Traffic Signal Warrants

Guidelines for Conducting a Traffic Signal Warrant Analysis, 2nd Edition

Revised Edition based on 2006 Texas MUTCD

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CHAPTER 1:
INTRODUCTION

Traffic signals are electronically controlled traffic control devices that control the movement of competing traffic at intersections. The evolution of traffic signals goes back to the early days of the automobile when a wide variety of lighted devices were used for intersection control. By the mid-1930s, the three-indication red-yellow-green traffic signal was established as the national standard for the appearance of a traffic signal. Since that time, there have been many improvements in the use and operation of traffic signals, but the basic concept of a red-yellow-green signal controlling intersection traffic has remained the same.

Traffic signals are one of the most restrictive forms of traffic control that can be used at an intersection. In order to ensure that the use of traffic signals is limited to favorable situations, practitioners have developed a series of traffic signal warrants to define the minimum traffic conditions that should be present before a traffic signal is installed.

The application of these traffic signal warrants can be complicated at times. The general public, elected and government officials, and even some practitioners sometimes misunderstand the signal warrants. This document provides detailed guidelines on how to use the traffic signal warrants to evaluate the need for installing a traffic signal. It addresses many of the issues that have typically been left to interpretation and is intended to improve the consistency of the warranting process.

This second edition is an update of the first edition, which was originally published in 1998. Since that time, the federal and state traffic signal warrant guidelines have been substantially revised and reformatted. This edition was prepared to provide practitioners with an up-to-date guide on how conduct a signal warrant analysis.

TRAFFIC SIGNALS

The intersection of two or more roadways provides one of the more significant traffic control challenges for the responsible jurisdiction. Traffic on these intersecting roadways must share the same pavement area, requiring that access to this pavement area be alternately assigned to the conflicting traffic movements. This traffic can include cars, trucks, motorcycles, bicycles, pedestrians, mass transit, and emergency vehicles. Vehicular movements can include both through and turning movements. Geometric constraints can further complicate intersection traffic control. Various control methods can be used, including no control, yield control, stop control, and signal control, listed in order from the least to the most restrictive. There are multiple levels of complexity for some of these methods.

Because traffic signals are the most restrictive form of intersection traffic control, they have a profound influence on traffic, and their use should be limited to situations where they will be more effective than the other types of intersection traffic control. To promote appropriate and uniform installation, design, and operation of signals, practitioners have developed a series of guidelines and warrants.

Traffic Signals and the MUTCD

The *Manual on Uniform Traffic Control Devices* (MUTCD) is the guiding document for the selection, design, installation, operation, and maintenance of all types of traffic control devices, including traffic signals. The purpose of the MUTCD is to provide uniformity in traffic control devices across the United States. As such, the Federal Highway Administration (FHWA) is responsible for the national MUTCD. The current national MUTCD was adopted in 2003[1]. The information in the current MUTCD is significantly reorganized from editions prior to 2000, and much of it was rewritten as well. States have the option of adopting the national MUTCD or developing a state MUTCD or state supplement that is in substantial compliance with the national MUTCD. In Texas, the Texas MUTCD establishes minimum criteria for the use of traffic control devices. The 2006 Texas MUTCD[2] is the current version of the state MUTCD and it is based on the 2003 national MUTCD. The 2006 Texas MUTCD is the document that establishes the legal requirements and guiding principles for traffic control devices used on all public roads in Texas. The guidelines in this document are based on the content of the 2006 Texas MUTCD. The warrants in the national and Texas MUTCDs are identical except for two additional criteria that are added to the Roadway Network Warrant (Warrant 8) in the Texas MUTCD.

The MUTCD is one of the key documents in the traffic engineering field. It is also a complex document. An understanding of the role of the MUTCD is an essential element of using the document to make decisions about traffic control devices. Even though the MUTCD provides guidelines and warrants for traffic signals and other traffic control devices, the application of these guidelines and warrants should be exercised by a competent traffic engineer and only after a thorough study of the critical factors. Appendix A provides additional background information about the role of the MUTCD. Part 4 of the MUTCD establishes minimum criteria for the installation of traffic signals and for many elements of traffic signal design and operation. MUTCD Chapter 4C describes the warrants for traffic signal installation. Appendix B presents the eight warrants from the 2006 Texas MUTCD.

Official FHWA MUTCD Rulings and Interpretations

In its role of maintaining the MUTCD, the FHWA is responsible for responding to questions and requests regarding the MUTCD as described in Section 1A.10 of the 2003 National MUTCD. FHWA has been fulfilling this responsibility since the early 1970s, and there have been numerous previous interpretations related to traffic signal warrants. This document presents those interpretations where they are pertinent to a particular aspect of the warranting process. When presented, these interpretations are shown as tables and include the FHWA number assigned to the request.

Advantages and Disadvantages of Traffic Signals

The public often views traffic signals as a cure-all for traffic problems at intersections. As a result, traffic signals have often been installed at intersections where less restrictive traffic

[1] *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, Washington, D.C., 2003.
[2] *Texas Manual on Uniform Traffic Control Devices*, Texas Department of Transportation, Austin, Texas, 2006.

control would have been more appropriate and effective. Traffic signal warrants have been developed to establish minimum criteria for evaluating the need for a traffic signal at a specific intersection. These warrants do not define the need for a traffic signal, but merely indicate where further study of a traffic signal installation is justified. When properly justified and installed, traffic signals can have many positive benefits. However, traffic signals also have negative impacts, particularly if the signal is improperly justified or installed.

When the installation of a traffic signal is properly justified, and the design, operation, and maintenance are in accordance with current principles, the signal can have many positive benefits on the efficiency and safety of vehicular and pedestrian traffic at the intersection. The advantages to a properly justified and installed traffic signal may include one or more of the following:

- It can provide for the orderly movement of traffic.
- It can increase the traffic-handling capacity of the intersection if proper physical layouts and control measures are used and the signal operational parameters are reviewed and updated on a regular basis to maximize the ability of the traffic control signal to satisfy current traffic demands.
- It can reduce the frequency of certain types of crashes, especially right-angle collisions.
- By coordinating the signal with adjacent signals, it can provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
- It can be used to interrupt heavy traffic on the major street to permit vehicular and pedestrian traffic on the minor street to cross.

