





TOPIC 1: WHY?

<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Office of Traffic, Safety & Technology</p> 	 <h1 style="text-align: center;">Traffic Signals 101</h1> <p style="text-align: center;">Topic 1 Why?</p>	<p>This chapter will address the issue as to why a traffic signal is installed. This includes:</p> <ul style="list-style-type: none"> • Who initiates a signal • Traffic Signal Warrants • Intersection Control Evaluation (ICE) Reports • Associated Manuals
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Office of Traffic, Safety & Technology</p> 	<h2 style="color: #0056b3;">Why?</h2> <p>➤ Who initiates a signal?</p> <ul style="list-style-type: none"> – Developer – City/County – Politician – Public – State 	<p>A signal may be initiated in many ways. If a study shows such a signal is justified, then the signal must be programmed, that is, budgeted for and put into the letting schedule.</p>



Why?



➤ Signal Warrants

- Traffic control signals should not be installed unless one or more of the signal warrants in the MN MUTCD are met
- The satisfaction of a warrant or warrants is not in itself **justification** for a signal
- Information should be obtained by means of engineering studies and compared with the requirements set forth in the warrants
- An Intersection Control Evaluation report needs to be prepared (see slide 8)

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Traffic signal warrants are found in the Minnesota Manual on Uniform Traffic Control Devices (MN MUTCD), Chapter 4C, December 2011 (often referred to as the “MUTT”).

In addition to meeting a warrant, to be justified a signal should meet perceived safety or operational needs.

An Intersection Control Evaluation (ICE) report is required. Details are found later in this section.



Why?

➤ Signal Warrants

- Warrant 1 - Eight-Hour Vehicular Volume
- Warrant 2 - Four-Hour Vehicular Volume
- Warrant 3 - Peak Hour
- Warrant 4 - Pedestrian Volume

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There are nine (9) warrants contained in the MN MUTCD.

A detailed description of these warrants is included at the end of this topic as a handout. This information is a printout of Chapter 4C of the MN MUTCD and can be found on the Office of Traffic, Security & Technology web site. Please visit the website listed at the bottom of this page for the most current version of the MN MUTCD.

Office of Traffic, Security & Technology publications website:

www.dot.state.mn.us/trafficeng/publ/index.html



Why?

➤ Signal Warrants

- Warrant 5 - School Crossing
- Warrant 6 - Coordinated Signal System
- Warrant 7 - Crash Experience
- Warrant 8 - Roadway Network
- Warrant 9, Intersection Near a Grade Crossing

Other warrants are less strong, and require careful justification to avoid placing signals that cause more problems than they solve.

For instance, consider Warrant 3. If only one hour is met for Warrant 3, then a signal could be installed that is only needed 1 hour out of 24 hours (on a weekday).

Another example is Warrant 7. Note that the language states “Five or more reported crashes, of types susceptible to correction by a traffic control signal, ...”. A rear-end collision is not considered to be an accident that could be corrected by a signal (in fact, this type often increases).

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Why?

➤ Warrant 1 Example

- The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.
- The Interruption of Continuous Traffic, Condition B, 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.

Warrant 1 requires at a minimum eight hours of traffic data. To meet warrant 1, at least eight distinct hours must meet the threshold volumes.

Warrant 1 Table

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Why?

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

Time	Vehicles Per Hour		Minimum Required		Hour Satisfied?
	Total of Both Major Street Approaches	Higher Minor Street Approach	Total of Both Major Street Approaches	Higher Minor Street Approach	
6:00 to 7:00	650	205	600	200	Yes
7:00 to 8:00	690	250	600	200	Yes
8:00 to 9:00	640	201	600	200	Yes
9:00 to 10:00	600	190	600	200	No
10:00 to 11:00	550	100	600	200	No
11:00 to 12:00	560	120	600	200	No
12:00 to 1:00	600	160	600	200	No
1:00 to 2:00	590	130	600	200	No
2:00 to 3:00	580	180	600	200	No
3:00 to 4:00	600	190	600	200	No
4:00 to 5:00	630	220	600	200	Yes
5:00 to 6:00	700	250	600	200	Yes
6:00 to 7:00	680	230	600	200	Yes
7:00 to 8:00	550	200	600	200	No
8:00 to 9:00	450	190	600	200	No
9:00 to 10:00	400	100	600	200	No

Warrant not met for Condition A (6 of 8 hours met)

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To be warranted, one of the following must occur:

1. Condition A or B is met for at least 8 hours a day as shown on the 100% column
2. Condition A or B is met for at least 8 hours a day as shown on the 70% column if the posted or 85th percentile speed on the mainline exceeds 40 MPH or the intersection lies within the built-up area of an isolated community having a population of less than 10,000.

This example only looks at Condition A.



Why?

