of receiving approach (B in Figure 1) is the distance from the curb or edge of the roadway for the track phase and the mid-point of the inside lane (centerline) into which vehicles turn from the roadway parallel to the tracks.

Line 5. Offset distance of left turn stop bar (O_{SB} in Figure 1) is the distance between the line extended from the curb or edge of the roadway for the track phase and the stop bar of the nearest turn lane that is used by left turning vehicles to turn onto the tracks.

Line 6. Approach grade (0 if approach is on downgrade) is the percent grade of the track phase approach. The grade is typically an average of grade measurements taken at the stop bar, 30’ from the stop bar, and 60’ from the stop bar on the side of the tracks opposite of the signalized intersection. See tractor-trailer location in Figure 1.

Line 7. Angle of turn at Intersection is the angle (Φ in Figure 1) that a vehicle turning left towards the tracks has to make to make the left turn maneuver. This is an approximate value and can be assumed to be 90 degrees for intersections that are nearly perpendicular.

DESIGN VEHICLE DATA

Line 8. Select Design Vehicle: The form selects the Interstate Semi-Truck as the default design vehicle. This design vehicle is recommended for all non-residential locations. For selecting a different design vehicle, check the appropriate box.

Line 9. Design vehicle length, in feet, is the length of the design vehicle, the longest vehicle permitted by road authority statute on the subject roadway. The worksheet has a default value of 75 feet based on the selection of the Interstate Semi-Truck as the default design vehicle. Selection of a different design vehicle will autofill the appropriate design vehicle length as noted in Table 1 as stated by the *AASHTO Green Book (A Policy on Geometric Design of Highways and Streets)*. The use of the Interstate Semi-Truck is recommended for non-residential locations. Note that additional truck length may be added on line 9a for special circumstances where a 75 foot vehicle is not sufficient.

Table 1. AASHTO Design vehicle lengths and heights.

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

Line 10. Total Design vehicle length (DVL in Figure 1), in feet, is the total length of the vehicle and is obtained by adding Line 9 and Line 9a if used.

Line 11. Centerline turning radius of design vehicle: This is the radius of the design vehicle which is auto filled based on the selection of the design vehicle.

Line 12. Passenger car vehicle length. This value is auto filled (19 feet) and is used in calculations for Line 31.

SECTION 2: RIGHT-OF-WAY TRANSFER TIME CALCULATION

Preempt Verification and Response Time

Line 13. 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 should be a whole number value entered into the controller unit for purposes of preempt call validation, and may not be available on all manufacturer’s controllers.

Line 14. Unlike preempt delay time (Line 13), which is a value entered into the controller timing parameters, **controller response time to preempt** is the time that elapses while the controller unit electronically registers the preempt call. The controller manufacturer should be consulted to find the correct value (in seconds) for use here. Record the controller manufacturer and firmware version to the right.

Line 15. The sum of Line 13 and Line 14 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 16. Minimum green time during right-of-way transfer is the minimum number of seconds that any existing phase will 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. A default value of 5 seconds is provided to meet driver expectations and reduce the chance of a rear end collision at the intersection, but may be reduced if necessary. Note that this value is not the same as a minimum green value during normal operation; it only comes into play when a preempt call is received from the railroad. The TMUTCD allows for this minimum green time to be set as low as 0 for cases where the preemption time required from the railroad needs to be reduced.

If the current phase is green when a preempt call is received from the railroad, the amount of green time already displayed is subtracted from the minimum green time during right-of-way transfer. For example, if a phase has already been green for 3 seconds when the preempt call is processed from the railroad, the indication will stay green for 2 additional seconds (assuming a minimum green right-of-way transfer time of 5 seconds). Or, if the existing phase has been green for 5 seconds or more, the controller will terminate the green immediately (assuming a minimum green right-of-way transfer time of 5 seconds).

Line 17. If any additional green time is preserved beyond the preempt minimum green time for the worst-case vehicle phase, 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 18. Yellow change time is the required yellow change interval time during right-of-way transfer prior to the track clearance. Section 4D.13 of the *TMUTCD* states that the normal yellow change interval shall not be shortened or omitted during the transition into preemption control. Since most controller manufacturers require one input value for yellow change time during right-of-way transfer, the highest yellow change time value for all normal phases is recommended.

Line 19. Red clearance time is the required red clearance interval time during right-of-way transfer prior to transition to track clearance. Section 4D.13 of the *TMUTCD* states that the normal red clearance interval shall not be shortened or omitted during the transition into preemption control. Since most controller manufacturers require one input value for red clearance time during right-of-way transfer, the highest red clearance time value for all normal phases is recommended.

Line 20. Worst-case conflicting vehicle time is the sum of lines 16 through 19. It will be compared with the worst-case conflicting pedestrian time to determine which of vehicle or pedestrian phase times are most critical in their impact on warning time requirements during the transition to the track clearance green interval.

Worst-case Conflicting Pedestrian Time

Line 21. Minimum walk time during right-of-way transfer (seconds) is the minimum pedestrian walk indication time. The *TMUTCD* permits the shortening (i.e. truncation) or complete omission of the pedestrian walk interval. A default value of 0 is inserted on the form and is recommended.

Line 22. Pedestrian clearance time during right-of-way transfer (seconds) is the clearance (i.e., flashing don't walk indication) time. The *TMUTCD* 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. See the Appendix for recommendations for pedestrian clearance time.