Even when properly justified and installed, a traffic signal can have a detrimental impact on certain aspects of traffic flow at an intersection. If a signal is properly justified and installed, the resulting advantages offset associated disadvantages.

However, additional disadvantages may result if a traffic signal is not properly justified or if the traffic signal is ill-designed, ineffectively placed, improperly operated, or poorly maintained. The disadvantages that may be associated with an improperly justified, installed, operated, or maintained traffic signal include:

- It can increase delay for all traffic movements.
- It can lead to an increase in traffic violations at the intersection.
- It can increase the frequency of traffic crashes at the intersection (primarily rear-end crashes).
- It can cause road users to increase the use of alternative routes to avoid the signal. Often, these alternative routes travel through neighborhoods or other less adequate roads.

Traffic crashes are included in both the advantages and disadvantages of traffic signals. This is because a properly installed traffic signal often results in an increase in certain types of crashes, most notably rear-end collisions. However, the crashes that typically result from signal

installation are typically less severe than the crashes that would occur if the signal was not installed.

Once installed, traffic signal operation should be periodically reviewed to determine whether the physical characteristics of the signal and the intersection, the type of control, and the signal timing meet the current needs of the traffic at the intersection.

Alternatives to Traffic Signal Control

As described previously, the installation of a traffic signal can have a detrimental effect on the operations and/or safety at an intersection. Before a traffic signal is installed, consideration should be given to less restrictive forms of assigning right-of-way at an intersection which may have less severe impacts on the intersection. The objective is to utilize the least restrictive form of traffic control that produces safe and efficient vehicle and pedestrian operation. These other forms of right-of-way control should be considered even if the intersection meets one or more of the traffic signal warrants. There are several different methods of controlling right-of-way at a roadway intersection. Each method places a different level of restriction on traffic flow at the intersection. The various options available for intersection right-of-way control are listed below in order from the least restrictive to the most restrictive.

- No control (right-of-way assignment established by statute).
- Yield control with Yield sign (see Texas MUTCD Section 2B.09 for Yield sign applications).
- Manual traffic control by a police officer or other official.
- Two-way stop control with Stop sign only (see Texas MUTCD Section 2B.05 for Stop sign applications).
- Two-way stop control with Stop sign and stop sign beacon (see Texas MUTCD Section 4K.05 for stop sign beacon).
- Two-way stop control with Stop sign and red/yellow intersection beacon (see Texas MUTCD Section 4K.02 for intersection control beacon).
- Multiway stop control with Stop sign only (see Texas MUTCD Section 2B.07 for Multiway Stop sign applications).
- Multiway stop control with Stop sign and stop sign beacon (see Texas MUTCD Section 4K.05 for stop sign beacon).
- Multiway stop control with Stop sign and red/red intersection beacon (see Texas MUTCD Section 4K.02 for intersection control beacon).
- Traffic signal.

Other less restrictive uses of traffic control device treatments should also be considered before installing a traffic signal. Examples of these types of alternative intersection treatments include:

- Installing warning signs in advance of the intersection (examples include Cross Road, Stop Sign Ahead, Yield Sign Ahead, and Pedestrian Crossing).
- Increasing the size of regulatory and/or warning signs on the intersection approach.

- Installing warning beacons on warning signs in advance of the intersection (see Texas MUTCD Section 4K.03 for warning beacon).
- Relocating the stop line(s) and/or making other changes (such as trimming vegetation) to improve the sight distance at the intersection.
- Installing edge and channelizing lines along the major roadway approaches to narrow the lane width, which will encourage reduced approach speeds.
- Increasing enforcement of existing traffic control measures.
- Adding one or more lanes on a roadway approach to reduce the number of vehicles per lane on the approach.
- Revising the geometrics at the intersection to channel vehicle movements and reduce the time required for a vehicle to complete a movement, which could also assist pedestrians.
- Installing roadway lighting if a disproportionate number of crashes occur at night.
- Restricting one or more turning movements (perhaps on a time-of-day basis) if alternate routes are available.
- Installing measures designed to reduce speeds on the approaches.
- Installing flashing beacons on Stop signs or warning signs.
- Converting the intersection to a roundabout.
- Employing other alternatives, depending on conditions at the intersection.

TRAFFIC SIGNAL WARRANTS

The traffic signal warrants contained in Chapter 4C of the Texas MUTCD establish minimum criteria for further evaluation of traffic signal installation. The current Texas MUTCD contains eight traffic signal warrants, as listed in Table 1. These warrants address a variety of intersection conditions such as vehicular volume, pedestrian volume, crashes, progression, and delay. The specifics associated with these warrants are described in detail in the warrant analysis guidelines chapter (see page 23). The MUTCD warrants have evolved into their present state over a period of many years and represent the experiences of many traffic signal installations.

Table 1. Texas MUTCD Traffic Signal Warrants

Warrant Number and Title		Basis for Analysis
1	Eight-Hour Vehicular Volume	Eight-hour vehicular volumes
2	Four-Hour Vehicular Volume	Four-hour vehicular volumes
3	Peak Hour	Vehicular volume and delay on minor street
4	Pedestrian Volume	Pedestrian volumes and gaps
5	School Crossing	Number of school children and gaps
6	Coordinated Signal System	Vehicular volumes and road classification
7	Crash Experience	Crashes and Warrants 1 or 4
8	Roadway Network	Projected volumes and Warrants 1, 2, or 3

These warrants represent several changes in formatting from the warrants that were in the 1980 Texas MUTCD (which served as the basis for the first edition of this document). The 1980 Texas MUTCD contained 12 signal warrants. Some of these warrants were combined (for example, Warrants 1, 2, and 8 from 1980 are now Warrant 1). Others have been renumbered. The actuated signals warrant (1980 Warrant 12) was exclusive to the Texas MUTCD (it was not a part of the national MUTCD) and has been deleted. Table 2 identifies how the warrants in the 1980 Texas MUTCD have been incorporated into or deleted from the warrants in the 2006 Texas MUTCD.