➤ Intersection Control Evaluation (ICE)

- In the past, the only perceived solution to traffic delay and safety problems for at-grade intersections was the installation of a traffic signal
 - Based on Signal Justification Reports (SJR)
- Other options including stop control, roundabouts, and unconventional reduced-access intersections, may be acceptable alternatives



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Previously, Signal Justification Reports (SJR's) must have been completed before a new signal or significant modification of a signal could proceed (MN MUTCD and Mn/DOT Traffic Engineering Manual updated July 1, 2003). The SJR is straight-forward but does not consider other alternatives.

Why?



➤ ICE Definition

- Intersection Control Evaluation, or ICE, is a process that identifies the **best** intersection control through a comprehensive analysis and documentation of the technical (safety and operational), economic, and political issues of viable alternatives



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Why?

➤ Purpose of ICE

- Evaluate various intersection designs
- Select the optimal control for an intersection based on an objective analysis for the existing conditions and future needs
- Document all technical, financial, and political issues in the ICE Report
 - Replaces the SJR



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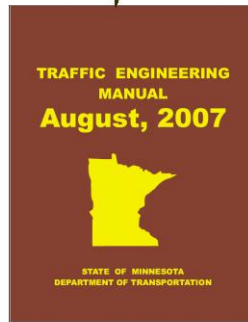


Why?

➤ Cover Manuals

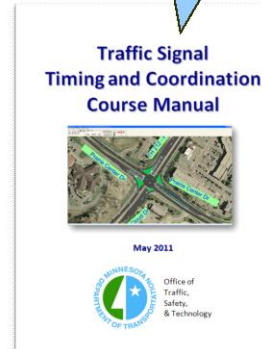


Standard Specifications



Traffic Engineering Manual (TEM)

Signal Optimization and Timing Manual



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The Standard Specifications are used for all types of construction. Refer to Topic 13 of this workbook for more details.

The Traffic Engineering Manual (TEM) contains a variety of information related to signals.

The Signal Optimization and Timing Manual is a manual for how to run and operate a traffic signal and signal system.

Visit the Office of Traffic, Security & Technology website for up-to-date publications (including this manual).



Why?

➤ For up-to-date information, visit:

<http://www.dot.state.mn.us/trafficeng/>



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Visit the Office of Traffic, Security & Technology (OTST) website for a wide range of up-to-date resources.

Many of the references used in this Manual can be downloaded via the Publications link.

Handout

Excerpts from MN MUTCD (Page 4C-1 to 4C-13)

For the latest version of the MN MUTCD, please visit:

www.dot.state.mn.us/trafficeng/publ/mutcd/index.html

PART 4. HIGHWAY TRAFFIC SIGNALS

Chapter 4C. Traffic Control Signal Needs Studies

4C.1 Studies and Factors for Justifying Traffic Control Signals

STANDARD:

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.

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

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

SUPPORT:

Sections 8D.9 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:

A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.

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.

A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.

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 above signal warrants.

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.

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.

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.

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:

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.

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.

For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

SUPPORT:

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:

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.

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 the preceding paragraph:

- 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.

4C.2 Warrant 1, Eight-Hour Vehicular Volume

SUPPORT:

The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

The Interruption of Continuous Traffic, Condition B, 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.

It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then Warrant 1 is satisfied and analysis of Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then Warrant 1 is satisfied and an analysis of the combination of Conditions A and B is not needed.

STANDARD:

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

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-1. Warrant 1, Eight-Hour Vehicular Volume

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:

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.

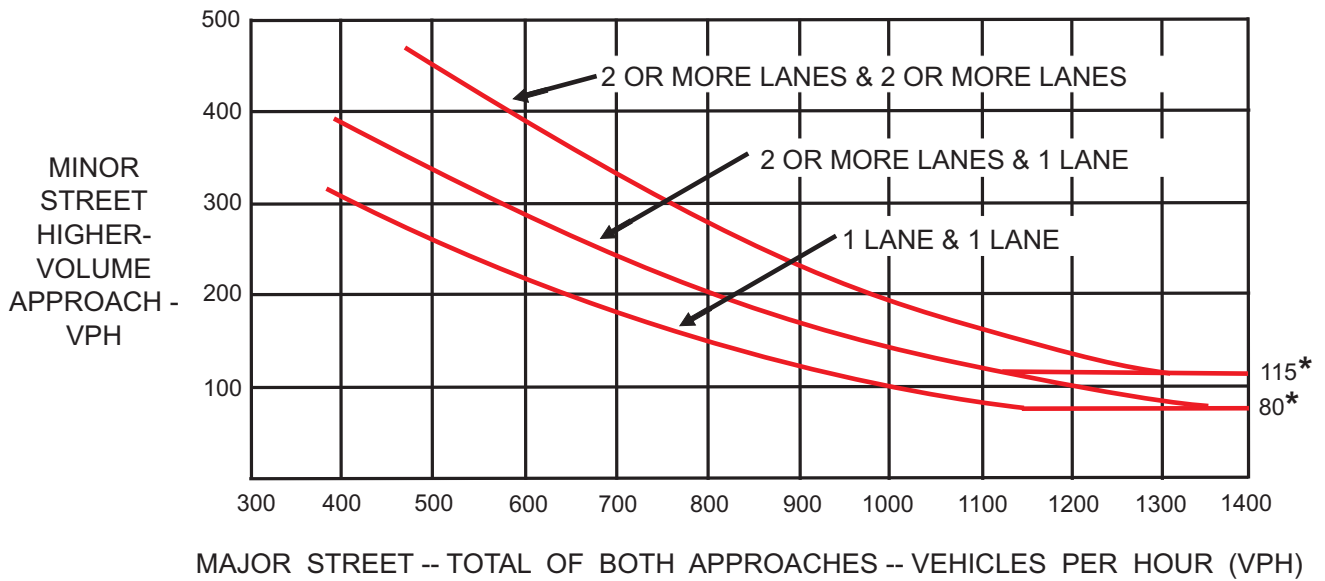
GUIDANCE:

The combination of Conditions A and B 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:

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:

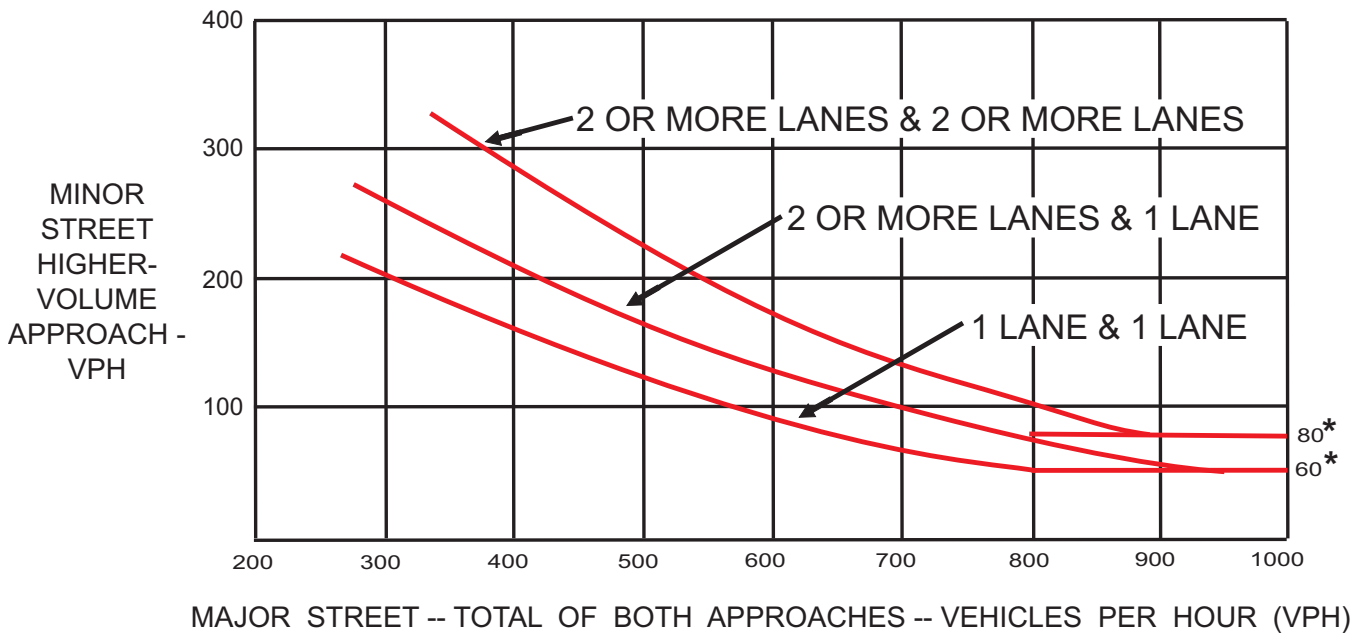
- A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and



*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-1. Warrant 2 - Four-Hour Vehicular Volume

(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.

Figure 4C-2. Warrant 2 - Four-Hour Vehicular Volume (70% Factor)

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.

OPTION:

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.

4C.3 Warrant 2, Four-Hour Vehicular Volume

SUPPORT:

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:

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:

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 may be used in place of Figure 4C-1.

4C.4 Warrant 3, Peak Hour

SUPPORT:

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:

This signal warrant shall be applied only in unusual cases. Such cases include, but are not limited to, office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.

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.