Line 23. Enter a **Yellow change time** if the pedestrian clearance interval does not time simultaneously with the yellow change interval of the corresponding vehicular phase; enter zero if does. Also, note than not all traffic signal controllers allow simultaneous timing of the pedestrian clearance interval and the yellow change time. Simultaneous timing of the pedestrian clearance interval and the yellow change interval (i.e. a zero value on line 23) 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 18, since the worst-case pedestrian phase may not be the same as the worst-case vehicular phase.

Line 24. 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 than 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 24) 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 19, since the worst-case pedestrian phase may not be the same as the worst-case vehicular phase.

Line 25. Add lines 21 through 24 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 26. The **Worst-case conflicting vehicle or pedestrian time** (in seconds) is computed in the worksheet by comparing lines 20 and 25 and filling in the larger of the two values.

Line 27. Calculate the **Right-of-way transfer time** by adding lines 15 and 26. 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.

SECTION 3: QUEUE CLEARANCE TIME CALCULATION

This section calculates the time required to clear the queue off the tracks before the arrival of the train. This time is impacted by the time required by a truck turning left from the street parallel to the tracks and potentially impeding the first vehicle in the queue to start moving upon the onset of the track phase. The time to clear the vehicles off the tracks is then determined by calculating the time required for the design vehicle to start moving and then moving through the design vehicle clearance distance. The section starts by asking the user if the preemption timing should account for a left turn design vehicle turning left onto the tracks.

Line 28. Are there left-turns towards the tracks?: The user has to select a box 'Yes' or 'No' to indicate whether to consider a left turn design vehicle turning left onto the tracks. If the user selects 'Yes', values for boxes 29, 31, and 32 are automatically calculated and filled in. In some cases, a value of 'No' may be selected in order to minimize the amount of preemption time requested from the railroad.

Line 29. Distance travelled by the truck during left-turn towards the tracks: This is the distance (LTL) travelled by the truck while making the turn. This calculation is used later in Line 31 and is a function of the centerline turning radius of the left turn design vehicle and the angle of the street from which the left turn design vehicle is making the left turn and is illustrated in the equation below and in Figure 2:

$$LTL = \pi R\theta/180$$

Where:
R = the centerline turning radius of the left turning design vehicle (line 11), and
Θ = angle of the street from which the left turn design vehicle is making the left turn (line 7)

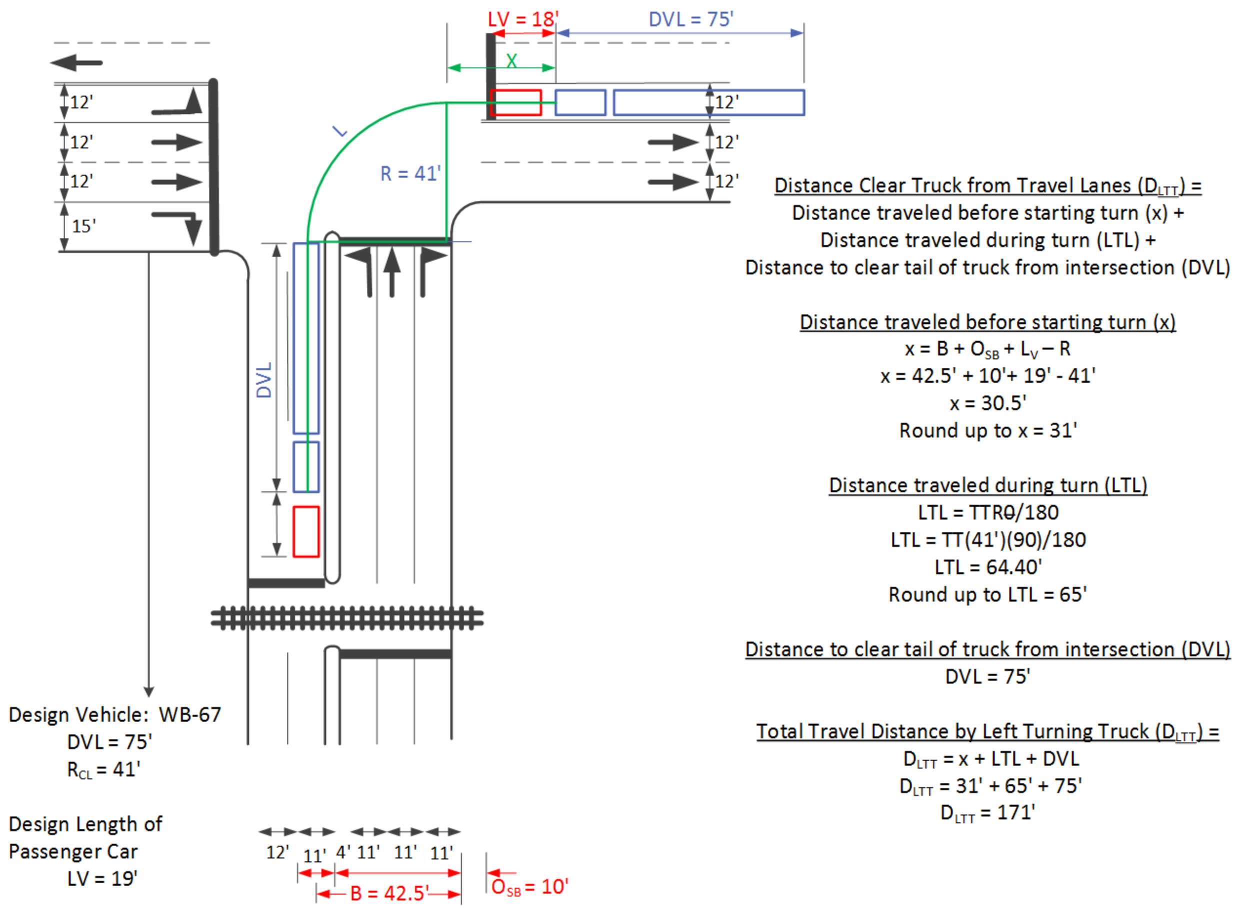

Figure 2. Sample calculation of the distance required to clear left-turning truck from travel lanes on track clearance phase.

