

CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals

Standard:

- 01 **An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.**
- 02 **The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants:**
- Warrant 1, Eight-Hour Vehicular Volume**
 - Warrant 2, Four-Hour Vehicular Volume**
 - Warrant 3, Peak Hour**
 - Warrant 4, Pedestrian Volume**
 - Warrant 5, School Crossing**
 - Warrant 6, Coordinated Signal System**
 - Warrant 7, Crash Experience**
 - Warrant 8, Roadway Network**
 - Warrant 9, Intersection Near a Grade Crossing**
- 03 **The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**
- Support:
- 04 Sections 8C.09 and 8C.10 contain information regarding the use of traffic control signals instead of gates and/or flashing-light signals at highway-rail grade crossings and highway-light rail transit grade crossings, respectively.
- Guidance:
- 05 *A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.*
- 06 *A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.*
- 07 *A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.*
- 08 *The study should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the signal warrants listed in Paragraph 2.*
- 09 *Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics should dictate whether an approach is considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, if engineering judgment indicates that it should be considered a one-lane approach because the traffic using the left-turn lane is minor, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach. The approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.*
- 10 *Similar engineering judgment and rationale should be applied to a street approach with one through/left-turn lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.*
- 11 *At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. Except for locations where the engineering study uses the satisfaction of Warrant 8 to justify a signal, a traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.*
- 12 *For signal warrant analysis, a location with a wide median, even if the median width is greater than 30 feet, should be considered as one intersection.*

Option:

- 13 At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher of the major-street left-turn volumes as the “minor-street” volume and the corresponding single direction of opposing traffic on the major street as the “major-street” volume.
- 14 For signal warrants requiring conditions to be present for a certain number of hours in order to be satisfied, any four sequential 15-minute periods may be considered as 1 hour if the separate 1-hour periods used in the warrant analysis do not overlap each other and both the major-street volume and the minor-street volume are for the same specific one-hour periods.
- 15 For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

Support:

- 16 When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

Option:

- 17 Engineering study data may include the following:
- A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
 - B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
 - C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
 - D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
 - E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
 - F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
 - G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.
- 18 The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods described in Item B of Paragraph 17:
- A. Vehicle-hours of stopped time delay determined separately for each approach.
 - B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
 - C. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.
 - D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.
 - E. Queue length on stop-controlled approaches.

Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume

Support:

- 01 The Minimum Vehicular Volume, Condition A or A1, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.
- 02 The Interruption of Continuous Traffic, Condition B or B1, is intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.
- 03 It is intended that Warrant 1 be treated as a single warrant. If Condition A or A1 is satisfied, then Warrant 1 is satisfied and analyses of Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B or B1 is satisfied, then Warrant 1 is satisfied and an analysis of the combination of Conditions A and B is not needed.

Standard:

04 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:**

- A. **The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or**
- B. **The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.**

In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Option:

05 When comparing vehicular volume of both approaches of the major street against the volume of the side street approaches, each side street approach may independently be evaluated against the criteria listed in Condition A and Condition B of TABLE 4C- 1.

06 Temporary traffic signals may be installed at new intersections on predicted hourly vehicular volumes, providing the predicted volumes meet the prescribed minimum vehicular volume levels as noted in Condition A or Condition B of TABLE 4C-1.

07 Temporary traffic signals may be installed at new intersections on predicted average daily traffic volumes, providing the predicted volumes meet prescribed minimum levels as noted in Condition A1 or Condition B1 of TABLE 4C-2. The temporary traffic signals may be placed in signal operation until proper traffic data and experience can be obtained. No downward adjustments are to be made to the ADT required volumes.

08 The basis for use of TABLE 4C-2 are:

1. The traffic volumes used shall be assigned current volumes.
2. Conditions A1 or B 1 lists the minimum Average Daily Traffic volumes which may justify consideration of signalization, and which are considered to be equivalent to the hourly traffic volume stipulations denoted by Condition A and Condition B respectively.
3. Surveillance should be maintained on the temporary traffic signal to assure that the signal operation is not creating any undue problems.
4. An engineering study should be conducted, normally, after six months of operation and before one year of operation as a temporary traffic signal control, to determine if the traffic signal is needed and should become a permanent installation.
5. If the temporary traffic signal is not justified by an engineering study, it may be removed immediately and the appropriate traffic control devices, commensurate to justification revealed by the engineering study, may be installed.
6. If the engineering study indicates that the traffic signal is justified, it shall remain in place and have the status of a permanent traffic signal installation.

09 Temporary traffic signals installed under this procedure must conform to the design requirements for traffic signals as stipulated in this manual.

10 Temporary traffic signals may become permanent traffic signals only after the completion of a traffic engineering investigation that verifies that permanent traffic signals are justified.

11 Conditions A1 or B1 lists the minimum Average Daily Traffic volumes which may justify consideration of signalization, and which are considered to be equivalent to the hourly traffic volume stipulations denoted by Condition A and Condition B respectively

Option:

12 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

Guidance:

13 *The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.*

Standard:

14 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:**

- A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and
- B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100% ^a	80% ^b	70% ^c	56% ^d	100% ^a	80% ^b	70% ^c	56% ^d
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100% ^a	80% ^b	70% ^c	56% ^d	100% ^a	80% ^b	70% ^c	56% ^d
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

^a Basic minimum hourly volume

^b Used for combination of Conditions A and B after adequate trial of other remedial measures

^c May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

^d May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Table 4C-2, Eight-Hour Vehicular Volume (ADT Equivalent)

Condition A1—Minimum Vehicular Volume (ADT Equivalent)

Number of lanes for moving traffic on each approach		Equivalent Average Daily Traffic Volumes Approaching From Both Directions On:	
Major Street	Minor Street	Major Street	Minor Street
1	1	8,300	4,600
2 or more	1	10,000	4,600
2 or more	2 or more	10,000	6,000
1	2 or more	8,300	6,000

Condition B1—Interruption of Continuous Traffic (ADT Equivalent)

Number of lanes for moving traffic on each approach		Equivalent Average Daily Traffic Volumes Approaching From Both Directions On:	
Major Street	Minor Street	Major Street	Minor Street
1	1	12,500	2,300
2 or more	1	15,000	2,300
2 or more	2 or more	15,000	3,100
1	2 or more	12,500	3,100

Option:

- 15 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.03 Warrant 2, Four-Hour Vehicular Volume

Support:

- 01 The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

- 02 **The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.**

Option:

- 03 When comparing vehicular volumes depicted in Figure 4C-1, the appropriate equations, as listed in Table 4C-3, may be used.
- 04 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-2 or Table 4C-4 may be used in place of Figure 4C-1.