It is worth noting that the numerical order in which the warrants are listed does not imply an ordered relationship between the warrants. Neither does the listed order relate to the frequency in which the warrants are used as part of the process to justify a signal installation or the ease of applying a warrant.

Table 2. Changes in Warrants from 1980 to 2006 Texas MUTCD

1980 Warrant Number and Name	Relation to 2006 Warrant Number and Name
1 - Minimum Vehicular Volume	1 - Eight-Hour Vehicular Volume
2 - Interruption of Continuous Traffic	1 - Eight-Hour Vehicular Volume
3 - Minimum Pedestrian Volume	4 - Pedestrian Volume
4 - School Crossing	5 - School Crossing
5 - Progressive Movement	6 - Coordinated Signal System
6 - Accident Experience	7 - Crash Experience
7 - Systems	8 - Roadway Network
8 - Combination of Warrants	1 - Eight-Hour Vehicular Volume
9 - Four-Hour Volumes	2 - Four-Hour Vehicular Volume
10 - Peak Hour Delay	3 - Peak Hour
11 - Peak Hour Volume	3 - Peak Hour
12 - Volumes for Traffic Actuated Signals	Deleted

Traffic Signal Warrants

Practitioners developed the traffic signal warrants to establish uniformity between jurisdictions regarding the conditions related to the installation of traffic signals. When considering the installation of a traffic signal at an intersection and the role of traffic signal warrants in the analysis process, the jurisdiction should consider the following factors:

- There are eight traffic signal warrants.
- Each warrant defines a minimum threshold(s) that must be present before further analysis of traffic signal installation can be conducted.
- If an intersection satisfies one or more of the warrants, further analysis of other factors should be conducted to determine whether installation of a signal is justified.
- Satisfaction of one or more warrants does not require the installation of a traffic signal.

- The number of warrants satisfied does not necessarily establish a priority index for the need of a traffic signal. (i.e., an intersection that meets five warrants does not necessarily indicate a higher installation priority for that intersection than an intersection that meets three warrants).

When a traffic signal is warranted on the basis of an engineering study, it is presumed that the signal and all related traffic control devices are installed according to MUTCD standards and guidelines. It is further presumed that signal indications are properly phased, that the proper type of signal control is utilized, that roadways are properly designed, that adjacent traffic signals are properly coordinated, and that the signal is adequately operated and maintained.

- A traffic signal should not be installed if it does not satisfy any of the warrants.
- A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.

Post-Warrant Analysis

Traffic signal warrants establish criteria for further analysis of the need for a traffic signal at a given location. If one or more of the warrants are met, the following factors should be considered in the additional analysis that follows a warrant analysis:

- The additional analysis should be conducted by a traffic engineer or under the supervision of a traffic engineer.
- The analysis should consider other less restrictive forms of intersection traffic control.
- Because of the restrictions imposed by a traffic signal, the installation of a signal should not occur unless the advantages of the installation clearly outweigh the disadvantages of installation.

A traffic signal should not be installed solely on the basis of satisfying a traffic signal warrant. The signal should improve the overall safety and operation of the intersection and should not seriously disrupt progressive traffic flow. The importance of the post-warrant analysis is indicated by a change that FHWA made in a previous edition (1988) of the national MUTCD. Table 3 summarizes the basis for this change. The change clearly indicates that satisfaction of a warrant is not sufficient justification for signal installation. Additional analysis must be conducted to determine if the signal installation will have a positive impact on safety and/or operations.

Table 3. Change in Previous MUTCD Edition Regarding Post-Warrant Analysis

IV-66 (Change) Warrants for Traffic Signal Installation
The national MUTCD was changed to provide more explicit guidelines in justifying a signal installation. The change indicated that the satisfaction of a warrant is not, in itself, a mandate for a signal. This change stipulated the need for an engineering study, considering factors other than those outlined in the warrant, to indicate whether installation of a signal will improve safety and/or operations. (Effective Date: March 9, 1987)

Removal of Traffic Signals

Although the original installation of a traffic signal may be based on the satisfaction of one or more warrants and other factors, changes in traffic flow over time may reduce the effectiveness of traffic signal control. When this occurs, it may be appropriate to remove a traffic signal. The Texas MUTCD addresses the removal of signals in Section 4B.02. It states that if changes in traffic patterns eliminate the need for a traffic control signal, consideration should be given to removing it and replacing it with appropriate alternative traffic control devices, if any are needed. However, it is possible that a signalized intersection that does not meet any of the warrants will meet at least one warrant after the signal is removed (due to increases in crashes, delay, or traffic patterns). Therefore, removal of a signal requires engineering judgment.

Due to the expense associated with the removal and possible reinstallation of a traffic signal, the following steps should be followed prior to the removal of a traffic signal.

- Determine the appropriate traffic control to be used after removal of the signal.
- Remove sight distance restrictions as necessary.
- Inform the public of the removal study, for example by installing an informational sign (or signs) with the legend TRAFFIC SIGNAL UNDER STUDY FOR REMOVAL at the signalized location in a position where it is visible to all road users.
- Place the traffic signal in flashing operation reflecting two-way or multiway stop control, as appropriate, and install Stop signs (or other traffic control devices) on the appropriate approaches.
- If, after an extended period of flashing operation (at least 90 days), intersection operation and safety are acceptable, the signal should be deactivated. Signal deactivation can be accomplished by covering the signal heads, turning them face down, or removing the signal heads completely. Signal related signing should be removed from the intersection. The signal poles, mast arms, and/or span wire can be left in place.
- If the engineering data collected during the removal study period confirms that the signal is no longer needed, the signal poles, mast arms, and/or span wire should be removed.