Line 30. Travel speed of left turning truck: This is the default speed of the left turn design vehicle turning left to cross the tracks, assumed to be 10 mph.

Line 31. Distance required to clear left-turning truck from travel lanes on track clearance approach (feet): This distance is calculated from the section on geometric data and section on design vehicle. This is the distance travelled by the truck, assumed to be the same length as the design vehicle, making a left turn. The formula used is as follows:

$$Distance\ required = (Line\ 4 + Line\ 5 + Line\ 12 - Line\ 11) + Line\ 29 + Line\ 10$$

Where:

Line 4 = Width of receiving approach (feet)
Line 5 = Offset distance of left turn stop bar (feet)

Line 12 = Passenger car length (feet)
Line 11 = Centerline turning radius of design vehicle (feet)
Line 29 = Distance travelled by the truck during the left turn (feet)
Line 10 = Total design vehicle length (feet)

Line 32. Additional time required to clear left-turning truck from travel lanes on track clearance approach (seconds): This is the time required to travel the distance calculated in Line 31 for the expected speed stated in Line 30. The duration of yellow and red clearance timings during right-of-way transfer (Lines 18 and 19) are subtracted out, under the assumption the left turn movement began at the onset of the yellow change interval. The time required is calculated as follows:

$$Additional\ time\ required = [\frac{(line\ 31 * 3600)}{(line\ 30 * 5280)} - line\ 18 - Line\ 19]$$

Line 33. Worst-case Left Turning Truck time (seconds): This presents the impact of a left turning truck on the clearance of queue during the track phase. This value is automatically calculated and is set to ‘0’ if ‘No’ is selected on line 28.

Line 34. 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. It is automatically calculated by the following formula:

$$L = Line\ 1 + Line\ 2 + Line\ 3$$

Line 35. Time required for the design vehicle to start moving (seconds) is the time elapsed between either (a) the time the left turning vehicle completes its turn so it is not blocking track clearance if ‘Yes’ is checked on line 28 or (b) the beginning of track clearance green if ‘No’ is checked on line 28, and the time the design vehicle, which is located at the stop bar 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 34) 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 36. 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 2), stop bar setback distance (Line 3), and the total design vehicle’s length (Line 10).

Line 37. The **Time for design vehicle to accelerate through the design vehicle clearance distance (DVCD) on level terrain**: This is the amount of time required for the design vehicle to accelerate from a stop and travel the complete design vehicle clearance distance over a level approach. This time value, in seconds, is automatically calculated by the worksheet and filled in. The formulae used for these calculations are represented by graphs in Figure 3.

Line 38. Factor to account for slower acceleration on uphill grade: If the approach over which the design vehicle has to accelerate over DVCD is an uphill grade, a factor is automatically calculated by the worksheet based on the entry in Line 6. The calculation for this factor is based on the formulae used to generate the factors in Table 2. For example, with a DVCD of 80 feet and a WB-50 intermediate truck 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 x 1.30 = 15.86 seconds, or 15.9 seconds rounded up to the next higher tenth of a second.