Section 4C.04 Warrant 3, Peak Hour

Support:

- 01 The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

Standard:

- 02 **This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**
- 03 **The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**
- A. **If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:**
 1. **The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach; and**
 2. **The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes; and**
 3. **The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.**
 - B. **The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.**

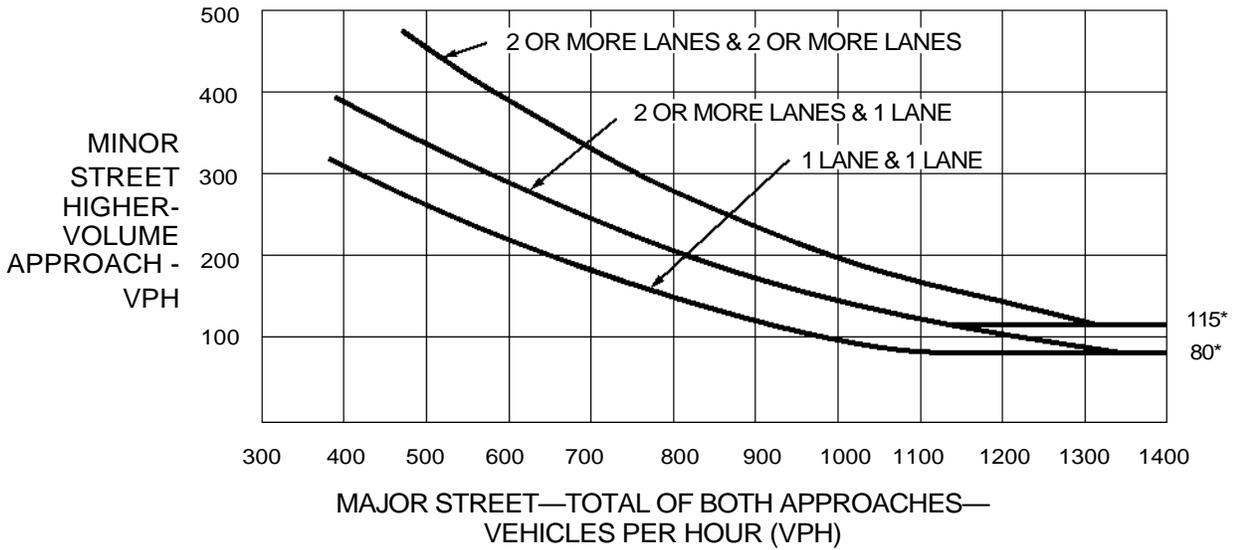
Option:

- 04 When comparing vehicular volumes depicted in Figure 4C-3, the appropriate equations, as listed in Table 4C-5 may be used
- 05 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 or Table 4C-6 may be used in place of Figure 4C-3 to evaluate the criteria in the second category of the Standard.
- 06 If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal may be operated in the flashing mode during the hours that the volume criteria of this warrant are not met.

Guidance:

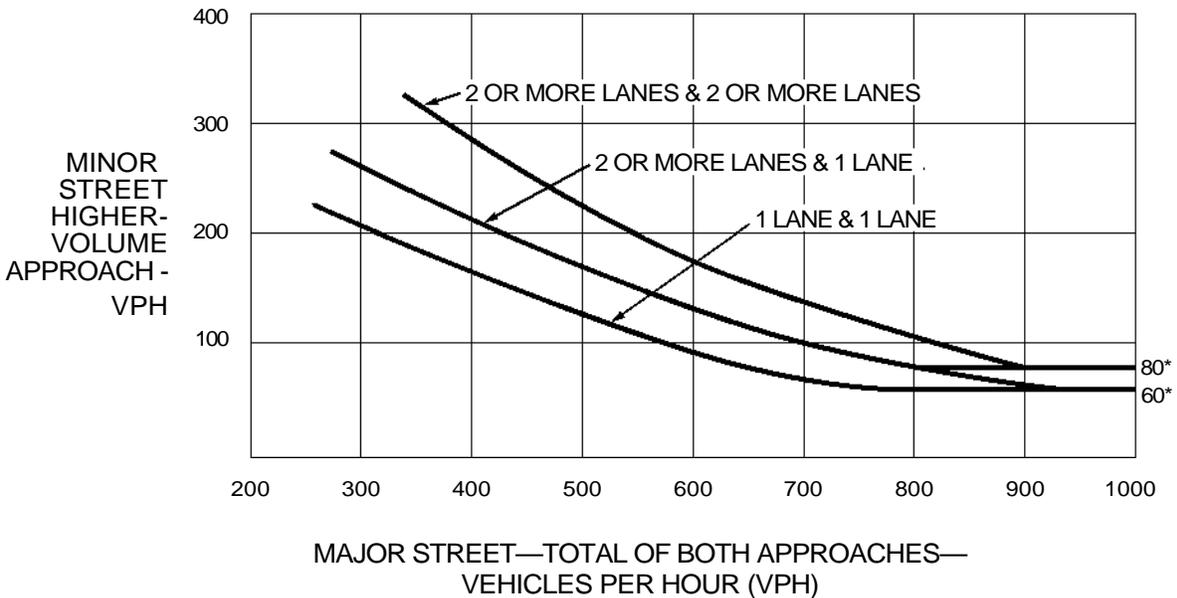
- 07 *If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal should be traffic-actuated*

Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

**Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)
(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)**



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane

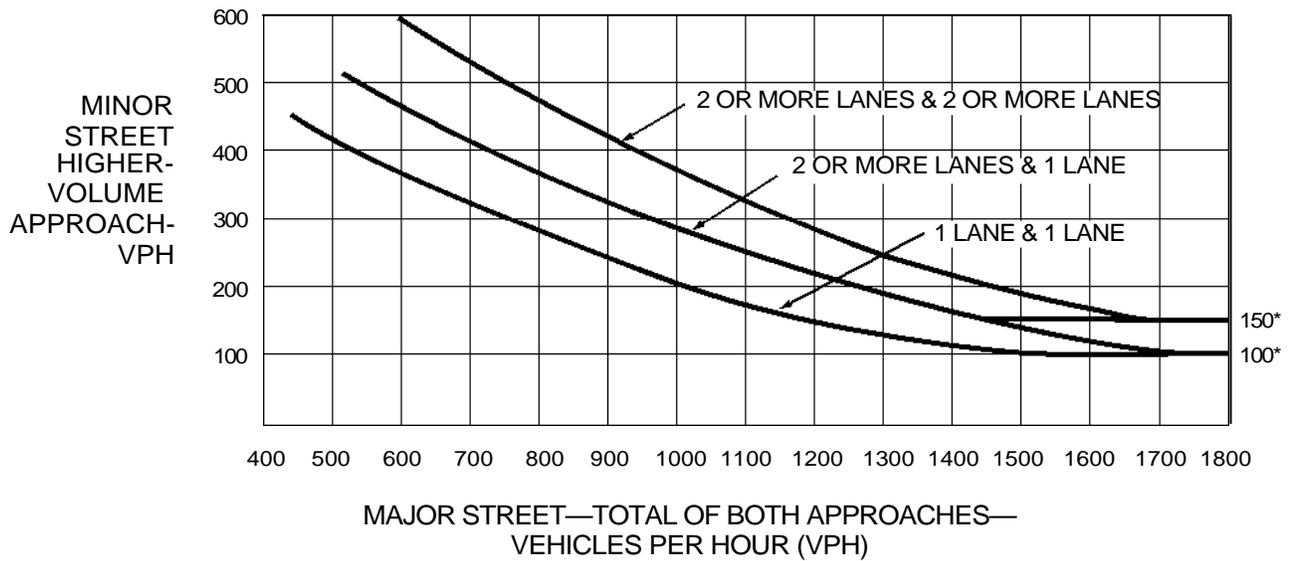
**Table 4C-3, Warrant 2, Four Hour Volume
Mathematical Equation Equivalency to Figure 4C-1**

X = sum of both major street approach volumes		
Y = volume of a) single minor street approach or b) minor street high volume approach		
Number of lanes for moving traffic on each approach		Equation
Minor Street	Major Street	
2 or more	2 or more	If $X \Rightarrow 1295$, $Y = 115$ or $Y = 879.232228 - 1.011380233X + 0.0003253082X^2$
2 or more	1	If $X \Rightarrow 1118$, $Y = 115$ or $Y = 651.50622395 - 0.7483745392X + 0.000240228X^2$
1	2 or more	If $X \Rightarrow 1340$, $Y = 80$ or $Y = 651.50622395 - 0.7483745392X + 0.000240228X^2$
1	1	If $X \Rightarrow 1092$, $Y = 80$ or $Y = 550.22697349 - 0.6996410769X + 0.0002462697X^2$

**Table 4C-4, Warrant 2, Four Hour Volume (70% Factor)
Mathematical Equation Equivalency to Figure 4C-2**

X = sum of both major street approach volumes		
Y = volume of a) single minor street approach or b) minor street high volume approach		
Number of lanes for moving traffic on each approach		Equation
Minor Street	Major Street	
2 or more	2 or more	If $X \Rightarrow 890$, $Y = 80$ or $Y = 613.77772474 - 0.9893678281X + 0.0004377428X^2$
2 or more	1	If $X \Rightarrow 797$, $Y = 80$ or $Y = 460.53837044 - 0.7635806818X + 0.0003591016X^2$
1	2 or more	If $X \Rightarrow 940$, $Y = 60$ or $Y = 460.53837044 - 0.7635806818X + 0.0003591016X^2$
1	1	If $X \Rightarrow 782$, $Y = 60$ or $Y = 377.22710663 - 0.6793503652X + 0.0003501046X^2$