The Traffic Engineering Section of the TxDOT Traffic Operations Division should be consulted for guidance when considering removal of a traffic signal.

Warrant Analysis Data

A warrant analysis cannot be conducted without a minimum amount of data about the physical, traffic, and operational characteristics of an intersection. Some of the data needed to conduct a warrant analysis are difficult and time-consuming to collect. Therefore, it is not uncommon to analyze selected warrants with the data that are easier to collect. If a signal does not meet any of these warrants, then the more difficult data are collected and the other warrants are analyzed. Examples of the types of data that are typically collected for analysis of one or more warrants are listed below. Other types of data may also be needed for a warrant analysis. More detailed descriptions of the data collection process are described in Chapter 2: Data Collection Procedures (page 11).

- Intersection geometry (intersection limits, population of area, distance between adjacent signals, distance to nearest existing signal, characteristics of a major route, pedestrian storage capacity of median).
- Traffic characteristics (hourly volumes per approach, major road speed, types of vehicles, size and number of gaps, platoon dispersion, vehicular delay).
- Pedestrian characteristics (number of pedestrians, ages, walking speed).
- Crash reports (number, type, and date of crashes).

ORDER OF WARRANT PRESENTATION

Using information gathered as part of a TxDOT/TTI research project on traffic signal warrants[1], the data collection and analysis guidelines in this document group the various warrants into phases according to the type of data used, the effort required to collect the data, and the frequency by which warrants are used to justify further analysis of traffic signal installation. In doing so, the warrants that are most frequently used or are easiest to collect data for are addressed first. This order is different than the numerical order in which the warrants are listed in the Texas MUTCD. Table 4 indicates the relative frequencies that the signal warrants were used in the process of analyzing the need for a traffic signal. It should be noted that the use of the warrants indicated in this table were associated with the warrants in the 1980 Texas MUTCD. The names of the warrants have been revised to reflect the warrants in the 2006 Texas MUTCD, but the usage data have not been updated.

Based on the order of the information in Table 4, this document presents the warrant analysis procedure as a five-phase process. Table 5 shows the order of this process. The material presented in both the data collection and warrant analysis chapters follows this order. By presenting the warrants in these phases, the procedure assumes that the warrants requiring difficult-to-collect data will not be analyzed if one or more of the warrants requiring easier-to-collect data can be satisfied. As a result, the time and expense associated with gathering difficult-to-collect data can be avoided if an intersection meets one of the other warrants.

FUTURE CHANGES TO TRAFFIC SIGNAL WARRANTS

At the time this document was prepared, the National Committee on Uniform Traffic Control Devices (NCUTCD) had proposed changes to some of the traffic signal warrants. If implemented by the FHWA, these changes would appear in the next edition of the national MUTCD (potentially in the 2008-2010 time frame) and in the Texas MUTCD after that. At this time, the proposed changes include a complete revision of the Pedestrian Warrant (Warrant 4) and the addition of a new warrant, Warrant 9, Intersection near Highway-Rail Grade Crossing.

[1] Carlson, P.J., and H.G. Hawkins, Jr. *Evaluation of Potential Traffic Signal Warrant Considerations*, Research Report 3991-1, Texas Transportation Institute, College Station, Texas, September 1998.

Table 4. Relative Use of Texas MUTCD Signal Warrants

Warrant Number and Title as Presented in the 1980 Texas MUTCD	Percent of Use for Signal Installation	Equivalent Warrant in the 2006 Texas MUTCD
1: Minimum Vehicular Volume	28%	1: Eight-Hour Vehicular Volume
12: Warrant Volumes for Traffic Actuated Signals	19%	Deleted
2: Interruption of Continuous Traffic	16%	1: Eight-Hour Vehicular Volume
11: Peak-Hour Volume	12%	3: Peak Hour
6: Accident Experience	7%	7: Crash Experience
7: Systems	4%	8: Roadway Network
8: Combination of Warrants	4%	1: Eight-Hour Vehicular Volume
5: Progressive Movement	3%	6: Coordinated Signal System
9: Four-Hour Volumes	3%	2: Four-Hour Vehicular Volume
10: Peak-Hour Delay	2%	3: Peak Hour
4: School Crossing	2%	5: School Crossing
3: Minimum Pedestrian Volume	0%	4: Pedestrian Volume

Source: Based on a survey of 19 TxDOT districts. The survey and responses are described in more detail in TxDOT Research Report 3991-1[1].

Table 5. Order of Warrant Analysis Process

Phase	Warrant Number and Title		Described in Guidelines on Page	
			Data Collection	Analysis Guidelines
1st Phase: Volumes	1	Eight-Hour Vehicular Volume	11	23
	2	Four-Hour Volumes		
	3	Peak-Hour (volume only)		
2nd Phase: Crashes	7	Crash Experience	17	30
3rd Phase: Signal Operation	6	Coordinated Signal System	17	32
	8	Roadway Network		
4th Phase: Delay	3	Peak-Hour Volume (delay)	19	34
5th Phase: Pedestrians	4	Pedestrian Volume	19	34
	5	School Crossing		

[1] Carlson, P.J., and H.G. Hawkins, Jr. *Evaluation of Potential Traffic Signal Warrant Considerations*, Research Report 3991-1, Texas Transportation Institute, College Station, Texas, September 1998.

CHAPTER 2:
DATA COLLECTION PROCEDURES

A traffic signal warrant analysis cannot be conducted without the necessary data. The effort required to collect these data varies from visual observation of the intersection being analyzed to measurement of the size of the gaps in the traffic stream. This chapter describes how to collect the data required to analyze the various warranting conditions. It is presented as a companion to the next chapter, which provides step-by-step guidelines for conducting a warrant analysis.

A full analysis of all the warrants requires a significant amount of data to be collected. However, many of the warrants can be analyzed with only a portion of the full data requirements. The general objective is to analyze the data that can be collected in the most reasonable manner before analyzing hard-to-collect data. As such, the data collection effort may consist of more than one phase. Often, only hourly vehicular volume and intersect characteristics are collected for the initial analysis. If an intersection does not meet a warrant using the hourly volume, the other types of data can be collected. Table 6 indicates the data that need to be collected with each of the warrant phases identified in Table 5. Table 6 is followed by specific instructions on how to collect each type of data needed in the various warrant analysis phases.