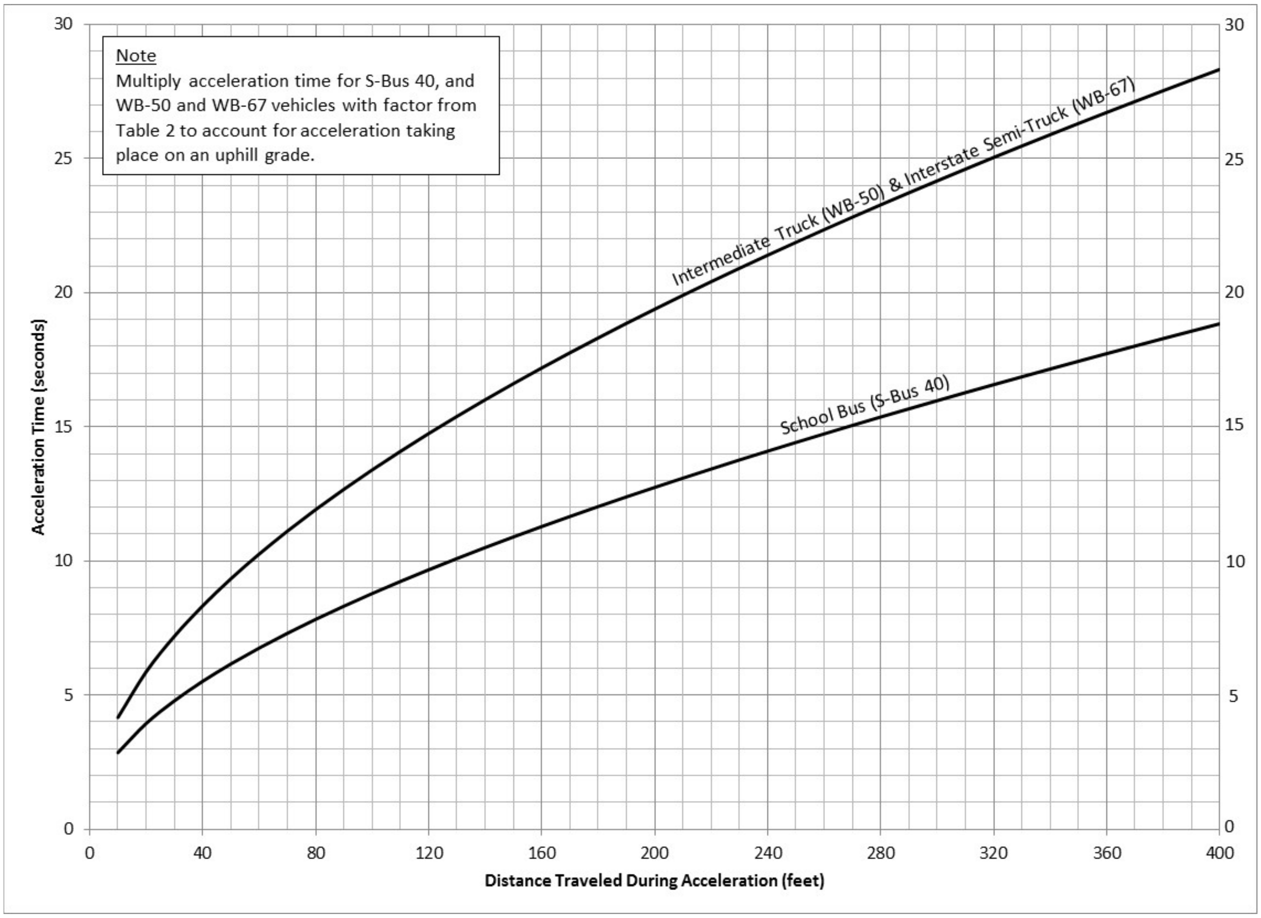

Figure 3. Acceleration time over a fixed distance on a level surface.

Table 2. Factors to account for slower acceleration on uphill grades

Acceleration Distance (ft)	Design Vehicle and Percentage Uphill Grade									
	School Bus (S-BUS 40)					Intermediate Truck (WB-50) and Interstate Semi-Truck (WB-67)				
	0-1%	**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

Line 39. Time for design vehicle to accelerate through DVCD (seconds) adjusted for grade: This value is calculated by multiplying the time for the design vehicle to accelerate through DVCD with the factor to account for the uphill grade (i.e. multiply Line 37 with Line 38).

Line 40. Queue clearance time is the total amount of time required (after the right-of-way transfer time) to begin moving a queue of vehicles through the queue start-up distance (L, Line 34) and then move the design vehicle from a stopped position at the far side of the crossing completely through the minimum track clearance distance (MTCD, Line 2). This value is the sum of the time required for the worst-case left turning truck to complete the turn movement (Line 33), the time for the design vehicle to start moving (Line 35), and the time for design vehicle to accelerate through the design vehicle clearance distance (Line 39).

SECTION 4: MAXIMUM PREEMPTION TIME CALCULATION

Line 41. Right-of-way transfer time, in seconds, recorded on Line 27. 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 42. Queue clearance time, in seconds, recorded on Line 40. 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 to start up and move completely out of the minimum track clearance distance.

Line 43. 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). Note that this value may be reduced to as low as 0 seconds if the necessary warning time is not available.

Line 44. 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 27), the queue clearance time (Line 40), and the desired minimum separation time (Line 43).

SECTION 5: SUFFICIENT WARNING TIME CHECK

Line 45. Required Minimum Time, MT (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 *TMUTCD* 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. The worksheet has a default value of 20 seconds filled in.

Line 46. 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. In cases where the minimum track clearance distance (Line 2) 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 47. Total Minimum Warning Time, MWT (seconds) is the sum of the minimum time (Line 45) and the clearance time (Line 46). 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 <u>does not</u> include buffer time (BT) or equipment response time. 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 <u>cannot be relied upon</u> by the traffic engineer for signal preemption and/or warning time calculations. Equipment response time is utilized up front by the railroad's constant warning technology to determine the approach speed of the train and send the preemption call to the traffic signal controller at the appropriate time.

Line 48. Required advance preemption time (APT) from railroad (seconds): This value is calculated by subtracting the total minimum warning time (MWT) in line 47 from the maximum preemption time for queue clearance in Line 44.

Line 49. APT currently provided by railroad (seconds), if provided, is the period of time that the notification of an approaching train is currently forwarded to the highway traffic signal controller unit or assembly <u>prior</u> 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. For new crossings or signals, a value of 0 seconds is entered.

SECTION 6: TRACK CLEARANCE GREEN TIME CALCULATION (IF NO GATE DOWN CIRCUIT PROVIDED)

Preempt Trap Check

Line 50. Warning Time Variability: 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. 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 accuracy of the warning time provided by the railroad depends on many factors. These include: the duration of APT if provided, the presence of any shunting yards or stations nearby, and whether the grade crossing is near the edges of towns or cities. The longer the APT required at a grade crossings, the greater the likelihood of variability in providing the expected warning time as there is a greater impact of a change in train speed on the warning time. The presence of shunting yards and stations near the crossings, results in trains slowing down or speeding up while on the track circuit, resulting in a variability in the warning time. Finally, grade crossings that are at the borders of towns or cities frequently have restrictions on train noise and require reduced train speeds within the cities. Hence, trains start slowing on the outskirts of cities resulting in greater variability in the warning time. The analyst must assess the variability of train warning times and select either consistent warning times, low warning time variability, or high warning time variability. Selection of one of these options generates a multiplier in Line 52.