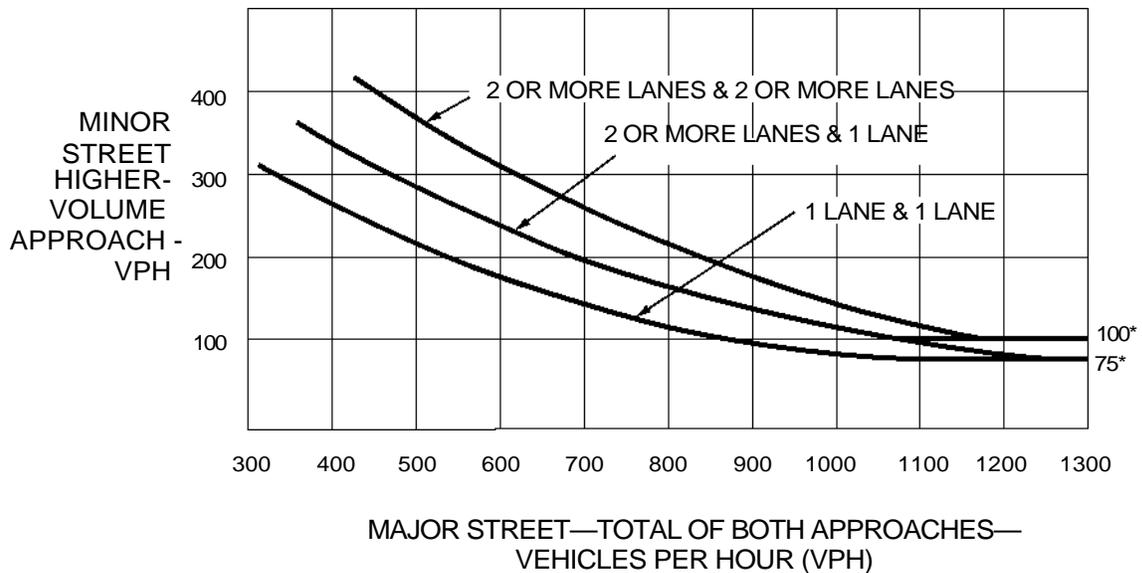
Figure 4C-3. Warrant, 3 Peak Hour



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lan

**Table 4C-5, Warrant 3, Peak Hour Volume
Mathematical Equation Equivalency to Figure 4C-3**

X = sum of both major street approach volumes		
Y = volume of a) single minor street approach or b) minor street high volume approach		
Number of lanes for moving traffic on each approach		Equation
Minor Street	Major Street	
2 or more	2 or more	If $X \Rightarrow 1672, Y = 150$ or $Y = 1060.5405451 - 0.889969286X + 0.0002059999X^2$
2 or more	1	If $X \Rightarrow 1461, Y = 150$ or $Y = 837.59424427 - 0.7219511908X + 0.0001720248X^2$
1	2 or more	If $X \Rightarrow 1759, Y = 100$ or $Y = 837.59424427 - 0.7219511908X + 0.0001720248X^2$
1	1	If $X \Rightarrow 1516, Y = 100$ or $Y = 745.652000052 - 0.7548866636X + 0.00021703X^2$

**Table 4C-6, Warrant 3, Peak Hour Volume (70% Factor)
Mathematical Equation Equivalency to Figure 4C-4**

X = sum of both major street approach volumes		
Y = volume of a) single minor street approach or b) minor street high volume approach		
Number of lanes for moving traffic on each approach		Equation
Minor Street	Major Street	
2 or more	2 or more	If $X \Rightarrow 1183, Y = 100$ or $Y = 771.842673 - 0.9817221615X + 0.0003498922X^2$
2 or more	1	If $X \Rightarrow 1040, Y = 100$ or $Y = 593.38729059 - 0.7471500045X + 0.000262383X^2$
1	2 or more	If $X \Rightarrow 1196, Y = 75$ or $Y = 593.38729059 - 0.7471500045X + 0.000262383X^2$
1	1	If $X \Rightarrow 1054, Y = 75$ or $Y = 520.01155026 - 0.7647561999X + 0.0003250549X^2$

**Table 4C-7, Warrant 4, Pedestrian Volume
Mathematical Equation Equivalency to Figures 4C-5 thru 4C-8**

X = sum of (both) major street approach volume (MSAV)		
Y = volume of pedestrians crossing the major street		
Figure	Min. Ped Value	Equations (Required Peds with MSAV)
Fig 4C-5	X=> 1100, Y=> 107	$Y = 760.62 - 1.02098 X + 0.0003875 X^2$
Fig 4C-6	X => 780, Y=> 75	$Y = 491.334 - 0.86656 X + 0.0004214 X^2$
Fig 4C-7	X => 1500, Y => 133	$Y = 1005.61 - 1.0188 X + 0.0002889 X^2$
Fig 4C-8	X => 1044, Y => 93	$Y = 669.187 - 0.96162 X + 0.0003915 X^2$

**Table 4C-8; Warrant 5, School Crossing
Vehicular Volume Equivalency Gaps In Vehicular Flow**

Average Number of Children Per Minute	Width of Street Vehicular Volume (v.p.h.)			
	30'	40'	50'	60'
1 - 5	645	610	570	530
6 - 10	620	580	545	505
11 - 15	590	555	515	480
16 - 20	565	530	490	450
21 - 25	540	500	465	425
26 - 30	510	475	435	400
31 - 35	485	450	410	370

Section 4C.05 Warrant 4, Pedestrian Volume**Support:**

01 The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street.

Standard:

02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

- A. **For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or**
- B. **For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

04 When comparing vehicular volumes depicted in Figures 4C-5, 4C-6, 4C-7, or 4C-8, the appropriate equations, as listed in Table 4C-7, may be used

Standard:

05 **The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal or STOP sign controlling the street that pedestrians desire to cross is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

06 **If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E.**

Guidance:

07 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

- A. *If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
- B. *If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
- C. *Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Option:

08 The criterion for the pedestrian volume crossing the major street may be reduced as much as 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 feet per second.