FIRST PHASE – VEHICULAR VOLUME WARRANTS

Three different warrants are based on the vehicular volume at the intersection: the Eight-Hour Vehicular Volume Warrant (Warrant 1), Four-Hour Vehicular Volume Warrant (Warrant 2), and the volume portion of the Peak Hour Warrant (Warrant 3). The basic differences between these warrants are the threshold criteria and the number of hours that must meet the threshold. Five types of data are used in the first phase of analysis, as indicated below. The rest of this section provides specific details on collecting the data.

- Intersection limits.
- Speed on the major roadway.
- Population of the area.
- Typical weekday hourly vehicular approach volumes.
- Number of lanes per approach.

Table 6. Suggested Data Collection Phases

Phase	Data	See Page	Warrant Categories				
			Vehicular Volume	Signal Operation	Crash	Delay	Pedestrian Related
First: Vehicular Volume	Intersection limits	13	✓	✓	✓	✓	✓
	Speed on the major roadway	13	✓	✓	✓		
	Population of the area	14	✓		✓		
	Typical weekday hourly vehicular approach volumes	14	✓	✓	✓	✓	
	Number of lanes per approach	16	✓		✓		
Second: Crash	Crash history	17			✓		
	Type of each crash	17			✓		
Third: Signal Operation	Distance between existing signals	18		✓			
	Roadway characteristics	18		✓			
	Hourly volumes for a typical non-business day	19		✓			
	Five-year projected hourly traffic volumes	19		✓			
Fourth: Delay	Peak hour vehicular delay on minor road	19				✓	
Fifth: Pedestrian Related	Distance to nearest existing signal	20					✓
	Distance to nearest crosswalk	20					✓
	Pedestrian walking speed	20					✓
	Hourly pedestrian volume	21					✓
	Storage capacity of median	21					✓
	Size of adequate gap	21					✓
	Number of gaps of adequate size	22					✓
	School crossing plan	22					✓
	Presence of school children	22					✓

Intersection Limits

For most intersections, identification of the approaches that define the intersection is a simple matter. However, when there are two closely spaced intersections, a question arises as to whether the intersections should be treated as one intersection or as separate intersections. This is particularly applicable to divided highway intersections and offset intersections. In the Uniform Vehicle Code, intersections more than 30 ft apart are treated as separate intersections by definition. However, MUTCD Section 4C.01 specifically states that an intersection with a wide median, even if the median is wider than 30 ft, should be considered as a single intersection for a warrant analysis. This warrant application is based on a previous FHWA interpretation, indicated in Table 7, which states a wide median intersection should be treated as a single intersection for warrant analysis purposes. A similar interpretation can be applied to closely spaced offset intersections.

Table 7. FHWA Interpretation Warrants for Wide Median Intersections

Sg-25 (Interpretation)	**Clarification on Computing Signal Warrants for Wide Median Intersections**
Interpretation of the following was requested: Is the definition of a wide median (which considers wide median intersections as separate intersections for purposes of regulation and control) applicable to the MUTCD signal warrants? It was ruled that traffic signal warrants were established to identify those conditions which present a high potential for traffic conflict with resultant crashes, congestion, and delay. These conditions essentially result from conflicts between crossing or nonparallel traffic movements. The physical separation of parallel traffic movements does not eliminate these conflicts and, accordingly, for purposes of warranting signalization, a wide median intersection should not be considered as two separate intersections. The definition which considers wide median intersections as separate intersections for purposes of regulation and control does not apply to MUTCD signal warrants.	

Speed on the Major Roadway

The volume warrants allow lower volume criteria to be used if the speed on the major roadway is greater than 40 mph. Both the current national and Texas MUTCDs indicate that this can be posted, statutory, or 85th percentile speed. Since the posted speed should be based on the 85th percentile speed, either speed can be used for analysis of the volume warrants. If it is necessary to measure the 85th percentile speed, instructions for calculating the speed can be found in most traffic engineering references. The FHWA has determined that this reduction can be applied to both rural and urban intersections. Table 8 is an FHWA interpretation indicating that the volume reduction criteria based on major street speed can be applied to both rural and urban intersections.

Table 8. FHWA Interpretation on Speed for Reduction of Volume Warrant

Sg-94 (Interpretation)	Reduction of Volume Warrant
The request was for clarification of MUTCD requirements in the vehicular volume warrants. The request was whether the 70 percent reduction in required volumes applies to both rural and urban areas. The FHWA response stated that the reduction can be applied to both rural and urban intersections.	

Population of Area Where Intersection Is Located

The volume warrant criteria can also be reduced if the intersection lies within the built-up area of an isolated community having a population of less than 10,000. The population criterion applies to the built-up area and not to individual government jurisdictions. Two neighboring cities, each with a population between 5,000 and 10,000, would not meet the reduced volume criteria based on population.

Typical Weekday Hourly Vehicular Approach Volumes

Traffic volume counts for the vehicular volume warrants are among the easiest of the data to collect, as they do not require the continuous presence of a worker while the data are being collected. They are also among the data that are the most widely used in analyzing the various warrants. Hourly vehicular volume counts are used in several of the warrants. As a result, these are usually the first type of data collected for analysis of signal warrants. Most transportation agencies are capable of conducting hourly volume counts. Vehicular volume counts are typically made using automatic counters with road tubes placed across the road on each approach. Other methods can also be used. The following factors should be addressed in conducting the count:

- Counts should be made so that the vehicles approaching the intersection are counted. (In other words, count only one direction of traffic on each approach.)
- The count locations should be located to avoid counting vehicles that turn before reaching the intersection or that turn onto the roadway downstream of the count location.
- The volume count should reflect the number of vehicles at the count location. Equivalency factors should not be used for heavy vehicles.
- The volume counts should represent a typical or average weekday. This is usually a Tuesday, Wednesday, or Thursday. Hourly counts from a single typical day may be used, but, to reduce daily volume variations, it is better to average hourly volumes on two or more typical days. Table 9 presents the text of an FHWA interpretation that describes the concept of an average day as it applies to the volume warrants.
- A traffic volume count made for purposes of a warrant analysis typically include 16 hours of volume data (5:00 a.m. to 9:00 p.m.), but shorter time periods may be counted. The hours should be selected to contain the greatest percentage of 24-hour traffic.
- The count data must be compiled into hourly volumes. Any hourly increment can be used, i.e., *:00-*:00 or *:15-*:15. Warrants cannot be analyzed with daily traffic volumes or by applying hourly percentages to daily volumes. Appendix C provides a format for compiling the hourly volumes.