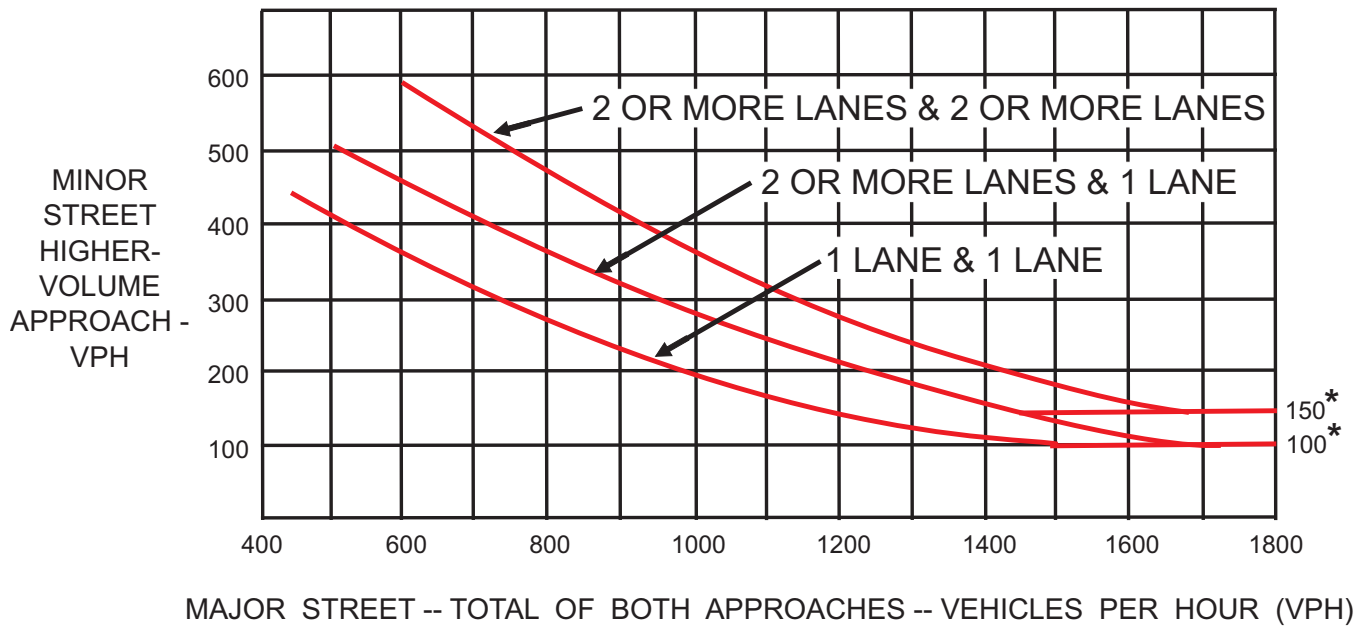
OPTION:

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 may be used in place of Figure 4C-3 to satisfy the criteria in the second category of the Standard.

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:

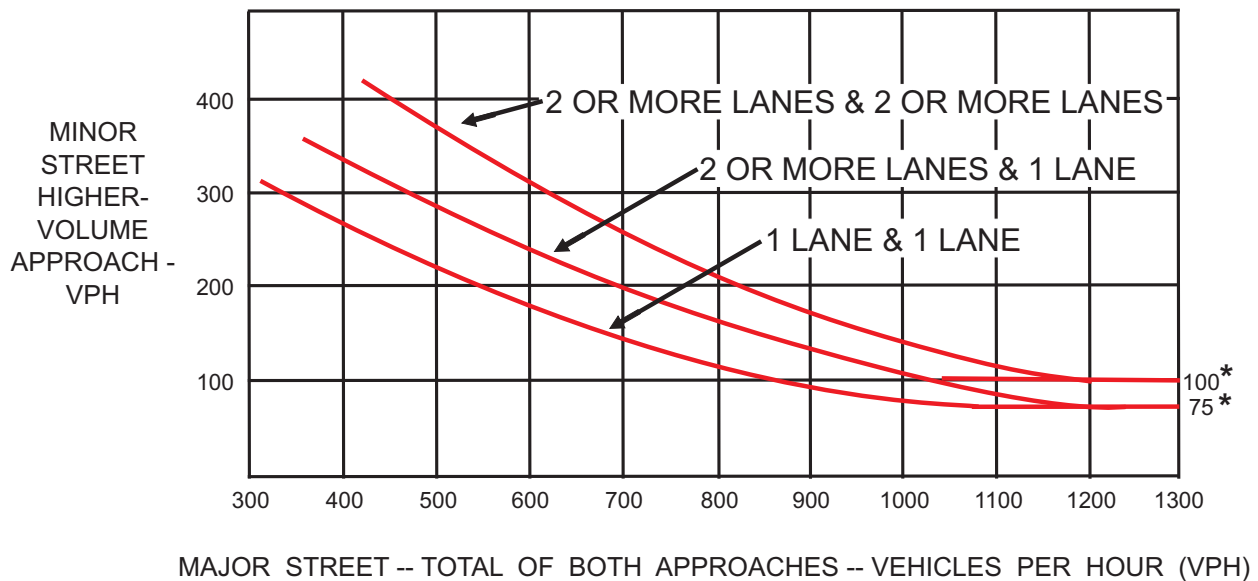
If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal should be traffic-actuated.