Line 51. Advance preemption time required or 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. The larger of Line 48 (required APT) and Line 49 (APT currently provided by railroad) is automatically filled in the box.

Line 52. Multiplier for maximum APT due to train handling: The multiplier for maximum APT can be estimated as 1.60 if warning time variability is high, 1.25 if warning time variability is low, or 1.00 for consistent warning times. High warning time variability can typically be expected in the vicinity of switching yards, branch lines, or anywhere low-speed switching maneuvers takes place. These values are automatically filled in based on the option selected in Line 50.

Line 53. 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 required or provided by the railroad (Line 51) with the multiplier for maximum APT due to train handling (Line 52).

Line 54. 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.

The 15 seconds minimum duration for the track clearance green interval is calculated from Federal regulations and requirements of the *TMUTCD*. Section 8D.06 of the *TMUTCD* 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 55. Track clearance green time to avoid Preempt Trap: This is calculated by the form by adding the Maximum APT (Line 53) with the minimum duration of the track clearance green (Line 54). 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

This section calculates the track clearance green and considers the time required from clearing of the design vehicle based on the geometry of the crossing.

Line 56. Time waiting on left-turn truck (seconds): This is the time needed by a truck that is turning left from the street parallel to the tracks and can potentially block the vehicle on the track phase to start moving after the onset of the track clearance phase. This is the value in Line 33.

Line 57. Time required for design vehicle to start moving, recorded on Line 35, is the number of seconds that elapses between either (a) the time the left turning vehicle completes its turn so it is not blocking track clearance if 'Yes' is checked on line 28 or (b) the beginning of track clearance green if 'No' is checked on line 28 and the time the design vehicle, which is located at the stop bar of the railroad crossing on the opposite side from the signalized intersection, begins to move.

Line 58. 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). This is the same value as recorded on Line 36.

Line 59. Portion of CSD to clear during track clearance, This is the portion of the clear storage distance (CSD), in feet, that must be cleared of vehicles before the track clearance green interval ends. The worksheet automatically enters the value of CSD for this field based on user inputs on 2 questions before line 59.

If the CSD is smaller than the design vehicle, i.e., the spacing between the tracks and the curb is smaller than the length of the design vehicle, it is essential that the design vehicle must clear through the entire CSD before the track clearance green terminates. Hence, the CSD will be entered in Line 59.

If however the CSD is larger than the length of the design vehicle, the analyst has to decide whether to clear the design vehicle through the entire CSD or to clear the design through just the design vehicle length. If the vehicle has to clear through CSD, the CSD will be entered in Line 59. However, if the vehicle just has to clear the design vehicle length, Line 59 will be equal to DVL. 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 59 to the full value of CSD (Line 1). 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 60. Design vehicle relocation distance 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 36) and the portion of CSD to clear during the track clearance green interval (Line 59).

Line 61. The **Time required for design vehicle to accelerate through DVRD**, **Level Terrain**: 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, is calculated by the worksheet and entered in Line 61.

Line 62. Factor to account for slower acceleration on uphill grade: This is a value automatically calculated based on the grade entered in Line 6.

Line 63. Time required to accelerate design vehicle through DVRD adjusted for grade: This value is automatically calculated by multiplying Line 61 and 62.

Line 64. Time to clear portion of clear storage distance, in seconds, is the total amount of time required (after the right-of-way transfer time ends), for the left turning vehicle to get out of the way of the vehicles on the track phase (Line 56), the time required for the design vehicle to start moving (Line 57), and the time required for the design vehicle to move through the DVRD adjusted for grade (Line 63).

Line 65. The **Track clearance green interval** is the time required, in seconds, for the track clearance green interval to avoid the occurrence of the preempt trap <u>and</u> to provide enough time for the design vehicle to clear the portion of the clear storage distance specified on Line 59. The track clearance green interval time is the maximum of the track clearance green time to avoid a preempt trap (Line 55) and the track clearance green time required to clear a portion of clear storage distance (Line 64). Note that this value corresponds to a design that does not include use of a separate gate down circuit preempt.

Maximum Duration of Track Clearance Green after the gates are down (in the absence of a gate down circuit)

This section calculates the estimated duration of the track clearance green indication due to the onset of preemption after the gates are down if a separate gate down circuit preempt is not used. It is possible for a preempt to occur in any state of the traffic signal. When preempt occurs such that the right-of-way-transfer time is the maximum, it is highly likely that the track phase will continue to display the green indication after the gates are down. How long this is depends on the duration of the track clearance interval. This value will provide the analyst a tool in deciding whether or not to incorporate a gate down circuit into the preemption design. A gate down circuit, in addition to eliminating a preempt trap, provides an additional operational benefit of reducing unnecessary track clearance green time after the train has arrived at the crossing. Gate down circuits may be recommended when the value on line 68 exceeds 30 s, train counts are high, or traffic volumes on the route parallel to the tracks are high.

Line 66. Time to complete track clearance green (seconds): This is the amount of time that passes from the onset of the preemption call until the track clearance green terminates and is calculated by adding the right-of-way transfer time (Line 27) with the track clearance green interval (Line 65).

Line 67. Total time before gates are down (seconds): This is the duration for the gates to come down after the onset of preemption and is calculated by subtracting 5 seconds (the gates have to be down 5 seconds the arrival of the train) from the maximum preemption time for queue clearance (Line 44)

Line 68. Maximum Duration of Track Clearance Green after the gates are down (seconds): This value is obtained by subtracting Line 67 from Line 66 and indicates how long the track clearance indication can be green after the gates are down. The larger this value is, the more inefficient the signal operations will be. It is to be noted that this scenario would only occur when the right-of-way transfer is at its maximum value, (i.e., a green indication happens to just be starting when the preempt call is processed by the traffic signal controller). The train is assumed to travel at constant speed on the approach to the crossing.