09 A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street.

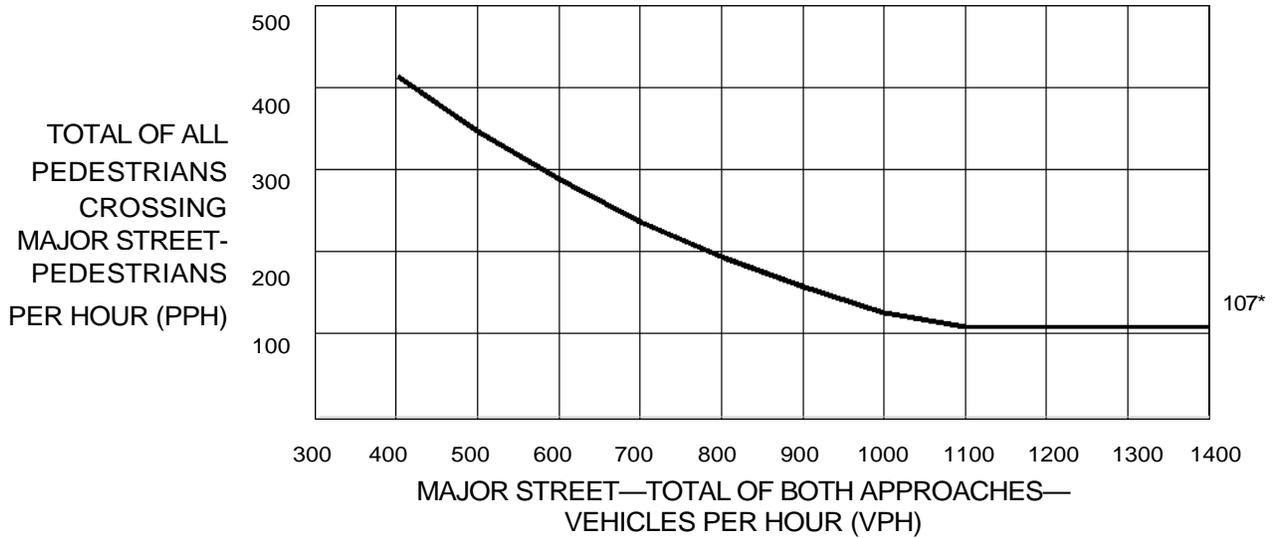
Section 4C.06 Warrant 5, School Crossing**Support:**

01 The School Crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "schoolchildren" includes elementary through high school students.

Standard:

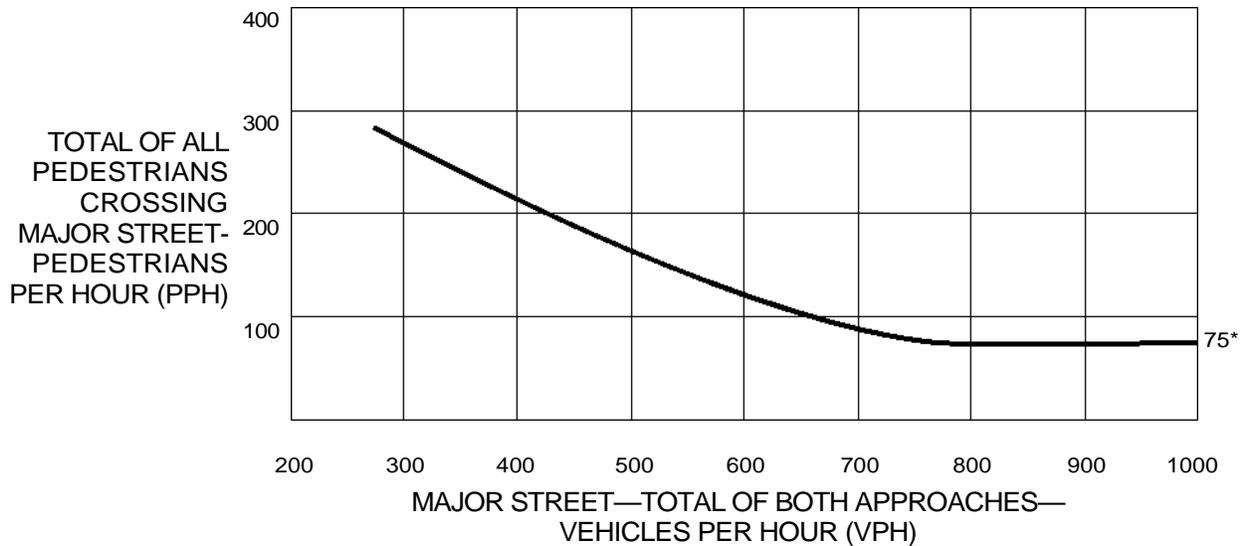
02 **The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.**

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



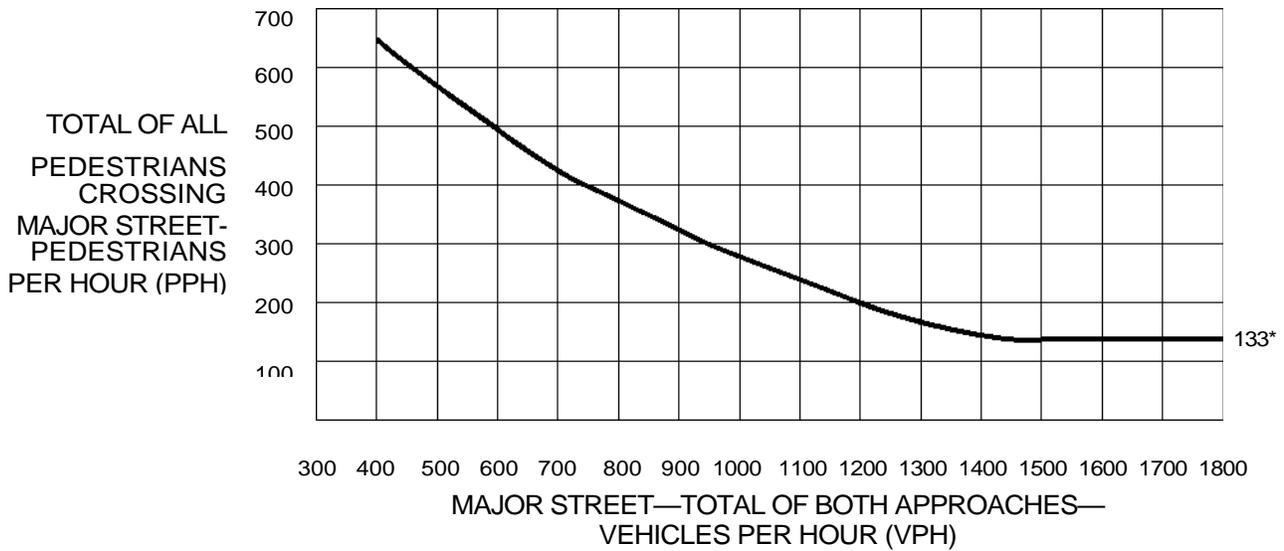
*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



