Washington State
Department of Transportation

Railroad-Traffic Signal Preemption Timing Worksheet Instructions

R1.1 General

The instructions are provided to assist in the completion of the WSDOT Railroad Preemption Timing Worksheet. This worksheet is used for traffic signal systems at intersections that have a railroad crossing in close proximity on one leg of the intersection, to determine the amount of preemption time needed to ensure that the traffic signal system will allow for the safe clearance of vehicles from the railroad crossing before the arrival of a train.

Key to data field colors:

- Items shown in green are user-entered data. Some items have restricted options and are chosen from a drop-down list after selecting the box.
- Items in yellow are the primary advance preemption time outputs to be provided to the railroad.
- Line numbers highlighted in yellow are items that have been separated into vehicle and pedestrian specific elements.
- All items that are not colored green are calculated and entered automatically.

The most critical items for the railroad are Lines 48, 48p, 49, and 49p. These are the advance warning times needed and provided by the railroad, such that the traffic signal preemption response operates with sufficient time for a safe and effective clearance of the tracks.

After completion of the worksheet, submit it to the HQ Traffic Office for review and approval.

NOTE: This worksheet will only address a rail crossing of one leg of an intersection. Contact the HQ Traffic Office for locations where the railroad crosses more than one leg of an intersection or through the center of an intersection.

This worksheet is based on the Texas Department of Transportation (TxDOT) form 2304, Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings. Since most users who have previously done railroad preemption time calculations for WSDOT are likely to be familiar with the TxDOT form, this document and the associated worksheet borrow heavily from the TxDOT original. The Washington State Department of Transportation (WSDOT) thanks the staff at TxDOT for their hard work over the years developing this system for determining preemption timing for traffic signals at intersections with rail crossings.

If there are any questions about the worksheet or these instructions, please contact:

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R1.2 Basic Information

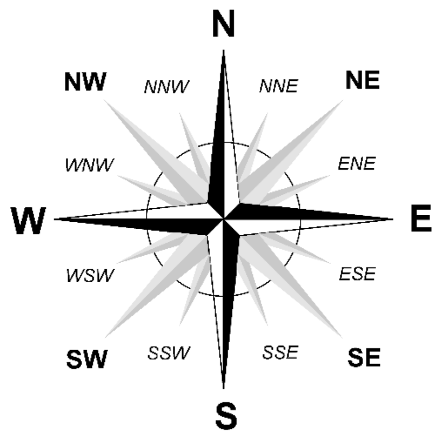
Enter the name of the person completing the form and the date of completion in the boxes at the top of the form.

Location Data

Note: Some location data fields are specific to WSDOT and may be ignored by local agencies using this form for locations that are not intersections on state highways. These items are marked with an asterisk (*).

- If the location is within the municipal boundary of a city (city limits), enter the name of the city.
- Enter the county where the intersection is located.
- *Enter the WSDOT Region where the intersection is located.
- *Enter the State Route, State Route Milepost (SRMP), and Accumulated Route Mileage (ARM) of the intersection, as shown in the State Highway Log. The ARM value is included because it will never change over the life of the highway, whereas the SRMP could.
- Enter the parallel road and crossing road names. The crossing road is the road with the railroad crossing. Use both the state highway identifier (ex: SR 999, US 999) and the local road name for state highways, when there is a local road name.
- Enter the reference direction compass direction. Locate the intersection diagram on the worksheet and its reference direction arrow. Orient the diagram to match the actual intersection. Select the closest approximate direction from the drop-down list – cardinals (N, S, E, W), ordinals (NE, SW, etc.), and secondary intercardinal directions (WNW, SSE, etc.) are provided (see Exhibit R1.2-1 for reference compass rose). This reference direction is used as an aid in orienting the diagram when no other orientation references are available.

Exhibit R1.2-1 Intersection Orientation Compass Rose



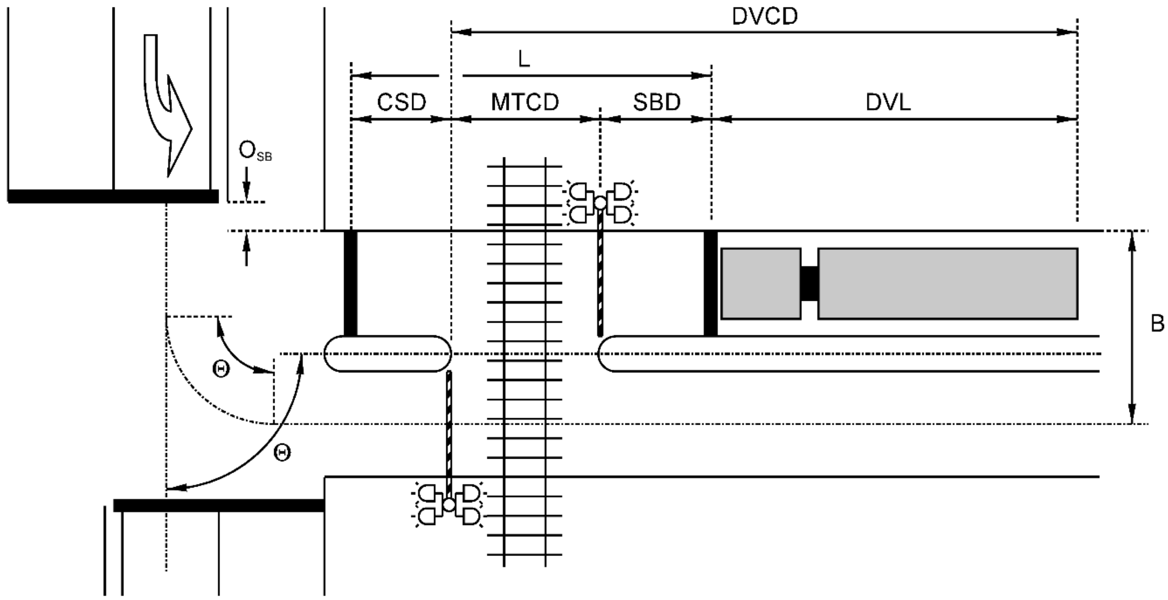
Railroad Data

This block documents the railroad crossing information. Enter the following information for the railroad:

- Railroad: the name of the owning railroad company
- Railroad Contact, Contact E-mail, and Contact Phone #: The name of the point of contact for the railroad company, their e-mail address, and their phone number.
- Rail Crossing DOT #. All railroad crossings have a federal US DOT Crossing number consisting of a seven-character ID (six numbers and one letter). The crossing DOT # should be obtained from the crossing site, but can also be looked up through the US DOT Federal Railroad Administration (FRA) by Location Query at https://safetydata.fra.dot.gov/officeofsafety/publicsite/crossing/xingqryloc.aspx, or the Washington State Utilities and Transportation Commission (UTC) Railroad Crossings Inventory site at https://www.utc.wa.gov/regulated-industries/transportation/regulated-transportation-industries/railroads/inventory-public-railroad-crossings. These inventories may use different road names than expected, so field verification of the crossing US DOT # is necessary.