SECTION 7: SUMMARY OF CONTROLLER PREEMPTION SETTINGS

This section summarizes in one place all the controller timings that are determined by the analysis of the Preemption Worksheet. All units are in seconds. This section should be used by the traffic signal technician when programming the controller and for field verification in the future.

Line 69. Duration Time: This value is set at 0 as a default value to ensure a preempt call is not dropped unnecessarily.

Line 70. Preemption Delay Time: This value is based on Line 13.

Right of Way Transfer Phase

Note that some traffic signal controllers may refer to this phase as ‘Selective’, ‘Entrance’, ‘Enter’ or ‘Begin’ phase.

Line 71. Minimum Green Interval: This value is based on Line 16.

Line 72. Pedestrian Walk Interval: This value is based on Line 21.

Line 73. Pedestrian Clearance Interval: This value is based on Line 22.

Line 74. Yellow Change Interval: This value is based on Line 18.

Line 75. All Red Vehicle Clearance: This value is based on Line 19.

Track Clearance Phase

Line 76. Green Interval (in the absence of gate down circuit): This value is based on Line 65.

Line 77. Green Interval (with gate down circuit): This value is based on Line 40 (queue clearance time). When using a gate down preempt circuit, only the queue clearance time is required to ensure the design vehicle sufficiently clears the tracks.

Line 78. Yellow Change Interval: This value is based on Line 18.

Line 79. All Red Vehicle Clearance: This value is based on Line 19.

Exit Phase

Note that some traffic signal controllers may refer to this phase as a ‘Return’ phase.

Line 80. Dwell/Cycle Minimum Green Time: This value is set to 0 as a recommendation to ensure that the traffic signal re-enters preemption as soon as possible in the event of a 2nd train.

Line 81. Yellow Change Interval: This value is based on Line 18.

Line 82. All Red Vehicle Clearance: This value is based on Line 19.

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APPENDIX

GENERAL GUIDELINES FOR WHEN TO TRUNCATE PEDESTRIAN CLEARANCE INTERVALS DURING PREEMPTION EVENTS AT HIGHWAY-RAIL GRADE CROSSINGS

The Texas *Manual on Uniform Traffic Control Devices* (TMUTCD) indicates that "During the transition into preemption control … The shortening or omission of any pedestrian walk interval and/or pedestrian change interval shall be permitted." The following is intended to provide general guidance to assist local transportation officials when it *may* be appropriate to truncate the pedestrian clearance interval in the presence of preemption call at a railroad grade crossing.

- The decision on whether or not to truncate the pedestrian clearance interval rests solely with the local transportation officials, in consultation with the railroad Diagnostic Team, and should be based on an engineering study of the crossing that considers the following:

    - **Pedestrian volumes**: lower pedestrian volumes reduces the probability of a pedestrian event conflicting with a train event
    - **Frequency of preemption events**: less frequent preemption events result in fewer pedestrian clearance interval/time truncations or omissions
    - **Signal timing**: if pedestrian movements are active only during a small portion of the cycle, there is less chance that a pedestrian clearance interval will be truncated or omitted
    - **Intersection geometry**: Wider crosswalks require longer pedestrian clearance intervals that are more susceptible to truncation

- Full pedestrian clearance protection should be considered at signalized intersections located on established Safe Routes to School or crossings located near a school (elementary, middle, and/or high school) facility; or at pedestrian crossings frequented by less mobile, or mobility/sight impaired pedestrian groups.
- Full truncation or Intermediate truncation may be appropriate at intersections where the width of the pedestrian crossing is less than 40 feet, or where the pedestrian clearance interval is approximately equal to the maximum vehicle change (yellow) and clearance (all-red) intervals at the intersection. Table 3 provides guidance for when to use different truncation strategies at an intersection where the maximum roadway width to be crossed by pedestrians is less than 40 feet. The following provides a general guidance that can be used to determine the pedestrian condition present at the crossing:

    - **Very Light** – This is intended to represent conditions where pedestrians crossing at the intersection are rare. These intersections would be generally located in rural areas or lightly developed areas. These would include intersections where the Diagnostic Team and local transportation officials agree that very little pedestrian traffic exists or where no pedestrian traffic was observed during the Diagnostic Team review. As general guidance, these would be intersections where one cycle out of every 20 or more cycles was used to cross pedestrians during the heaviest pedestrian times.
    - **Light** – This is intended to represent conditions where pedestrians crossing at an intersection occur, but only occasionally. These intersections might be located generally in lightly developed areas, industrial or warehouse areas, or small urban communities. These would include intersections where the Diagnostic Team and local transportation officials agree that pedestrian traffic is "light" or where during a site visit, the Diagnostic Team observes several pedestrians in the area (but not necessarily using the intersection). As general guidance, pedestrian volumes at these intersections are such that a pedestrian is likely to cross any approach at an intersection 1 cycle every 10 to 20 cycles.
    - **Moderate** – This is intended to represent conditions where pedestrians crossing at an intersection occur with regular frequency, but not all the time. These intersections might

be located generally in more densely developed areas, including areas with residential, retail, and commercial developments. These would include intersections where the Diagnostic Team and local transportation officials agree that pedestrian traffic is moderate or where during a site visit, the Diagnostic Team observes individual or small groups of pedestrians using the intersection, but not every cycle. As general guidance, pedestrian volumes at these intersections are such that a pedestrian is likely to cross any approach at an intersection 1 cycle every 4 to 10 cycles.