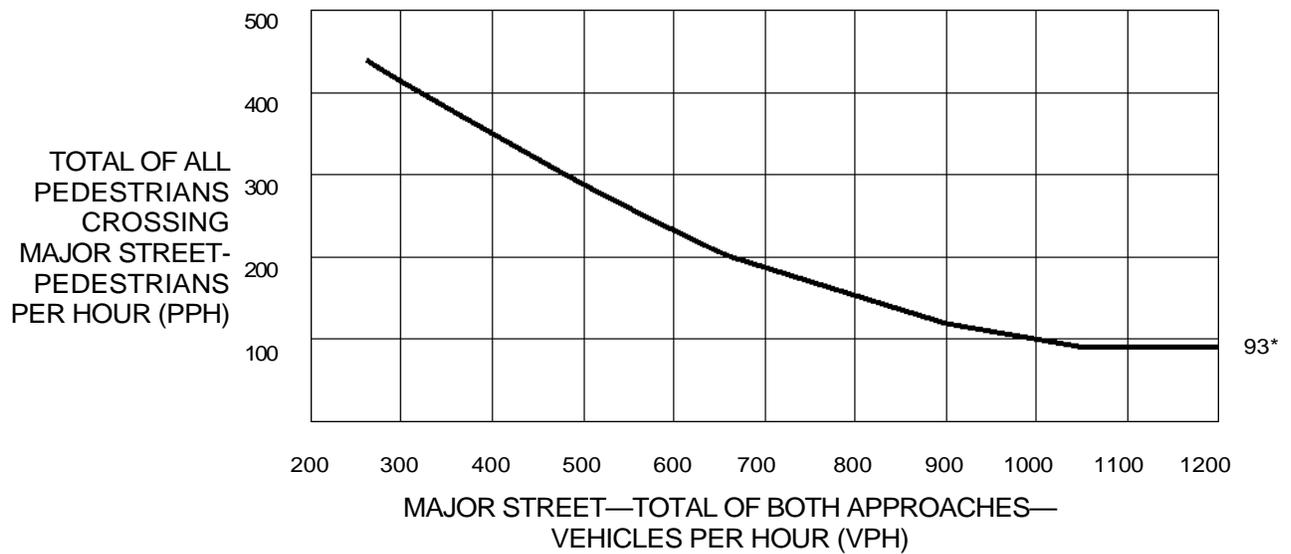
*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

03 **Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

04 **The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

- 05 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*
- A. *If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
 - B. *If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.*
 - C. *Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

- 02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**
- A. **On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.**
 - B. **On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.**

Guidance:

03 *The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Section 4C.08 Warrant 7, Crash Experience

Support:

01 The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal.

Standard:

- 02 **The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**
- A. **Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and**
 - B. **Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and**
 - C. **For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.**

Option:

- 03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.09 Warrant 8, Roadway Network

Support:

- 01 Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

- 02 **The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**
- A. **The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or**
 - B. **The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).**
- 03 **A major route as used in this signal warrant shall have at least one of the following characteristics:**
- A. **It is part of the street or highway system that serves as the principal roadway network for through traffic flow.**
 - B. **It includes rural or suburban highways outside, entering, or traversing a city.**
 - C. **It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.**

Section 4C.10 Warrant 9, Intersection Near a Grade Crossing

Support:

- 01 The Intersection Near a Grade Crossing signal warrant is intended for use at a location where none of the conditions described in the other eight traffic signal warrants are met, but the proximity to the intersection of a grade crossing on an intersection approach controlled by a STOP or YIELD sign is the principal reason to consider installing a traffic control signal.

Guidance:

- 02 *This signal warrant should be applied only after adequate consideration has been given to other alternatives or after a trial of an alternative has failed to alleviate the safety concerns associated with the grade crossing. Among the alternatives that should be considered or tried are:*
- A. *Providing additional pavement that would enable vehicles to clear the track or that would provide space for an evasive maneuver, or*
 - B. *Reassigning the stop controls at the intersection to make the approach across the track a non-stopping approach.*

Standard:

- 03 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following criteria are met:**
- A. **A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach; and**
 - B. **During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance D, which is the clear storage distance as defined in Section 1A.13.**

Guidance:

- 04 *The following considerations apply when plotting the traffic volume data on Figure 4C-9 or 4C-10:*
- A. *Figure 4C-9 should be used if there is only one lane approaching the intersection at the track crossing location and Figure 4C-10 should be used if there are two or more lanes approaching the intersection at the track crossing location.*

Figure 4C-9. Warrant 9, Intersection Near a Grade Crossing (One Approach Lane at the Track Crossing)