Table 9. FHWA Interpretation on Average Day

Sg-7 (Interpretation)	Interpretation of Signal Warrants as Applied to Rural Locations
The request was for clarification of the term "an average day" as used in the minimum vehicular volume of the Eight-Hour Vehicular Warrant (Warrant 1, Condition A). The concern was about how this warrant applies in small farm towns and resort areas where the prescribed minimum volumes may be met only on weekends or during certain months of the year. FHWA ruled that "average day," as used in the warrant, is intended to mean weekday representing traffic volumes normally and repeatedly found at the location.	

- The volume for the major road should represent the sum of both directions of travel.
- The volume for the minor road should represent the highest volume approach for a given hour. The direction of the high-volume approach can change from one hour to another. For example, the minor street high volume may be eastbound in the morning hours and westbound in the evening hours.

When collecting volumes for warrant analysis, some agencies also collect vehicular volume data that can be used for signal operation parameters. These volumes include turning movements and vehicle classifications. Neither type of data is required to conduct an analysis, with one exception. It may be appropriate to subtract the volumes of right or left turns from the approach volume before conducting the analysis as described in Table 10. The count locations should not include turning vehicles if the traffic using the turn lane is minor. Table 10 presents the text of an FHWA interpretation that indicates the need to apply engineering judgment in determining whether turning volumes should be included in the approach volume count. With respect to turning traffic on the minor street approaches, MUTCD Section 4C.01 also indicates the need to use engineering judgment to determine what portion of turning traffic should be subtracted from the minor street traffic count.

In some cases, it may be appropriate to treat turning movements on the major street as the conflicting minor street volume in conducting the warrant analysis. MUTCD Section 4C.01 provides one example of such a treatment by specifying that the higher of the major street left-turn volumes can be considered as the "minor street" volume and the corresponding single direction of opposing traffic on the major street as the "major street" volume. Other combinations of conflicting traffic volumes may also be used to conduct a warrant analysis.

Table 10. FHWA Interpretation on Lane Count and Turn Volume

IV-65 (Interpretation)	Signal Warrants, Determining Number of Approach Lanes

Considerable engineering judgment must be exercised in applying various traffic signal warrants to cases where approaches consist of one lane plus one right-turn or one left-turn lane. The site specific traffic characteristics will dictate whether an approach should be considered as a one-lane approach or a two-lane approach. For example, for a minor street approach with one lane plus a left-turn lane, engineering judgment would indicate that it should be considered a one-lane approach if the traffic using the left-turn lane is minor. In such a case, judgment would also indicate that only the volume of traffic in the through/right-turn lane should be considered against the warrants. Conversely, it would be considered as two-lane approach if the lane split approached 50/50.

A similar rationale could be applied to a minor street approach with one lane plus a right-turn lane. Judgment, in the case of right-turn lanes, must also be exercised relative to the degree of conflict of minor street right-turn traffic with traffic on the major street. Thus, right-turn traffic would not be included in the minor street volume if the movement operated as a merge, semi-merge, or even, with typical intersection geometrics, entered the major street with a minimum of conflict. In such cases, the approach would be evaluated as a one-lane approach and only the traffic in the through/left-turn lane considered.

Number of Lanes per Approach

The number of lanes on each intersection approach must be determined to conduct the vehicular volume warrants. The number of approach lanes represents the number of moving lanes. MUTCD Section 4C.01 states:

> "*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 dictate whether an approach should be 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, engineering judgment could indicate that it should be considered a one-lane approach if the traffic using the left-turn lane is minor. In such a case, 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 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.*"

In addition to addressing the turning volume, the FHWA interpretation presented in Table 10 also indicates the need to exercise engineering judgment in determining whether to include a turning lane in the approach lane count.

SECOND PHASE – CRASH WARRANT

The data needs for the Crash Experience Warrant (Warrant 7) build upon those used in the vehicular volume warrants. One portion of the Crash Experience Warrant requires the intersection to have at least 80 percent of the volumes required for the Eight-Hour Vehicular Volume Warrant (Warrant 1) or at least 80 percent of the pedestrian volumes required for the Pedestrian Volume Warrant (Warrant 4). In addition to the vehicular volume data, this warrant requires crash history information for the intersection. The specific data and the related purpose are described below. The following paragraphs provide specific details on collecting the data.

- Previously collected data:
  - Speed on the major roadway
  - Population of the area
  - Typical weekday hourly vehicular approach volumes
  - Number of lanes per approach
- Additional data requirements:
  - Crash history
  - Type of each crash
  - Date of each crash

Crash History

A list of all the crashes that have occurred at the intersection should be obtained from the agency responsible for maintaining the crash database for a given area. In Texas, this is the Department of Public Safety for highways on the state system and the local law enforcement agency for crashes off the state system. Only those crashes that have occurred during the most recent 12-month period (in which data are available) should be used in analyzing the Crash Experience Warrant.

Types of Crashes

Only those crashes that are susceptible to correction by a traffic control signal are used in the Crash Experience Warrant. Table 11 provides examples of the types of crashes that are, and are not, susceptible to correction by a traffic control signal.