- **Frequent** – This is intended to represent conditions where pedestrian are frequent users of the intersection. These might be intersections where a pedestrian crosses the intersection 1 cycle out of every 1 to 3 cycles. This is also intended to represent crossings where large groups of pedestrians may use the intersection. Under this condition, the Diagnostic Team might observe the intersection being used by pedestrians almost every cycle or every other cycle. This type of condition might be found in highly developed areas with significant residential, retail, or commercial development.
- **School Crossings/Crossing Frequented by Less Mobile (Elderly) or Mobility and/or Visually Impaired Pedestrians** – This is intended to represent conditions where the intersection is located near a school and where there are significant number of school-aged children crossing the intersection. This category of crossing also applies where less mobile populations (elderly) and mobility/visually impaired pedestrians using the pedestrian crossing. These crossings include any grade crossings found along a school's Safe Routes to School walking path(s).

Table 3. Suggested Pedestrian Clearance Strategies to be used under Different Levels of Preemption Event Frequencies and Pedestrian Conditions where the Largest Pedestrian Crossing Width <u>is less than 40 feet</u>.

	Preemption Events			
Pedestrian Conditions	**Very Light (0-5 preemption events per day)**	**Light (5-10 preemption events per day)**	**Moderate (10-20 preemption events per day)**	**Frequent (> 20 preemption events per day)**
Very Light (1 cycle out of every 20 cycles or more is used to cross pedestrians)	Full Truncation	Full Truncation	Full Truncation	Full Truncation
Light (1 cycle out of every 10 to 20 cycles is used to cross pedestrians)	Full Truncation	Full Truncation	Full Truncation	Intermediate Truncation
Moderate (1 cycle out of every 4 to 10 cycles is used to cross pedestrians)	Full Truncation	Full Truncation	Intermediate Truncation	Intermediate Truncation
Frequent (1 cycle out of every 1 to 3 cycles is used to cross pedestrians)	Intermediate Truncation	Intermediate Truncation	Intermediate Truncation	Intermediate Truncation
School Crossings/Crossing Frequented by Less Mobile (Elderly) or Mobility and/or Visually Impaired Pedestrians	Full Pedestrian Clearance			

For wide intersections (40 feet or more), Table 4 provides guidance for when to use different truncation strategies at an intersection where the minimum roadway width to be crossed by pedestrians is more than 40 feet.

Table 4. Suggested Pedestrian Clearance Strategies to be used under Different Levels of Preemption Event Frequencies and Pedestrian Conditions where the Largest Pedestrian Crossing Width is 40 feet or more.

Pedestrian Conditions	Preemption Events			
	Very Light (0-5 preemption events per day)	**Light (5-10 preemption events per day)**	**Moderate (10-20 preemption events per day)**	**Frequent (> 20 preemption events per day)**
Very Light (1 cycle out of every 20 cycles or more is used to cross pedestrians)	Full Truncation	Full Truncation	Full Truncation	Intermediate Truncation
Light (1 cycle out of every 10 to 20 cycles is used to cross pedestrians)	Full Truncation	Intermediate Truncation	Intermediate Truncation	Partial Truncation
Moderate (1 cycle out of every 4 to 10 cycles is used to cross pedestrians)	Intermediate Truncation	Partial Truncation	Partial Truncation	Full Pedestrian Clearance
Frequent (1 cycle out of every 1 to 3 cycles is used to cross pedestrians)	Partial Truncation	Partial Truncation	Full Pedestrian Clearance	Full Pedestrian Clearance
School Crossings/Crossing Frequented by Less Mobile (Elderly) or Mobility and/or Visually Impaired Pedestrians	Full Pedestrian Clearance			

- The preferred locations of crossing pedestrians at all newly installed traffic signals near railroad grade crossings is shown in Figure 4. In cases where the decision is to eliminate or truncate the pedestrian clearance intervals, agencies should consider relocating crosswalks as shown in Figure 4, where practical and where pedestrian crossing behavior permits. Relocating the crosswalks to these locations will increase the conspicuity of pedestrian that might be located in the crossing to vehicles using the track clearance phase. It allows track clearance vehicles to wait in the intersection (as opposed to on the approach) for pedestrians to finish clearing the intersection.