R1.3 Basic Geometric and Design Vehicle Data

Exhibit R1.3-1 Intersection Geometric Elements



Line 1: Enter the **Clear Storage Distance** (CSD, in Exhibit R1.3-1), in feet.

This distance is the shortest distance along the crossing road as measured between the intersection stop line of the crossing road and the edge of the rail crossing nearest the intersection. The edge of the rail crossing is measured from the edge of the typical dynamic envelope, which is a line parallel to the rail offset 6 feet to the outside of the tracks. Where the railroad crosses at an angle, use the <u>shortest</u> distance between the rail crossing and the crossing road intersection stop line, which will typically be along one of the edge lines of the road with the rail crossing.

Line 2: Enter the **Minimum Track Clearance Distance** (MTCD, in Exhibit R1.3-1), in feet.

This distance is the length along the road with the rail crossing, as measured from the automatic gate arm for the direction approaching the intersection to the far side of the dynamic envelope (normally 6 feet beyond the farthest rail from the crossing gate). Where the railroad crosses at an angle, use the longest distance between the crossing gate and the far side of the dynamic envelope. Where there is no automatic gate arm, use the rail crossing stop line instead.

Line 3: Enter the **Stop Bar Setback Distance** (SBD, in Exhibit R1.3-1), in feet.

This distance is the length along the road with the rail crossing, as measured between the automatic gate arm and the rail crossing stop line for the direction approaching the intersection. If there is no stop line, enter a value of zero. The default value is 8 feet, in accordance with MUTCD standards.

Line 4: Enter the **Width of the receiving approach** (B, in Exhibit R1.3-1), in feet.

This distance is measured on the roadway with the rail crossing, from the far-right edge of the lane(s) approaching the rail crossing and the intersection and the middle of the left-most lane leaving the rail crossing and the intersection.

Line 5: Enter the **Offset distance of the left-turn Stop Bar** (OSB, in Exhibit R1.3-1), in feet.

This distance is the distance between the right edge of the road approaching the rail crossing and the intersection, and the stop line for the left turn lane for traffic that will turn from the parallel road onto the road with the rail crossing.

Line 6: Enter the **Approach Grade**, in percent.

The approach grade is the grade of the roadway approaching the rail crossing and the intersection. If a grade has not been established, use the average of grade measurements taken along the lanes approaching the rail crossing and the intersection at the rail crossing stop line, 30 feet back from the stop line, and 60 feet back from the stop line – see the tractor trailer location in Exhibit R1.3-1. Where the approach grade is flat or downhill, enter a value of zero.

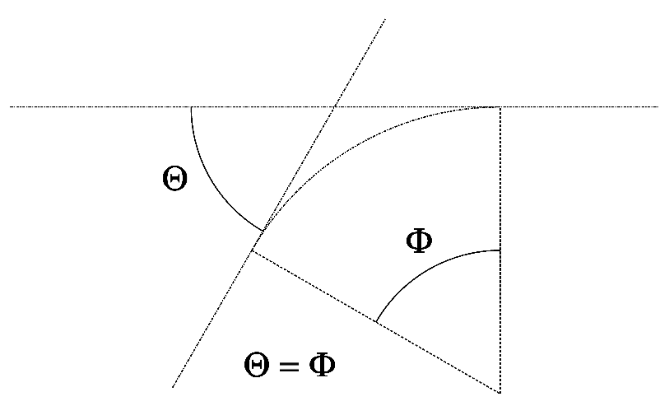
Line 7: Enter the **Angle of Turn at Intersection** (Θ, in Exhibit R1.3-1), in degrees.

This is the angle of the turn made by a vehicle turning left onto the roadway approach with the rail crossing. Measure one of the following (both angles are the same; see Exhibit R1.3-2):

- The angle of the arc made by a vehicle making the left turn (Φ).
- The angle between the centerlines of the approaches, facing the corner of the intersection formed by the parallel street approach opposite the left turn and the approach with the railroad crossing (Θ).

Round to the nearest one degree. Intersections that are effectively perpendicular can be assumed to be at 90 degrees.

Exhibit R1.3-2 Equivalent Angle Diagram



Line 8: Select the **Design Vehicle**

Select the desired design vehicle from the drop-down list:

- School Bus (or large City Bus)
- WB-40 (Intermediate) Truck
- WB-67 (Interstate Semi) Truck – default value
- Other Truck (75 ft)

Use the longest legal design vehicle for the approach with the rail crossing. Use the next larger vehicle size if the design vehicle is not listed.

Line 9: **Design Vehicle Length**, in feet

This value is entered automatically based on the Design Vehicle selected on Line 8:

- School Bus: 40 ft
- WB-40 (Intermediate) Truck: 55 ft
- WB-67 (Interstate Semi) Truck: 75 ft
- Other Truck: 75 ft

Additional vehicle length (in feet) can be added on **Line 9a** if a 75-foot vehicle is not sufficient.

Line 10: Total **Design Vehicle Length** (DVL, in Exhibit R1.3-1), in feet.

Total length of the design vehicle as calculated by adding Lines 9 and 9a.

Line 11: **Centerline turning radius of design vehicle** (R), in feet.

This is the approximate turning radius of the design vehicle. This value is entered automatically based on the Design Vehicle selected on Line 8:

- School Bus (35.4 ft)
- Intermediate Truck (41 ft)
- Semi Truck (41 ft)
- Other (41 ft)

Line 12: **Passenger car vehicle length** (LV), in feet.

This is the AASHTO length of a passenger car and is automatically set at 19 feet.

R1.4 Right of Way Transfer Time Calculation

Preempt verification and response time

Enter the traffic signal **Controller Manufacturer** and **Firmware Version**, when known.

Line 13: Enter the **Preempt Delay Time**, in seconds.

The preempt delay time is the amount of time that the traffic signal controller waits between when a preemption call is initially received before it initiates preemption. This value should be zero unless otherwise justified. Some controllers may not have this feature.

Line 14: Enter the **Controller response time to preempt**, in seconds.