THIRD PHASE – SIGNAL OPERATION WARRANTS

Two warrants are based upon how a signal would affect traffic operations at an intersection. The two warrants are the Coordinated Signal Systems Warrant (Warrant 6) and the Roadway Network Warrant (Warrant 8). These warrants require different types of data for analysis as indicated below, along with the warrant with which they are used, but each also uses some data collected in previous phases. The following paragraphs provide specific details on collecting the data.

Table 11. Types of Crashes Susceptible to Correction by a Traffic Signal

Examples of Crashes That May Be Susceptible to Correction by a Traffic Control Signal	Examples of Crashes That May Not Be Susceptible to Correction by a Traffic Control Signal
• Crashes between vehicles on conflicting approaches to the intersection. • Crashes between left-turning vehicles and through vehicles on the opposite approach. • Crashes involving pedestrians.	• Rear-end crashes. • Crashes between vehicles moving in the same direction.
Note: The examples above represent typical situations. Engineering judgment should be used on a case-by-case basis to determine whether a particular crash is susceptible to correction by a traffic signal.	

- Data previously collected:
  - 85th percentile speed (Coordinated Signal Systems Warrant)
  - Peak hour volume for a typical weekday (Roadway Network Warrant)
- Additional data requirements:
  - Distance between existing signals (Coordinated Signal Systems Warrant)
  - Information on platoon dispersion (Coordinated Signal Systems Warrant)
  - Roadway characteristics (Roadway Network Warrant)
  - Five-year projected hourly traffic volumes (Roadway Network Warrant)
  - Hourly volumes for a typical non-business day (Roadway Network Warrant)

Distance between Existing Signals

The distance between the proposed signal and existing signals is used in analyzing the Coordinated Signal Systems Warrant. This distance should be measured from center-of-intersection to center-of-intersection. It can be measured in the field or from a map if the map's scale is sufficient to provide an accurate measurement

Roadway Characteristics

The Roadway Network Warrant can only be applied to the intersection of two or more major routes. Table 12 identifies the characteristics of a major route as used in this warrant.

Table 12. Definition of a Major Route for Use with Systems Warrant

For purposes of the Roadway Network Warrant, a major roadway has one or more of the following characteristics:
• It is part of the street or highway system that serves as the principal roadway network for through traffic flow. • It includes rural or suburban highways outside, entering, or traversing a city. • It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.

Hourly Volumes for a Typical Non-Business Day

The hourly volumes for a typical non-business day should be collected in the same manner as those for a typical weekday, except that they are collected on Saturday, Sunday, and/or holiday instead of a weekday. The duration of the volume count should be sufficient to ensure that the five highest hours are counted.

Five-Year Projected Hourly Volumes

The Transportation Planning and Programming (TPP) Division of TxDOT can supply 5-year projected volumes. If projected volumes are developed from any other source, they should be approved by TPP.

FOURTH PHASE – DELAY WARRANT

Only the Peak Hour Warrant (Warrant 3) specifically considers the delay experienced by vehicles on the minor road. This warrant uses the peak hour volume collected in the first phase. It also requires that the minor road delay be determined. The following paragraphs provide specific details on collecting the data.

- Data previously collected:
  - Peak hour volume for a typical weekday
- Additional data requirements:
  - Peak hour vehicular delay on a minor road

Peak Hour Vehicular Delay on Minor Road

The peak hour delay experienced on a minor road approach to a stop-controlled intersection is the total of the time that vehicles spend on the approach waiting to enter or cross the major road. Delay can be measured in the field or calculated. The *Highway Capacity Manual*[1] contains procedures for measuring and calculating intersection delay. A procedure for measuring delay in the field can be found in Chapter 16, Appendix A. Although this chapter applies to signalized intersections, the procedure for measuring delay also can be applied to approaches controlled by a Stop sign. Procedures for calculating delay at unsignalized intersections are contained in Chapter 10 of the *Highway Capacity Manual*.

FIFTH PHASE – PEDESTRIAN RELATED WARRANTS

The Pedestrian Volume Warrant (Warrant 4) and the School Crossing Warrant (Warrant 5) are the two warrants that address the presence of pedestrians in analyzing the need for a traffic signal. All of the data used to analyze these warrants apply only to these warrants. The data needed to analyze these two warrants are also the most difficult and time-consuming to collect. As a result of these factors and others, they are among the least often used to warrant a signal.

[1] 2000 *Highway Capacity Manual*. Transportation Research Board, National Research Council, Washington, D.C. 2000.

The specific data and the related purpose are described below. The following paragraphs provide specific details on collecting the data.

- Data previously collected:
  - None
- Additional data requirements:
  - Distance to nearest existing signal (Pedestrian Volume Warrant)
  - Distance to nearest crosswalk (Pedestrian Volume Warrant)
  - Pedestrian walking speed (Pedestrian Volume Warrant)
  - Hourly pedestrian volume (Pedestrian Volume Warrant)
  - Width of median (Pedestrian Volume Warrant)
  - Size of adequate gap (Pedestrian Volume Warrant)
  - Number of gaps of adequate size (Pedestrian Volume and School Crossing Warrants)
  - School crossing plan (School Crossing Warrant)
  - Presence of school children (School Crossing Warrant)

Distance to Nearest Existing Signal

This is the distance from the proposed crosswalk to the nearest signalized intersection. This distance is measured from the center-of-crosswalk to the near side of the nearest intersection.

Distance to Nearest Crosswalk

If the signal under consideration is a midblock crossing signal, the distance from the proposed crosswalk to the nearest existing crosswalk is measured. The distance should be measured from center-of-crosswalk to center-of-crosswalk.

Pedestrian Walking Speed

There are currently no specific guidelines for measuring this speed. It can be determined from the equation below. A recent National Cooperative Highway Research Program report[1] recommended walking speeds of 3.5 ft/sec for the general population and 3.0 ft/sec for older or less able population.

$$\bar{s}_p = \frac{nd}{\sum_{i=1}^{n} t_i}$$

where $\bar{s}_p$ = average pedestrian walking speed,
t_i = time for pedestrian i to cross road,
n = number of pedestrians, and
d = crossing distance.