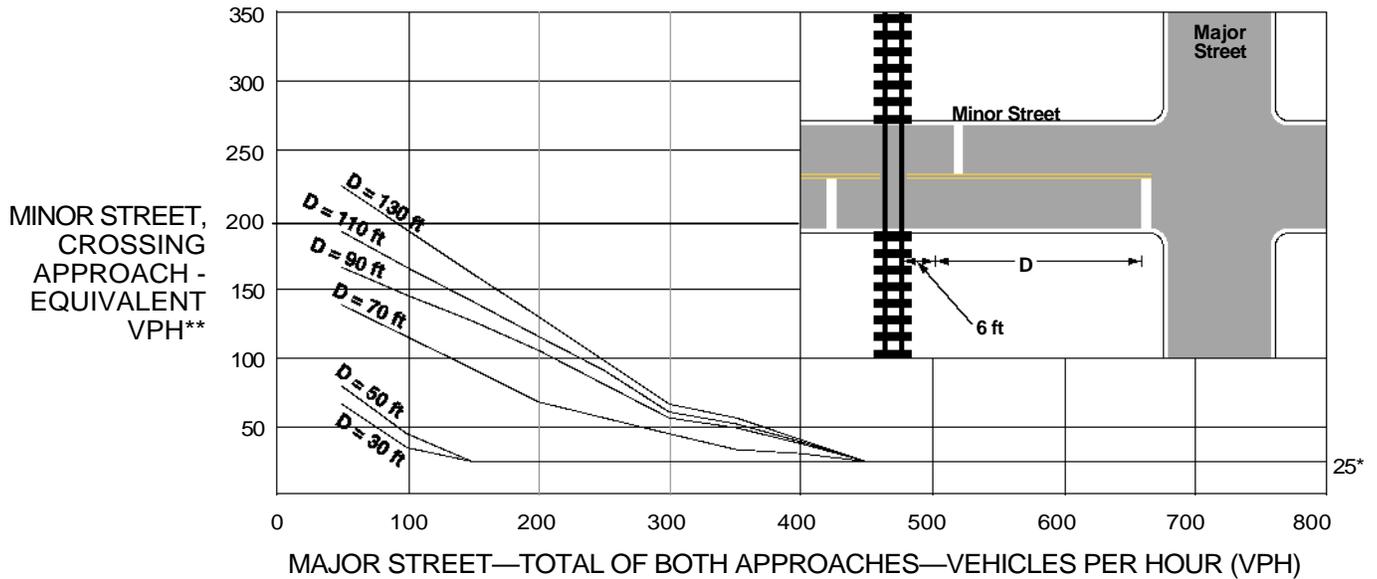
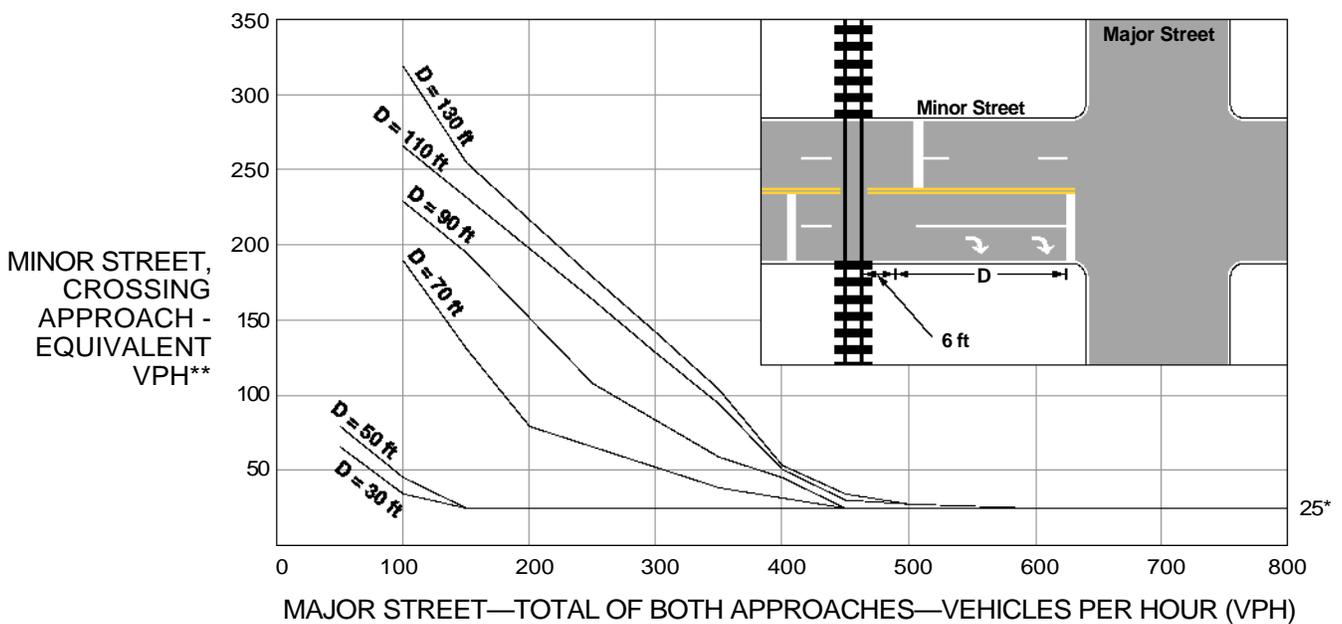


Figure 4C-10. Warrant 9, Intersection Near a Grade Crossing (Two or More Approach Lanes at the Track Crossing)



- B. After determining the actual distance *D*, the curve for the distance *D* that is nearest to the actual distance *D* should be used. For example, if the actual distance *D* is 95 feet, the plotted point should be compared to the curve for *D* = 90 feet.
- C. If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.

Option:

- 05 When comparing vehicular volumes depicted in Figures 4C-9, or 4C-10, the appropriate equations, as listed in Table 4C-12, or 4C-13, may be used
- 06 The minor-street approach volume may be multiplied by up to three adjustment factors as provided in Paragraphs 6 through 8.
- 07 Because the curves are based on an average of four occurrences of rail traffic per day, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-9 for the appropriate number of occurrences of rail traffic per day.
- 08 Because the curves are based on typical vehicle occupancy, if at least 2% of the vehicles crossing the track are buses carrying at least 20 people, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-10 for the appropriate percentage of high-occupancy buses.
- 09 Because the curves are based on tractor-trailer trucks comprising 10% of the vehicles crossing the track, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-11 for the appropriate distance and percentage of tractor-trailer trucks.

Standard:

- 10 **If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, then:**
 - A. The traffic control signal shall have actuation on the minor street;
 - B. Preemption control shall be provided in accordance with Sections 4D.27, 8C.09, and 8C.10; and
 - C. The grade crossing shall have flashing-light signals see Chapter 8C).

Guidance:

- 11 If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, the grade crossing should have automatic gates (see Chapter 8C).