This the time it takes the controller unit to respond to a preempt call. This value needs to be obtained from the controller manufacturer (may be provided in the controller documentation). Ideally this value is zero.

Line 15: **Preempt verification and response time**, in seconds.

This is the total time between when the controller receives a preempt call and when the controller initiates the preemption response (enters preemption). This value is the sum of lines 13 and 14 and is automatically calculated and entered.

Worst-case conflicting vehicle time

These items relate to the vehicle phase that it takes the longest to transition from and into the track clearance green phase.

Enter the **worst-case conflicting vehicle phase number**.

Line 16: Enter the **minimum green time during right-of-way transfer**, in seconds.

This is the minimum number of seconds that any existing phase will display a green indication before the controller will terminate the phase and commence the clearance interval to transition to the track clearance green phase. The default value is 5 seconds, and a minimum of 2 seconds is recommended. This value may be reduced to zero when justified. Note that this is not the same as the minimum green time for any phase during normal traffic signal system operations.

During a preemption event, any green time already displayed is subtracted from this value. For example, if this value is set at 5 seconds, and a green has been displayed for 3 seconds, then the clearance interval for that phase will start in 2 seconds.

Line 17: Enter any **other green time during right-of-way transfer**, in seconds.

If any additional green time is required beyond the preempt minimum green time for the worst-case vehicle phase, enter it here. This value is normally zero unless otherwise justified.

Line 18: Enter the **yellow change time**, in seconds.

This is the required yellow change interval time during right-of-way transfer to the track clearance green phase. The yellow change interval time shall not be shortened or omitted as part of preemption response. Where a controller only allows one input value for a yellow change time as part of preemption response, the longest yellow change interval time should be entered.

Line 19: Enter the **red clearance time**, in seconds.

This is the required red clearance (all red) interval time during right-of-way transfer to the track clearance green phase. The red clearance interval time shall not be shortened or omitted as part of preemption response. Where a controller only allows one input value for a red clearance time as part of preemption response, the longest red clearance interval time should be entered.

Line 20: **Worst-case conflicting vehicle time**, in seconds.

This is the longest total time necessary for the controller to shift to track clearance green from any other conflicting phase in green. This value is the sum of lines 16 through 19 and is automatically calculated and entered.

<u>Worst-case conflicting pedestrian time</u>

These items relate to the pedestrian phase that it takes the longest to transition from and into the track clearance green phase.

Enter the **worst-case conflicting pedestrian phase number**.

Line 21: Enter the **minimum walk time during right-of-way transfer**, in seconds.

This is the minimum time that the walk display is shown for the conflicting pedestrian phase. The MUTCD permits this to be shortened or omitted from standards during a preemption event. The default value is zero, which is recommended.

Line 22: Enter the **pedestrian clearance time during right-of-way transfer**, in seconds.

This is the time required for the conflicting pedestrian clearance interval (flashing don't walk indication). This time shall be calculated using standard engineering practices and <u>shall not be reduced or omitted</u>. Due to the risk of a pedestrian being deaf and/or blind, there is no way to safely ensure that the pedestrian knows that they need to move more quickly or change direction in order to clear the intersection faster.

Line 23: Enter any **vehicle yellow change time**, in seconds, that is not already included in line 22.

This value is any vehicle yellow change interval time after the completion of the pedestrian clearance phase. If the vehicle yellow change time ends at the same time as the pedestrian clearance interval, enter a value of zero. Some controllers will allow the vehicle yellow change interval to start early during a preemption event, as opposed to the WSDOT standard practice of starting the yellow change interval at the end of the pedestrian clearance interval. At no time should the vehicle red clearance interval start before the end of the pedestrian clearance interval. This value may be different from line 18, since the worst-case pedestrian phase may be different from the worst-case vehicle phase.

Line 24: Enter the **vehicle red clearance time**, in seconds.

This value is the vehicle red clearance interval time provided after the end of the pedestrian clearance interval. For WSDOT systems, the vehicle red clearance interval should not start until the end of the pedestrian clearance interval, so this value will never be zero.

Line 25: **Worst-case conflicting pedestrian time**, in seconds.

This is the longest total time necessary for the controller to shift to track clearance green from any other conflicting pedestrian walk phase. This value is the sum of lines 21 through 24 and is automatically calculated and entered.

Right-of-Way Transfer Times

These are the longest times it takes to transfer right-of-way to the track clearance green phase from the worst-case conflicting vehicle and pedestrian phases. These values are provided separately so that they can be used for the railroad advance preemption circuit and the railroad advance pedestrian preemption circuit, which are more frequently installed as separate circuits.

Line 26: **Vehicle right-of-way transfer time**, in seconds.

This is the total time required by the controller from the reception of the preemption signal to the start of the track clearance green phase, based on the worst-case conflicting vehicle phase. This value is the sum of lines 15 and 20, and is automatically calculated and entered.

Line 27: **Pedestrian right-of-way transfer time**, in seconds.

This is the total time required by the controller from the reception of the preemption signal to the start of the track clearance green phase, based on the worst-case conflicting pedestrian phase. This value is the sum of lines 15 and 25, and is automatically calculated and entered.

R1.5 Queue Clearance Time Calculation

This section calculates the time required to clear vehicles (the queue) from the tracks before the arrival of the train. The basis of this time is the time required for the design vehicle to start moving and then clear the design vehicle clearance distance. This time is impacted by the time required for a truck turning left from the parallel street to clear the intersection, which delays the start of the design vehicle clearing the tracks, if such a left turn is possible at the intersection.

Line 28: **Are there left turns towards the tracks?** (Yes/No)

Select “Yes” from the drop-down menu if it is possible to turn left from the street parallel to the tracks towards the rail crossing. Select “No” if this movement is not possible. This selection directly affects the values in lines 29, 31, 32, and 33.

NOTE: Lines 28a through 28d have been separated out from the basic design vehicle selected in Line 8. This is to provide greater flexibility in vehicle management, such as prohibiting left turns by certain vehicles without restrictions on any other movements.

Line 28a: Select the **Left Turn Design Vehicle** (LTDV)

Select the desired design vehicle from the drop-down list:

- School Bus (or large City Bus)
- WB-40 (Intermediate) Truck
- WB-67 (Interstate Semi) Truck – default value
- Other Truck (75 ft)

Use the longest legal design vehicle that is permitted to make a legal left turn onto the roadway approach with the rail crossing. Use the next larger vehicle szie if the design vehicle is not listed here.