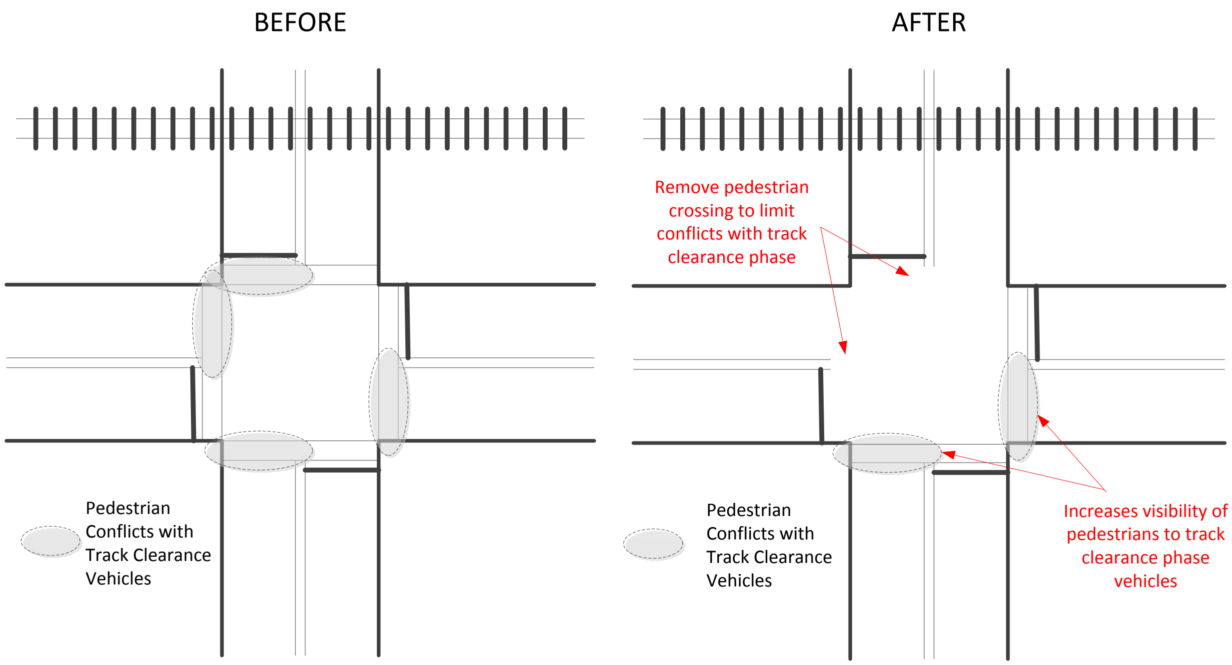

Figure 4. Recommendations for Relocating Pedestrian Crosswalks at Intersections with nearby Highway Rail Grade Crossings

The following provides a description of the different types of pedestrian clearance truncation strategies listed in Table 3 and Table 4. Truncation time (pedestrian clearance interval) is calculated by dividing the distance by 3 ft/s.

- With **Full Truncation**, the entire duration of the pedestrian clearance interval may be omitted before transitioning to the track clearance phase. Pedestrian protection is only provided during the vehicle change (yellow) and clearance (all-red) intervals of the right-of-way transition phase.
- Under the **Intermediate Truncation** strategy, the duration of the pedestrian clearance interval should be sufficient to get the pedestrian crossing from A to B and from A to D to the middle of the farthest travel lane in the pedestrian conflict zones closest to the grade crossing (see Figure 5).
- With the **Partial Truncation** strategy, sufficient time should be provided after terminating the "WALK" interval to get pedestrians crossings from B to C and crossing from C to D to the middle of the pedestrian conflict zones farthest for the grade crossing (as shown in Figure 5) to increase their conspicuity to motorists exiting the track clearance phase.
- With **Full Pedestrian Clearance**, the full amount of pedestrian clearance interval is provided after terminating the "WALK" interval before transitioning to the track clearance phase.

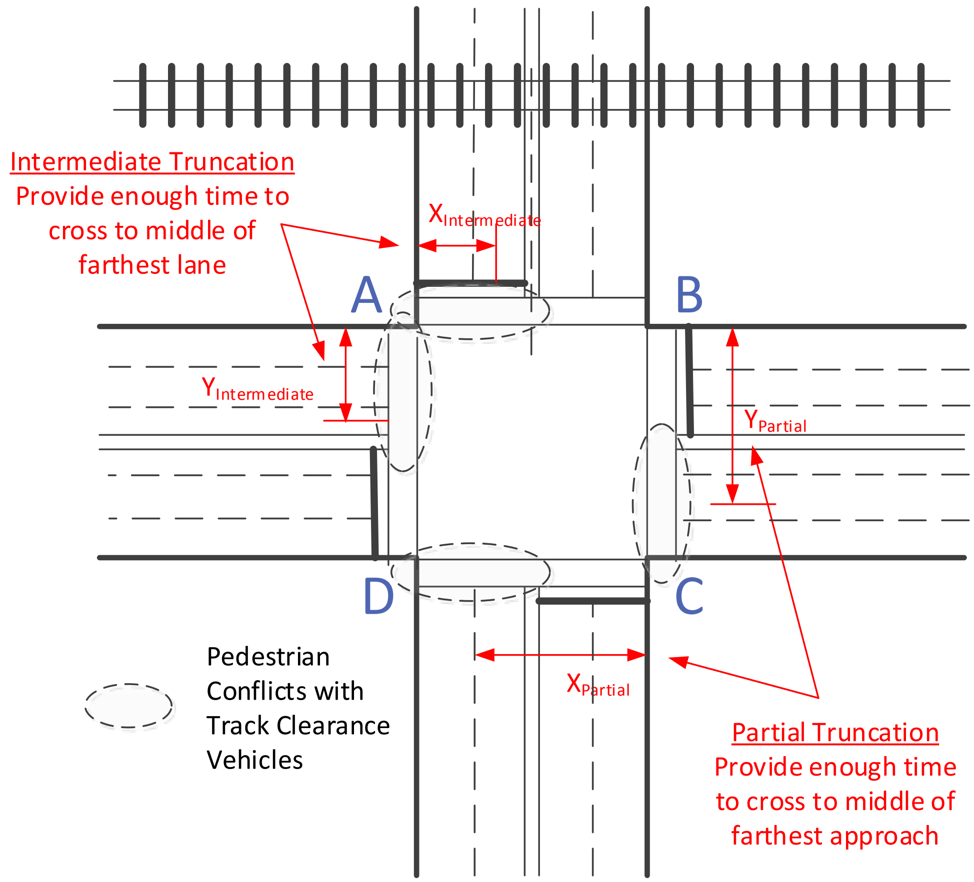

Figure 5. Crossing Distance during Truncated Pedestrian Clearance Intervals