Table 4C-9. Warrant 9, Adjustment Factor for Daily Frequency of Rail Traffic

Rail Traffic per Day	Adjustment Factor
1	0.67
2	0.91
3 to 5	1.00
6 to 8	1.18
9 to 11	1.25
12 or more	1.33

Table 4C-10. Warrant 9, Adjustment Factor for Percentage of High-Occupancy Buses

% of High-Occupancy Buses* on Minor-Street Approach	Adjustment Factor
0%	1.00
2%	1.09
4%	1.19
6% or more	1.32

* A high-occupancy bus is defined as a bus occupied by at least 20 people.

Table 4C-11. Warrant 9, Adjustment Factor for Percentage of Tractor-Trailer Trucks

% of Tractor-Trailer Trucks on Minor-Street Approach	Adjustment Factor	
	D less than 70 feet	D of 70 feet or more
0% to 2.5%	0.50	0.50
2.6% to 7.5%	0.75	0.75
7.6% to 12.5%	1.00	1.00
12.6% to 17.5%	2.30	1.15
17.6% to 22.5%	2.70	1.35
22.6% to 27.5%	3.28	1.64
More than 27.5%	4.18	2.09

**Table 4C-12, Warrant 9, Intersection Near a Grade Crossing
(One Approach Lane at the Track Crossing)
Mathematical Equation Equivalency to Figure 4C-9**

X = Major Street Volume (Both Directions)		
Y = Minor Street Approach Volume that crosses the RR Tracks		
Distance From Intersection To RR Crossing (Feet)	Major Street Volume Both App's	Equation
21 – 40	$X \leq 100$	$Y = -0.64 X + 99$
21 – 40	$100 < X < 150$	$Y = -0.2 X + 55$
21 – 40	$X \geq 150$	$Y = 25$
41 – 60	$X \leq 100$	$Y = 25 = -0.7 X + 115$
41 – 60	$100 < X < 150$	$Y = -0.4 X + 85$
41 – 60	$X \geq 150$	$Y = 25$
61 – 80	$X \leq 200$	$Y = -0.467 X + 163$
61 – 80	$200 < X \leq 350$	$Y = -0.24 X + 118$
61 – 80	$350 < X \leq 400$	$Y = -0.06 X + 55$
61 – 80	$400 < X < 450$	$Y = -0.12 X + 79$
61 – 80	$X \geq 450$	$Y = 25$
81 – 100	$X \leq 200$	$Y = -0.4 X + 185$
81 – 100	$200 < X \leq 300$	$Y = -0.48 X + 201$
81 – 100	$300 < X \leq 350$	$Y = -0.14 X + 99$
81 – 100	$350 < X < 450$	$Y = -0.25 X + 138$
81 – 100	$X \geq 450$	$Y = 25$
101 – 120	$X \leq 250$	$Y = -0.5 X + 215$
101 – 120	$250 < X \leq 300$	$Y = -0.58 X + 235$
101 – 120	$300 < X \leq 350$	$Y = -0.18 X + 115$
101 – 120	$350 < X < 450$	$Y = -0.27 X + 147$
101 – 120	$X \geq 450$	$Y = 25$
121 – 140	$X \leq 300$	$Y = -0.632 X + 257$
121 – 140	$300 < X \leq 350$	$Y = -0.2 X + 127$
121 – 140	$350 < X < 450$	$Y = -0.32 X + 169$
121 – 140	$X \geq 450$	$Y = 25$

**Table 4C-13, Warrant 9, Intersection Near a Grade Crossing
(Two or More Approach Lanes at the Track Crossing)
Mathematical Equation Equivalency to Figure 4C-10**

X = Major Street Volume (Both Directions)		
Y = Minor Street Approach Volume that crosses the RR Tracks		
Distance Fromntersection To RR Crossing (Feet)	Major Street Volume Both App's	Equation
21 – 40	$X \leq 100$	$Y = -0.62 X + 96$
21 – 40	$100 < x < 150$	$Y = -0.18 X + 52$
21 – 40	$X \Rightarrow 150$	$Y = 25$
21 – 40	$X \leq 100$	$Y = -0.7 X + 115$
41 – 60	$100 < x < 150$	$Y = -0.4 X + 85$
41 – 60	$X \Rightarrow 150$	$Y = 25$
41 – 60	$X \leq 150$	$Y = -1.2 X + 310$
61 – 80	$150 < X \leq 200$	$Y = -1.0 X + 280$
61 – 80	$200 < X \leq 350$	$Y = -0.28 X + 136$
61 – 80	$350 < x < 450$	$Y = -0.13 X + 84$
61 – 80	$X \Rightarrow 450$	$Y = 25$
81 – 100	$X \leq 144$	$Y = -0.682 X + 298$
81 – 100	$144 < X \leq 250$	$Y = -0.849 X + 322$
81 – 100	$250 < X \leq 350$	$Y = -0.5 X + 235$
81 – 100	$350 < X \leq 400$	$Y = -0.3 X + 165$
81 – 100	$400 < X < 450$	$Y = -0.4 X + 205$
81 – 100	$X \Rightarrow 450$	$Y = 25$
101 – 120	$X \leq 350$	$Y = -0.68 X + 333$
101 – 120	$350 < X \leq 400$	$Y = -0.9 X + 410$
101 – 120	$400 < X \leq 450$	$Y = -0.4 X + 210$
101 – 120	$450 < X < 600$	$Y = -0.033 X + 45$
101 – 120	$X \Rightarrow . 600$	$Y = 25$
121 – 140	$X \leq 150$	$Y = -1.32 X + 452$
121 – 140	$150 < X \leq 350$	$Y = -0.75 X + 366$
121 - 140	$350 < X \leq 400$	$Y = -1.0 X + 454$
121 - 140	$400 < X \leq 450$	$Y = -0.38 X + 206$
121 - 140	$450 < X \leq 500$	$Y = -0.133 X + 95$
121 - 140	$500 < X < 600$	$Y = -0.033 X + 45$
121 - 140	$X \Rightarrow 600$	$Y = 25$

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