Line 28b: **Left Turn Design Vehicle Length**, in feet

This value is entered automatically based on the Design Vehicle selected on Line 8:

- School Bus: 40 ft
- WB-40 (Intermediate) Truck: 55 ft
- WB-67 (Interstate Semi) Truck: 75 ft
- Other Truck: 75 ft

Additional vehicle length (in feet) can be added on **Line 28c** if a 75-foot vehicle is not sufficient.

Line 28d: Total **Design Vehicle Length** (DVL, in Exhibit R1.3-1), in feet.

Total length of the design vehicle as calculated by adding Lines 28b and 28c.

Line 29: The **distance travelled by truck (LTDV) during the left turn** (LTL), in feet.

This is the distance travelled by a truck turning left from the street parallel to the railroad towards the rail crossing. This distance is calculated through the following formula:

$$LTL = \frac{\pi R \theta}{180} \qquad \textit{Equation (L29)}$$

Where:

- R = The centerline turning radius of the left turning design vehicle, from Line 11.
- Θ = The angle of the street from which the design vehicle is making the left turn, from Line 7.

If "Yes" was selected on Line 28, the calculated value of LTL is automatically entered. If "No" was selected on Line 28, a value of zero is automatically entered.

Line 30: The **travel speed of the left turning truck (LTDV)** (SLTT), in MPH.

This is the average speed of the design vehicle making the left turn towards the rail crossing. This is set at 10 MPH by default.

Line 31: **Distance required to clear left turning truck (LTDV) from travel lanes on track clearance approach**, in feet.

This is the total distance traveled by the truck making a left turn towards the rail crossing until it clears the intersection. The total distance traveled is:

$$Distance = x + LTL + LTDVL \qquad \textit{Equation (L31-1)}$$

Where:

- x = The distance traveled before starting the turn, in feet.
- LTL = The distance traveled during the turn, in feet, from Line 29.
- LTDVL = The length of the Left Turn Design Vehicle, in feet, from Line 28d. This is the distance traveled until the rear of the design vehicle is clear of the intersection.

The equation for x is:

$$x = B + O_{SB} + L_V - R \qquad \textit{Equation (L31-2)}$$

Where:

- B = The width of the receiving approach, in feet, from Line 4.
- O_{SB} = The offset distance of the left turn stop bar, in feet, from Line 5.
- L_V = The standard passenger car length, in feet, from Line 12.

- R = The centerline turning radius of the design vehicle, as from Line 11.

If "Yes" was selected on Line 28, the total distance required is automatically calculated and entered. If "No" was selected on Line 28, a value of zero is automatically entered.

Line 32: **Additional time required to clear left turning truck from travel lanes on the track clearance approach**, in seconds.

This is the time required for the design vehicle to travel the distance calculated in Line 31 at the speed determined in Line 30. This time is calculated from the following equation:

$$Additional\ time\ required = [((Line\ 31 \times 3600))/((Line\ 30 \times 5280)\ )] - Line\ 18 - Line\ 19 \qquad \text{Equation (L32)}$$

The durations of the yellow change time (Line 18) and red clearance time (Line 19) are subtracted out, under the assumption that the left turn begins at the start of the yellow change interval. If "Yes" was selected on Line 28, the additional time required is automatically calculated and entered. If "No" was selected on Line 28, a value of zero is automatically entered.

Line 33: **Worst-case left-turning truck time**, in seconds.

This is the impact of a conflicting left-turning truck on the time required to clear any queue on the track crossing. If "Yes" was selected on Line 28, the value from Line 32 is automatically entered. If "No" was selected on Line 28, a value of zero is automatically entered.

Line 34: **Queue start-up distance** (L, in Exhibit R1.3-1), in feet.

This is the length of the queue which must start up and move so that the design vehicle can move out of the railroad crossing before the train arrives. This value is the sum of the CSD (Line 1), the MTCD (Line 2), and the SBD (Line 3), and is automatically calculated and entered.

Line 35: **Time required for design vehicle to start moving**, in seconds.

This is the time between when the first driver in the queue initiates response to either a clear intersection (if "Yes" selected on Line 28) or the start of track clearance green (if "No" selected on Line 28) and when the design vehicle, located at the rail crossing stop line, begins to move. This time is calculated as the queue start-up distance (L) divided by a wave speed of 20 feet per second, plus an additional 2 seconds to account for the perception/reaction time of the first driver in the queue. The 2 second perception/reaction time is conservative and accounts for a limited level of driver inattentiveness. The overall time is automatically calculated and entered.

Line 36: **Design vehicle clearance distance** (DVCD, in Exhibit R1.3-1), in feet.

This is the length, in feet, which the design vehicle must travel in order to enter and fully clear the minimum track clearance distance (MTCD). This value is the sum of Lines 2, 3, and 10, and is automatically calculated and entered.

Line 37: **Time for design vehicle to accelerate through the design vehicle clearance distance (DVCD) on level terrain**, in seconds.

This is the time required for the design vehicle to accelerate from a stop and travel the entire length of the DVCD on a level approach. This value is based on traveling the DVCD at a constant rate of acceleration. The formula for this value is:

$$Time\ to\ clear\ DVCD = \sqrt{}((2 \times DVCD)/a) \qquad \textit{Equation (L37)}$$

Where a is an acceleration rate of 2.3 feet/second^2 is used, where a School Bus is selected on Line 8, and is 1 foot/second^2 for all other design vehicles. The overall time is automatically calculated and entered.

Line 38: **Factor to account for slower acceleration on uphill grade**.

If the approach where the DVCD is evaluated is an uphill grade, a factor is automatically calculated based on the grade entered in Line 6. Factors are based on grade, distance, and design-vehicle type, as listed in Tables L38-1 (for school buses) and L38-2 (for all other design vehicles) below. These tables were developed by TxDOT and are reproduced here.