*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-3. Warrant 3 - Peak Hour

(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 lane.

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

4C.5 Warrant 4, Pedestrian Volume

SUPPORT:

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:

The need for a traffic control signal at an intersection or mid-block 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:

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 above and Figure 4C-8 may be used in place of Figure 4C-7 to evaluate Criterion B above.

STANDARD:

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.

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:

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 series of signals, the traffic control signal should be coordinated.

OPTION:

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 ft/sec.

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.

4C.6 Warrant 5, School Crossing

SUPPORT:

The School Crossing signal warrant is intended for application where the fact that school children 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:

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.3) and there are a minimum of 20 schoolchildren during the highest crossing hour.

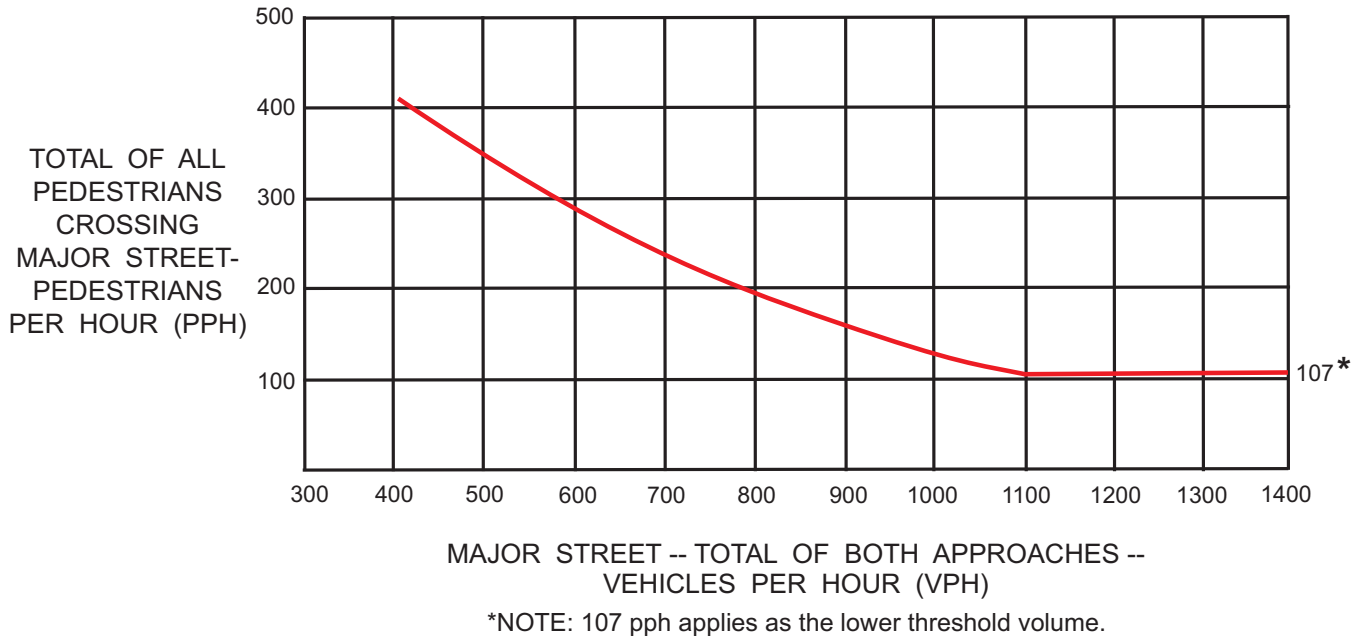


Figure 4C-5. Warrant 4 - Pedestrian Four-Hour Volume

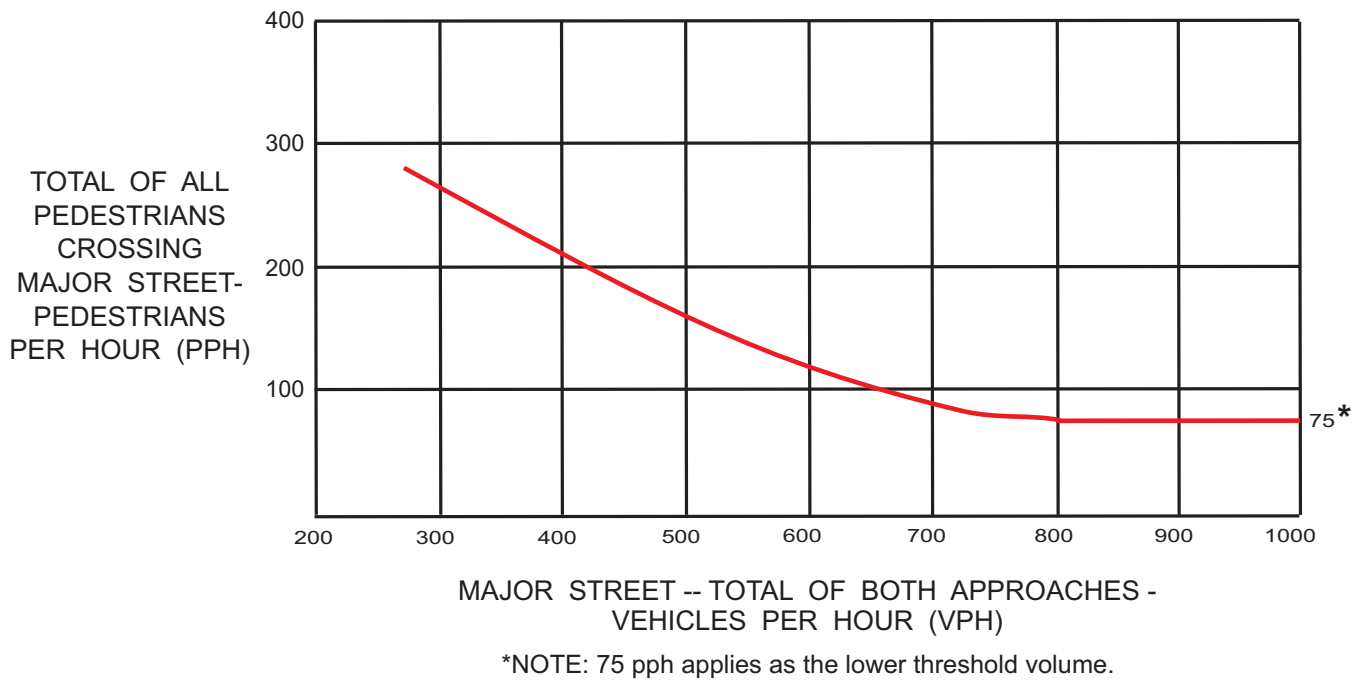
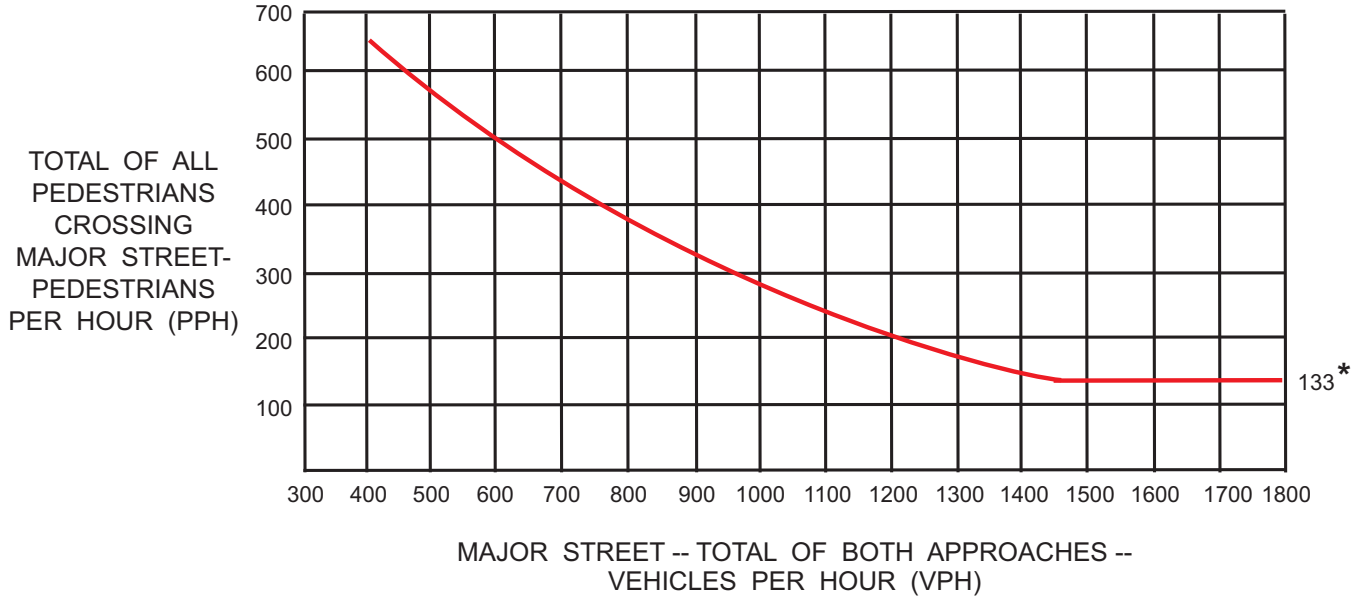
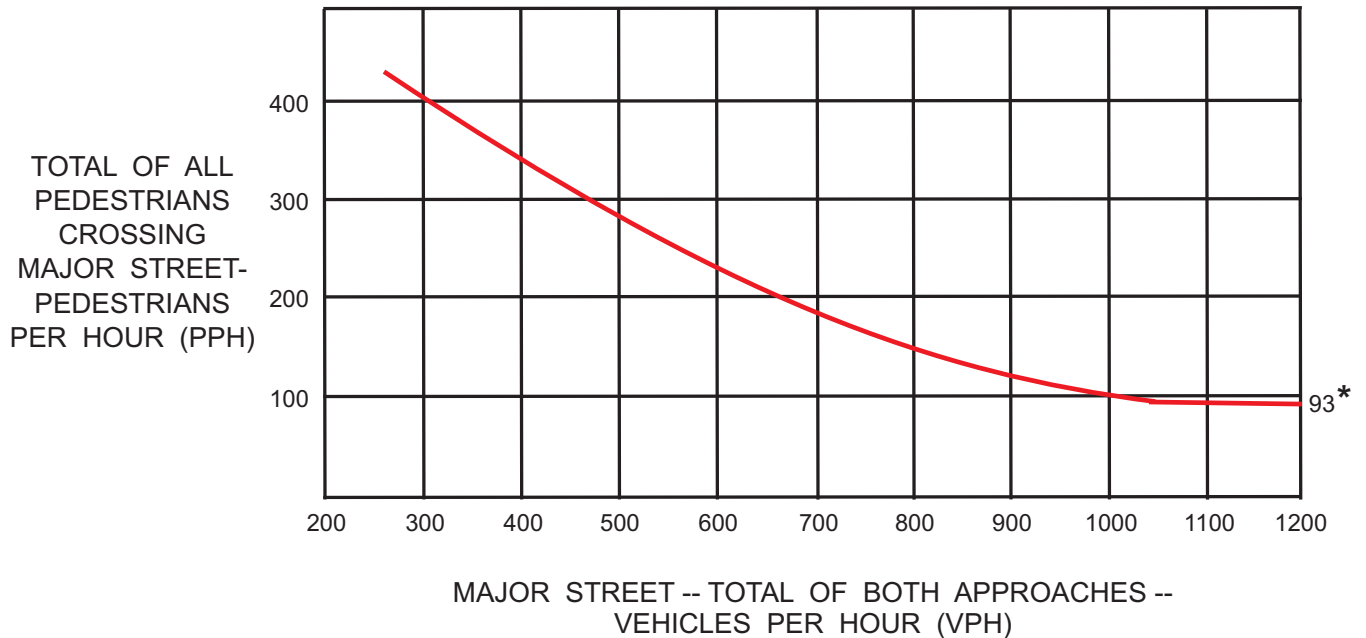