Table L38-1 Grade acceleration factors for school buses

Distance	0%	2%	4%	6%	8%
25	1	1.01	1.10	1.19	1.28
50	1	1.01	1.12	1.21	1.30
75	1	1.02	1.13	1.23	1.33
100	1	1.02	1.14	1.25	1.35
125	1	1.03	1.15	1.26	1.37
150	1	1.03	1.16	1.28	1.40
175	1	1.03	1.17	1.29	1.42
200	1	1.04	1.17	1.30	1.43
225	1	1.04	1.18	1.32	1.45
250	1	1.04	1.19	1.33	1.47
275	1	1.05	1.20	1.34	1.49
300	1	1.05	1.20	1.35	1.50
325	1	1.05	1.21	1.36	1.52
350	1	1.05	1.22	1.37	1.54
375	1	1.06	1.22	1.38	1.55
400	1	1.06	1.23	1.40	1.57

Table L38-2 Grade acceleration factors for all other design vehicles

Distance	0%	2%	4%	6%	8%
25	1	1.09	1.27	1.42	1.55
50	1	1.10	1.28	1.44	1.58
75	1	1.11	1.30	1.47	1.61
100	1	1.11	1.31	1.48	1.64
125	1	1.12	1.32	1.50	1.66
150	1	1.12	1.33	1.52	1.68
175	1	1.12	1.34	1.53	1.70
200	1	1.13	1.35	1.54	1.72
225	1	1.13	1.35	1.56	1.74
250	1	1.13	1.36	1.57	1.76
275	1	1.14	1.37	1.58	1.77
300	1	1.14	1.37	1.59	1.79
325	1	1.14	1.38	1.60	1.81
350	1	1.15	1.39	1.61	1.82
375	1	1.15	1.39	1.62	1.84
400	1	1.15	1.40	1.63	1.85

The worksheet automatically interpolates the appropriate grade factor based on the calculated DVCD (Line 36) and the grade entered on Line 6. The applicable factor is automatically determined and entered.

Line 39: **Time for design vehicle to accelerate through DVCD, adjusted for grade**, in seconds.

This is the time required for the design vehicle to accelerate from a stop and travel the entire length of the DVCD on an approach with an uphill grade. This value is determined by multiplying the time required to accelerate through DVCD on a level approach (Line 37) by the grade factor determined in Line 38. This value is automatically calculated and entered.

Line 40: **Queue clearance time**, in seconds.

This is the total amount of time required from the start of track clearance green (or after the intersection is clear from a conflicting turning truck) until the design vehicle in the queue has cleared the MTCD. This value is the sum of Lines 33, 35, and 39, and is automatically calculated and entered.

R1.6 Maximum Preemption Time Calculation

This section determines the amount of traffic signal system preemption time needed to clear the queue from the rail crossing. Times are provided for both vehicle preemption (advance preemption time) and pedestrian preemption (advance pedestrian preemption time).

<u>Maximum Vehicle Preemption Time Calculation</u>

Line 41: **Vehicle right-of-way transfer time**, in seconds.

> This is the amount of time required to transfer right-of-way from the worst-case conflicting vehicle phase to the start of the track clearance green phase. The value from Line 26 is automatically entered.

Line 42: **Queue clearance time**, in seconds.

> This is the time required for the queue across the tracks to clear, from the start of the track clearance green phase to the time the design vehicle has fully cleared the tracks. The value from Line 40 is automatically entered.

Line 43: Enter the **desired minimum separation time**, in seconds.

> This is time added as a “buffer” between the time the design vehicle has cleared the tracks (MTCD) and the time of arrival of the train. Separation time is added for both safety and driver comfort reasons. Having no separation time risks the possibility of a vehicle clearing the tracks at the same time as the train arrives, which is almost certain to result in severe driver discomfort and potentially unsafe behavior. A default recommended value of four seconds is provided, which is based off of ITE recommendations. This value may be reduced to as low as one second if the necessary warning time is not available. Reduction to zero is possible but not recommended.

Line 44: **Maximum preemption time for queue clearance without pedestrians**, in seconds.

> This is the total amount of time required from when the preemption signal is initiated by the railroad circuits until the design vehicle has cleared the tracks on the conflicting intersection approach, where the worst-case conflicting pedestrian phase is not active (no pedestrian crossing is occurring). This time is the sum of the vehicle right-of-way transfer time (Line 41), the queue clearance time (Line 42), and the desired minimum separation (buffer) time (Line 43). This value is automatically calculated and entered.

<u>Maximum Pedestrian Preemption Time Calculation</u>

Line 41p: **Pedestrian right-of-way transfer time**, in seconds.

> This is the amount of time required to transfer right-of-way from the worst-case conflicting pedestrian phase to the start of the track clearance green phase. The value from Line 27 is automatically entered.

Line 42p: **Queue clearance time**, in seconds.

This is the same time as described for line 42, and the value from Line 42 is automatically entered.

Line 43p: **Desired minimum separation time**, in seconds.

This is the same time as described for Line 43, and the value from Line 43 is automatically entered.

Line 44p: **Maximum preemption time for queue clearance with pedestrians**, in seconds.

This is the total amount of time required from when the preemption signal is initiated by the railroad circuits until the design vehicle has cleared the tracks on the conflicting intersection approach, where the worst-case pedestrian phase is active (a pedestrian crossing is occurring). This time is the sum of the vehicle right-of-way transfer time (Line 41), the queue clearance time (Line 42), and the desired minimum separation (buffer) time (Line 43). This value is automatically calculated and entered.

R1.7 Sufficient Warning Time Check

This section determines the amount of warning time needed from the railroad beyond what is normally provided for the rail crossing signal (and gate, when present) system. The values determined in this section are used to establish the Advance Vehicle Preemption Time (AVPT) and Advance Pedestrian Preemption Time (APPT) needed from the railroad.

Line 45: **Required minimum time (MT)**, in seconds.

This is the minimum amount of time that the rail crossing warning system shall be active before a train arrives at the crossing. This value is automatically entered as 20 seconds in accordance with MUTCD Section 8C.08. This time may be reduced under the specific conditions described in MUTCD Section 8C.08 – any reduction should be addressed, and the final time(s) needed updated by hand and described in the remarks block after Line 49p.

Line 46: **Clearance Time (CT)**, in seconds.

This is the additional time that may be provided by the railroad to account for longer crossing times at wide (such as multiple-track) or skewed-angle crossings. In cases where the minimum track clearance distance (MTCD, Line 2) exceeds 35 feet, the railroad *AREMA Manual* requires clearance time at a ratio of one second for each additional 10 feet of MTCD be provided. This value is calculated using by subtracting 35 from Line 2 (MTCD), dividing by 10, and then rounding up to the nearest full second. Where the MTCD is greater than 35 feet, this value is automatically calculated and entered. Where the MTCD is 35 feet or less, a value of zero is automatically entered.

Line 47: **Total Minimum Warning Time (MWT)**, in seconds.

This is the actual minimum time that the railroad crossing signals can be expected to operate before the arrival of a train at the crossing under normal operations, where a train does not start, stop, or make a significant speed change while near or at the crossing. The MWT does not include railroad signal Buffer Time (BT) or equipment response time. BT may be added by the railroad to ensure that the MWT is always provided despite potential variations in warning times but is not consistently provided and cannot be relied upon for signal preemption time calculations. Equipment response time is utilized 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, based on that speed. Because this occurs before the preemption signal is sent to the traffic signal controller, it is not included in the signal preemption time calculations. The value for MWT is the sum of the minimum time (Line 45) and the clearance time (Line 46), and is automatically calculated and entered.

Line 47a: **Buffer Time (BT) from railroad**, in seconds.

This is additional time provided to account for trains that may accelerate on approach to a crossing. Typical value is 10 seconds (entered by default), but this must be verified with the railroad.

Line 47b: **Equipment Response Time (ERT) from railroad**, in seconds.

This is additional time provided to allow the railroad preemption equipment to determine the speed of the approaching train. Typical value is 4 seconds (entered by default), but this must be verified with the railroad.

Line 48: **Required advance vehicle preemption time (AVPT) from railroad**, in seconds.

This is the total time needed from the railroad beyond the MWT already provided for the rail crossing signals in order to support traffic signal preemption, where the worst-case pedestrian phase is not active (no pedestrian crossing is occurring). This value subtracts the MWT (Line 47) from the maximum preemption time for queue clearance without pedestrians determined on Line 44 and is automatically calculated and entered.

Line 48a: **Total Approach Time – Vehicles (TAT-V)**, in seconds.

This is the total railroad circuit preemption time. This value is the sum of the following:

- MWT (Line 47)
- BT (Line 47a)
- ERT (Line 47b)
- AVPT (Line 48)

The AREMA Communications & Signals Manual, Part 3.1.10, Section C, restricts the total system design to 50 seconds, not including equipment response time. If the TAT-V exceeds 50 seconds plus the ERT, then the cell will flag red for notification. The worksheet will automatically update to show the allowed TAT (50 seconds plus ERT) value in the remarks.

If the TAT-V exceeds the maximum time allowable, then revisions will need to be made, and additional discussions with the railroad may be necessary.

Line 48p: **Required additional advance pedestrian preemption time (APPT) from railroad**, in seconds.

This is the additional time needed from the railroad, beyond that needed for the AVPT, in order to support traffic signal preemption, where the worst-case pedestrian phase is active (a pedestrian crossing is occurring). This value subtracts the MWT (Line 47) and the AVPT (Line 48) from the maximum preemption time for queue clearance with pedestrians determined on Line 44p and is automatically calculated and entered.

Line 48pa: **Total Approach Time – Pedestrians (TAT-V)**, in seconds.

This is the total railroad circuit preemption time. This value is the sum of the following:

- MWT (Line 47)
- BT (Line 47a)
- ERT (Line 47b)
- AVPT (Line 48)
- APPT (Line 48p)

Similar to the TAT-V, if the TAT-P exceeds 50 seconds plus the ERT, then the cell will flag orange for notification. There is some flexibility to allow for an advance pedestrian preemption circuit to extend beyond the 50 seconds plus ERT time, but any allowable extended time must be established with the railroad. It is preferable to try and get TAT-P time below the 50 seconds plus ERT threshold. The worksheet will automatically update to show the allowed TAT (50 seconds plus ERT) value in the remarks.

Line 49: Enter the **AVPT currently provided by railroad**, in seconds.

This is the amount of AVPT currently provided by the railroad, if any, provided in advance of the railroad MWT. Only enter a value for an existing crossing where the existing provided value can be verified. For new rail crossings or new traffic signals, the default value of zero is used.

Line 49p: Enter the **APPT currently provided by railroad**, in seconds.

This is the amount of AVPT currently provided by the railroad, if any, provided in advance of the railroad MWT. Only enter a value for an existing crossing where the existing provided value can be verified. For new rail crossings or new traffic signals, the default value of zero is used.

Notes and remarks.

The end of this subsection includes important notes and remarks to be made by the person completing the worksheet.

There is a reminder of the following items:

- If Line 48 and Line 49 are not the same, then additional Advance Preemption Time (AVPT) must be requested from the railroad to increase the value in Line 49 so that they do match.
- If Line 48p and Line 49p are not the same, then additional Advance Pedestrian Preemption Time (APPT) must be requested from the railroad to increase the value in Line 49p so that they do match.

Recent changes to railroad track circuit guidelines have resulted in these two preemption times now being more commonly provided as separate circuits.

In the remarks section, include the following:

- If the clearance time (CT) on Line 46 needs to be manually increased, note the manual increase here and the associated changes to Lines 48 and 48p. Since this is an extremely rare occurrence, a manual change to CT is not available within the calculations.
- Any other notes or comments that affect user entered data and will not fit in the line specific comments box.

The remarks section may also include general notes or comments about the location.

Submitting preemption times to a railroad

Railroads will typically have their own preemption request forms, with places to enter requested preemption times.

When submitting a preemption time request to a railroad, it is important to note how they want the preemption time needed described to them. The worksheet provides an APPT time as additional time to be added to the AVPT (often just “Advance Preemption Time” (APT) on railroad forms). If is requested as a separate total preemption time, add Line 48p to Line 48 and provide the total time as the APPT (uncommon).

R1.8 Track Clearance Green Time Calculation

This section is provided to help calculate the time needed for the track clearance green phase. The time provided in this section is necessary when a gate down circuit is not provided by the railroad, so that the track clearance green phase can be terminated at the appropriate time and reduce the risk of late, illegal, or dangerous crossings. All new installations should include a gate down circuit.

Preempt Trap Check

This section determines the amount of track clearance green time to avoid a preempt trap. A preempt trap occurs when the track clearance green phase ends before the rail crossing signal system starts (or the gates are fully lowered, when present), potentially resulting in vehicles being stopped on the tracks when the rail crossing signal system starts and unable to clear the tracks due to the phase of the traffic signal.

Line 50: Select the **warning time variability**.

This is the likelihood of the railroad advance warning time varying due to train operations. The railroad may guarantee a minimum duration for advance preemption time (APT), but there are cases where the APT will be longer than the minimum due to variations in railroad operations, such as a train accelerating or decelerating near the crossing – referred to as “train handling”. If a train changes speed near the crossing, the railroad warning system cannot accurately estimate the arrival time of the train, and the APT ends up being different than expected. These variations need to be taken into account in order to provide the safest operations possible.

To prevent a preempt trap, the maximum value of APT needs to be determined so that the traffic signal track clearance green interval can be programmed to be long enough to end after the crossing gates are fully down. Where APT is provided, the difference between the minimum and maximum values of APT are referred to as “excess APT”. Excess APT usually occurs when a train decelerates as it approaches a crossing, or where train handling affects the accuracy of the estimated time of train arrival at the crossing such that the preempt sequence is activated earlier than expected. The amount of excess APT is increased by the following conditions:

- Increased variations in train speeds (more speeding up and slowing down).
- Lower train speeds: a fixed rate of deceleration has a greater effect at slow speeds.
- Longer warning times: there is more opportunity for the train to decelerate before reaching the crossing.