Figure 4C-6. Warrant 4 - Pedestrian Four-Hour Volume (70% Factor)



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

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



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

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

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.

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 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

GUIDANCE:

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 series of signals, the traffic control signal should be coordinated.

4C.7 Warrant 6, Coordinated Signal System

SUPPORT:

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:

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:

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.

4C.8 Warrant 7, Crash Experience

SUPPORT:

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:

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.2), 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:

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.

4C.9 Warrant 8, Roadway Network

SUPPORT:

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

STANDARD:

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).

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; or
- B. It includes rural or suburban highways outside, entering, or traversing a city; or
- 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.

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

SUPPORT:

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:

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:

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:

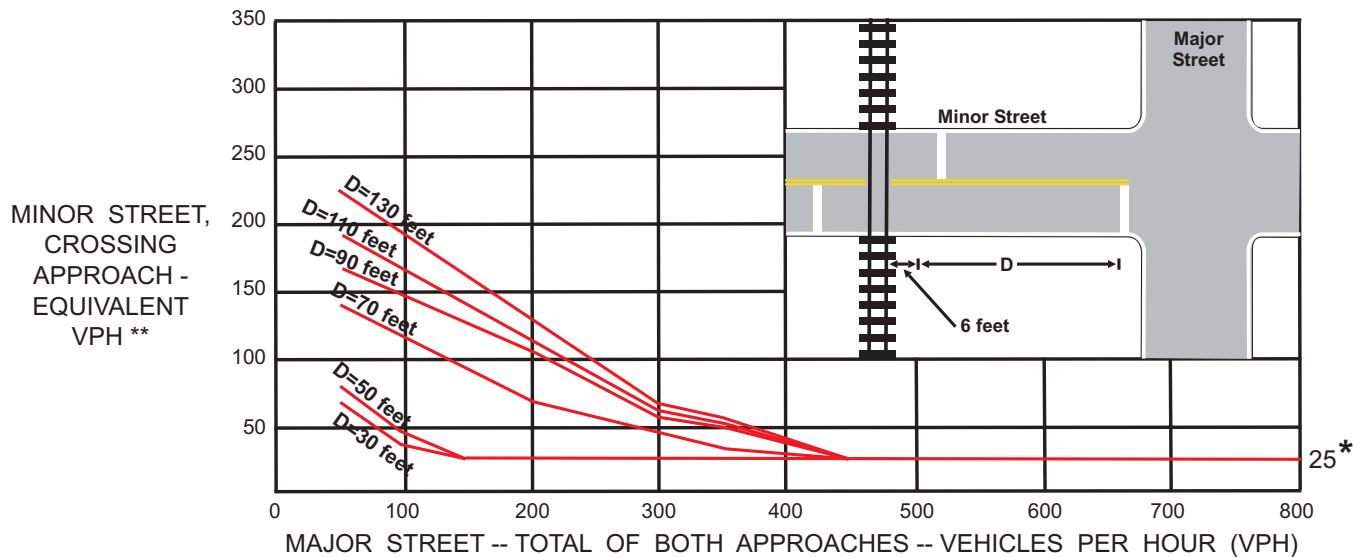
The following considerations apply when plotting the traffic volume data on Figure 4C-9 or 4C-10:

- 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.
- 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:

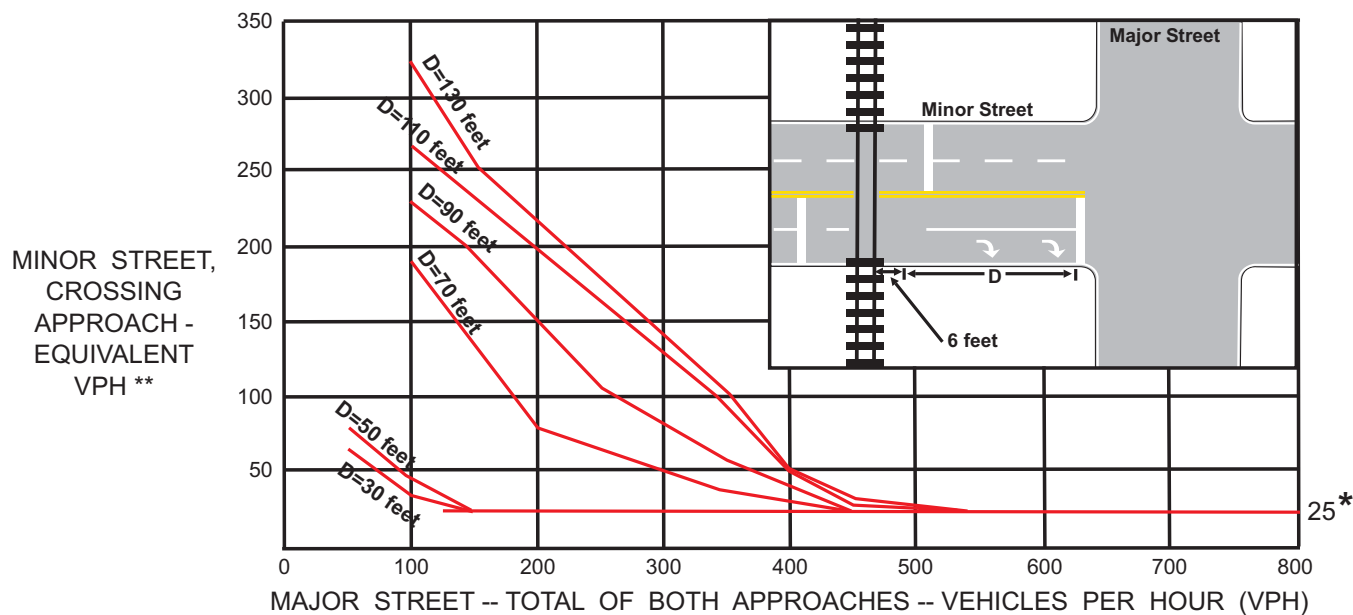
The minor-street approach volume may be multiplied by up to three adjustment factors as provided in Paragraphs 6 through 8.

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-2 for the appropriate number of occurrences of rail traffic per day.



* 25 vph applies as the lower threshold volume
 ** VPH after applying the adjustment factors in Tables 4C.2, 4C.3, and/or 4C-4, if applicable

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



* 25 vph applies as the lower threshold volume
 ** VPH after applying the adjustment factors in Tables 4C.2, 4C.3, and/or 4C-4, if applicable

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

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-3 for the appropriate percentage of high-occupancy buses.

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-4 for the appropriate distance and percentage of tractor-trailer trucks.

STANDARD:

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.9, and 8C.10; and
- C. The grade crossing shall have flashing-light signals (see Chapter 8C).

GUIDANCE:

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).

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-2. Warrant 9 - Adjustment Factor for Daily Frequency of Rail Traffic

% 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-3. Warrant 9 - Adjustment Factor for Percentage of High-Occupancy Buses

% 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-4. Warrant 9 - Adjustment Factor for Percentage of Tractor-Trailer Trucks