The accuracy of the APT provided by the railroad depends on many factors, such as the duration of APT provided, the presence of nearby shunting yards or stations, or if the crossing is near the edge of a city or town (speed change area).

- Longer APTs increase the chances of a train changing speed before reaching the crossing.

- Nearby shunting yards and stations are more likely to result in more train handling activities.
- Many cities and towns have train noise restrictions, and often require lower train speeds to accommodate, resulting in speed changes in these areas – particularly slowing down on entry.

Select the probability of variability from the dropdown menu:

- Consistent: It is highly unlikely that train speed and APT will vary. Typically used in rural areas where trains are not likely to change speeds.
- Low Variability: It is possible that train speed and APT will vary. Typically used in most cases where the crossing is sufficiently distant from a location likely to drive variable train speeds, but train handling may occur anyway. This is the default selection.
- High Variability: It is highly likely or expected that train speed and APT will vary. Typically used at crossings close to rail yards, shunting yards, stations, active commercial spurs, speed limit changes, or known frequent train handling activities.

The variability selected will affect the multiplier provided for Line 52.

Line 51: **Advance preemption time required or provided**, in seconds.

This is the larger of the values for advance vehicle preemption time (AVPT) required (Line 48) or provided (Line 49), and is entered automatically. Advance pedestrian preemption time (APPT) is not considered, as the additional time needed for APPT is in advance of the start of AVPT, and may result in an unnecessarily long track clearance green interval.

Line 52: **Multiplier for maximum AVPT due to train handling**.

This is an estimated multiplier to account for potential variability in AVPT. Values are 1.60 for high variability, 1.25 for low variability, and 1.00 for consistent times. The appropriate value is automatically entered based on the selection made for Line 50.

Line 53: **Maximum AVPT**, in seconds.

This is the largest value for AVPT that can typically be expected, corresponding to the earliest possible time for the preemption sequence to be activated before the rail crossing warning system is activated. This value is the AVPT time (Line 51) multiplied by the multiplier in Line 52, and is automatically calculated and entered.

Line 54: **Minimum duration for track clearance green interval**, in seconds.

This is the minimum time required for the track clearance green interval to be active in the event of no advance preemption, such that the track clearance green interval ends no earlier than when the rail crossing gates are fully closed, preventing vehicles from entering the crossing after the track clearance green phase is complete and getting stuck (preempt trap). Where no advance preemption is provided, preemption is simultaneous and starts at the same time as the rail crossing signals.

This value is determined by normal MUTCD requirements for the rail crossing signals to start operating a minimum of 20 seconds before the arrival of any train at the crossing (Section 8C.08), and that automatic gates reach their fully lowered position no less than 5 seconds before the arrival of any train at the crossing (Section 8C.04). The resulting minimum value of 15 seconds is automatically entered.

Line 55: **Track clearance green time to avoid preempt trap**, in seconds.

This is the minimum time that the track clearance phase needs to remain green in order to avoid the preempt trap. This value is the sum of the maximum AVPT calculated in Line 53 and the minimum duration of track clearance green from Line 54, and is automatically calculated and entered.

<u>Clearing of Clear Storage Distance (CSD)</u>

This section calculates the recommended length of the track clearance green interval, taking into account both the time needed to avoid the preempt trap and the time needed to clear the design vehicle from the crossing.

Line 56: **Time waiting on left turning truck**, in seconds.

This is the value determined on Line 33 and is automatically entered.

Line 57: **Time required for design vehicle to start moving**, in seconds.

This is the value determined on Line 35 and is automatically entered.

Line 58: **Design vehicle clearance distance**, in feet.

This is the value determined on Line 36 and is automatically entered.

Line 58a: **Is the CSD less than or equal to the design vehicle length (DVL)**, Yes/No?

The worksheet will compare the CSD (Line 1) to the DVL (Line 10) and will enter "Yes" or "No" as appropriate.

Line 58b: Select **Should the design vehicle clear the entire CSD**, Yes/No?

If the design vehicle length (DVL) is shorter than the CSD, it must be determined if the design vehicle should clear the entire CSD or not. If the CSD is not cleared, it is possible that a vehicle becomes trapped on that approach between the intersection and the tracks during limited service operations (dwell). Depending on where the driver wishes to go, this may result in unsafe driver behavior depending on how long they will have to wait for the preemption event to complete.

For crossings 150 feet or less from the stop line for the intersection, always select “Yes” to clear the full CSD. For crossings more than 150 feet from the stop line for the intersection, selecting “Yes” is also recommended, but “No” may be considered following engineering judgment regarding site specific conditions.

Line 59: **Portion of CSD to clear during track clearance**, in feet.

This is the portion of the CSD to be cleared during the track clearance green interval. The length of the CSD will automatically be entered unless “No” is present for both Line 58a and Line 58b, in which case the DVL will automatically be entered instead.

Line 60: **Design vehicle relocation distance (DVRD)**, in feet.

This is the distance that the design vehicle must accelerate through during the track clearance green interval. This value is the sum of the DVCD (Line 36) and the portion of the CSD to clear during track clearance (Line 59). This value is automatically calculated and entered.

Line 61: **Time required for design vehicle to accelerate through DVRD** on level terrain, in seconds.

This is the time required for the design vehicle to accelerate from a stop and travel the entire length of the DVRD on a level approach. This value is determined using the same method as described for Line 37, using DVRD in place of DVCD, and is automatically calculated and entered.

Line 62: **Factor to account for slower acceleration on uphill grade**.

This factor is determined using the same method described for Line 38, using DVRD in place of DVCD, and is automatically determined and entered.

Line 63: **Time required to accelerate design vehicle through DVRD, adjusted for grade**, in seconds.

This is the time required for the design vehicle to accelerate from a stop and travel the entire length of the DVRD on an approach with an uphill grade. This value is determined by multiplying the time required to accelerate through DVRD on a level approach (Line 61) by the grade factor determined in Line 62. This value is automatically calculated and entered.

Line 64: **Time to clear portion of clear storage distance**, in seconds.

This is the total amount of time required from the start of track clearance green (or after the intersection is clear from a conflicting turning truck) until the design vehicle in the queue has cleared the DVRD. This value is the sum of Lines 56, 57, and 63, and is automatically calculated and entered.

Line 65: **Track clearance green interval**, in seconds.

This is the time required for the duration of the track clearance green interval to prevent preempt trap and provide sufficient time for the design vehicle to clear the DVRD. This value is the higher of Lines 55 and 64, and is automatically determined and entered. Note that this value does not account for the inclusion of a separate gate down circuit preempt.

Maximum duration of track clearance green after the gates are down (in absence of a gate down circuit)

This section calculates the estimated duration of the track clearance green interval due to the initiation of a preempt after the gates are down if a separate gate down circuit preempt is not used, since a preempt may occur at any time during any operational phase of the traffic signal system. When preempt occurs such that the right-of-way transfer time is the maximum, it is highly likely that the track clearance green interval will continue to display green indications after the gates are down. How long it continues to display green after the gates are down depends on the duration of the track clearance green interval.

The determination of this time can provide support for requesting a gate down circuit, particularly where the absence of a gate down circuit may result in an excessive amount of time where track clearance green is displayed after the gates are down, resulting in an unnecessary delay to the start of limited service operations. Although gate down circuits should always be requested, the need for a gate down circuit is more critical when the value of Line 68 exceeds 25 seconds.

Lines 66-68 are based on vehicle preemption times. Lines 66p-68p are based on pedestrian preemption times. The resulting values for Lines 68 and 68p should match, and is verified on Line 68x.

Vehicle

Line 66: **Time to complete track clearance green**, in seconds.

This is the amount of time from the start of the preemption call until the end of the track clearance green interval, and is the sum of the vehicle right-of-way transfer time (Line 26) and the track clearance green interval time determined on Line 65. This value is automatically calculated and entered.

Line 67: **Total time before gates are down**, in seconds.

This is the total time from the start of the preemption call until the gates are down. AREMA and MUTCD requirements state that the gates must be fully down a minimum of 5 seconds before the arrival of the train. This value is 5 seconds less than the maximum preemption time for queue clearance without pedestrians (Line 44), and is automatically calculated and entered.

Line 68: **Maximum duration of track clearance green after gates are down**, in seconds.

This is the amount of time the track clearance green interval is expected to remain green after the gates are down. The longer the duration, the greater the delay to the start of limited service operations and the more inefficient the intersection operates. This is based on the worst possible operating phase of the traffic signal system. This value is determined by subtracting the total time before the gates are down (Line 67) from the time to complete track clearance green (Line 66), and is automatically calculated and entered.

Pedestrian

Line 66p: **Time to complete track clearance green**, in seconds.

This is the amount of time from the start of the preemption call until the end of the track clearance green interval, and is the sum of the pedestrian right-of-way transfer time (Line 27) and the track clearance green interval time determined on Line 65. This value is automatically calculated and entered.

Line 67p: **Total time before gates are down**, in seconds.

This is the total time from the start of the preemption call until the gates are down. AREMA and MUTCD requirements state that the gates must be fully down a minimum of 5 seconds before the arrival of the train. This value is 5 seconds less than the maximum preemption time for queue clearance with pedestrians (Line 44p), and is automatically calculated and entered.

Line 68p: **Maximum duration of track clearance green after gates are down**, in seconds.

This is the amount of time the track clearance green interval is expected to remain green after the gates are down. The longer the duration, the greater the delay to the start of limited service operations and the more inefficient the intersection operates. This is based on the worst possible operating phase of the traffic signal system. This value is determined by subtracting the total time before the gates are down (Line 67p) from the time to complete track clearance green (Line 66p), and is automatically calculated and entered.

Calculation Check

Line 68x: **Check that Lines 68 and 68p match**, Yes/No.

This is a quick check to verify that the values determined for Lines 68 and 68p match. These values should always match. The advance pedestrian preemption is extended in advance of advance vehicle preemption, and the track clearance green time does not change, so the difference between lines 66 and 66p, and between lines 67 and 67p, should be the same. In all cases, the following should be true:

- Line 66p – Line 66 = Line 67p – Line 67
- Line 66p – Line 67p = Line 66 – Line 67

R1.9 Summary of Controller Preemption Settings

This section provides a convenient reference for controller timing entries determined by the preemption worksheet. These values should be used when programming the traffic signal controller. All values are in seconds, and are automatically entered based on the applicable source data line.

<u>Basic Settings</u>

Line 69: **Duration Time**. This value is set at zero to ensure that a preempt call is not dropped.

Line 70: **Preemption delay time** (from Line 13).

<u>Right of Way Transfer Phase</u>

Line 71: **Minimum green interval** (from Line 16).

Line 72: **Pedestrian walk interval** (from Line 21).

Line 73: **Pedestrian clearance interval** (from Line 22).

Line 74: **Yellow change interval** (from Line 18).

Line 75: **All red vehicle clearance** (from Line 19).

<u>Track Clearance (Green) Phase</u>

Line 76: **Green interval (in absence of gate down circuit)** (from Line 65).

Line 77: **Green interval (with gate down circuit)** (from Line 40). When a gate down circuit is provided, only the queue clearance time is required to ensure that the design vehicle sufficiently clears the tracks.

Line 78: **Yellow change interval** (from Line 18).

Line 79: **All red vehicle clearance** (from Line 19).

<u>Exit Phase</u>

Line 80: **Dwell/Cycle minimum green time**. This value is automatically set at zero to ensure that the traffic signal re-enters preemption as soon as possible in the event of a second train crossing.

Line 81: **Yellow change interval** (from Line 18).

Line 82: **All red vehicle clearance** (from Line 19).

R1.10 References

The following references are used in the development of this document.

A Policy on Geometric Design of Highways and Streets, 7th Edition, AASHTO, Washington DC (2018)

Design Manual (M55-01.19), Chapter 1330 (Traffic Control Signals), Washington State Department of Transportation (September 2020); https://wsdot.wa.gov/Publications/Manuals/M22-01.htm

Guide for Determining Time Requirements for Traffic Signal Preemption at Highway-Rail Grade Crossings (TxDOT Form 2304) and Instructions for Form 2304 (TxDOT Form 2304-I), Texas Department of Transportation (TxDOT) (July 2017); http://www.txdot.gov/inside-txdot/forms-publications/forms/rail.html

Highway-Rail Crossing Handbook, 3rd Edition, Report No. FHWA-SA-18-040/FRA-RRS-18-001, Federal Highway Administration (FHWA), Washington, DC (July 2019); https://rosap.ntl.bts.gov/view/dot/43668

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), including Revisions 1 and 2, U.S. DOT, FHWA, Washington, DC (2009-2012); http://mutcd.fhwa.dot.gov/

Washington State modifications to the MUTCD, Chapter 468-95 WAC