[1] Fitzpatrick, K., et al. Improving Pedestrian Safety at Unsignalized Crossings, TRCP Report 112; NCHRP Report 562, Transportation Research Board, National Research Council, Washington, D.C., 2006.

Hourly Pedestrian Volume

The hourly pedestrian volume is the number of pedestrians crossing each roadway at the intersection. The volume counts should represent a typical or average weekday. This is usually a Tuesday, Wednesday, or Thursday. Hourly counts from a single typical day may be used, but it is better to average hourly volumes on two or more typical days. The count data must be compiled into hourly volumes. Any hourly increment can be used, i.e., *:00-*:00 or *:15-*:15.

Storage Capacity of Median

If the median is of sufficient width to store pedestrians crossing the road, then the gap size requirements are separated for each direction of traffic. For purposes of this warrant analysis, an adequate median has all of the following characteristics:

- Median width is 4 ft or greater and
- If the pedestrian phase of the signal is actuated, pedestrian push buttons are located in the median. The push buttons are needed so that pedestrians that use the median for storage have the ability to complete the crossing maneuver on a succeeding pedestrian phase.

Size of Adequate Gaps

The size of adequate gap is determined by dividing the walking distance by the walking speed. If there is no median or the median is not wide enough, then the walking distance is from the near curb to the far curb. If there is a median of sufficient width to serve as a pedestrian storage, separate adequate gaps should be calculated for each direction of traffic. In this case, the walking distance is from the near curb to the median.

The Institute of Transportation Engineers (ITE) *Manual of Transportation Engineering Studies*[1] describes the procedure for calculating the minimum adequate gap for pedestrians. The formula from that procedure is shown below.

$$G = \frac{W}{S} + (N-1)H + R$$

where G = minimum safe gap in traffic, sec.
W = crossing distance or width of roadway, ft.
S = walking speed, ft/sec.
N = predominant number of rows (group size).
H = time headway between rows, sec.
R = pedestrian startup time, sec.

[1] *Manual of Transportation Engineering Studies,* Institute of Transportation Engineers, Washington, D.C., 2000.

Commonly used values for these variables include:

S = 3.5 or 4.0 ft/sec.
H = 2 sec.
R = 3 sec.

Number of Gaps of Adequate Size

Measuring gaps in the traffic stream is a difficult and labor-intensive effort. Once the size of the adequate gap has been determined, only those gaps that are equal to or larger than the adequate size need to be measured. The ITE *Manual of Transportation Engineering Studies*[1] describes the procedure for measuring the number of gaps of adequate size.

The ITE *Traffic Control Devices Handbook*[2] presents a theoretical model for determining the number of gaps of a given size in a traffic stream of a given volume. The model is based on the negative exponential distribution. Appendix D provides an example of how to use this model to calculate the theoretical number of gaps in traffic of at least a given size that will occur during the analysis period. A modified version of the model in the ITE publication is presented below. This version accounts for the difference in vehicle headway and gap size for pedestrian crossing. Appendix D gives an example of how to use this formula to calculate the number of adequate gaps in a traffic stream of a given volume.

$$N_g = e^{-qg} \times Q$$

where N_g = number of gaps of minimum size g (sec).
q = length of measurement period (sec)/vehicle count in measurement period.
$g = G + L/(1.47v)$.
G = minimum acceptable gap length, sec.
L = average vehicle length, ft.
v = mean vehicle speed, mph.
Q = vehicle count in measurement period.

School Crossing Plan

The School Crossing Warrant can only be applied at intersections that have established school crossings. The local school district should be contacted to determine the location of established school crossings.

Presence of School Children

The number of minutes that school-age children are crossing the roadway during specific periods is determined from visual observation.

[1] *Manual of Transportation Engineering Studies*, Institute of Transportation Engineers, Washington, D.C., 2000.
[2] *Traffic Control Devices Handbook*, Institute of Transportation Engineers, Washington, D.C., 2001.

CHAPTER 3:
WARRANT ANALYSIS GUIDELINES

The determination of whether an intersection meets one or more of the traffic signal warrants is a relatively straightforward procedure if approached in an organized manner. This chapter provides a step-by-step process for conducting a complete traffic signal warrant analysis at an intersection. It assumes that the person conducting the analysis is familiar with the material described in the previous chapters of this document. As indicated in Table 5, the warrants are organized in an order which attempts to minimize the data collection effort to meet one or more warrants.

FIRST PHASE – VEHICULAR VOLUME WARRANTS

Three of the eight warrants are based on hourly vehicular approach volumes at the intersection. Table 13 shows these warrants. Based on the findings of a TxDOT/TTI research project (see Table 4), the majority of signalized intersections are warranted on the basis of one of the vehicular volume-based warrants. The volume data are also among the simplest to collect. If an intersection does not meet one of the volume-based warrants, then the analysis can proceed to the next analysis phase.

Table 13. Vehicular Volume Based Traffic Signal Warrants

Number and Title		Hours[a]	Application
1	Eight-Hour Vehicular Volume	8	• Where a large volume of intersecting traffic is the principal reason to consider installing a signal. • Where the traffic volume on a major roadway is so heavy that traffic on a minor intersecting roadway suffers excessive delay or hazard in entering or crossing the major roadway
2	Four-Hour Vehicular Volume	4	• Where the volume of intersecting traffic is the principal reason to consider installing a signal
3	Peak Hour Volume	1	• Where minor street traffic suffers undue delay entering or crossing the major street during 1 hour of the day.

Notes: [a]Number of hours for which volume criteria must be satisfied.

Other than the actual volume thresholds, the analysis of these three warrants is essentially the same. One aspect of these warrants is that the threshold volumes can be reduced if the major roadway speeds are high or if the intersection is located in an isolated area as described below.

Data Requirements

To conduct an analysis of the vehicular volume-based warrants, the following data should be collected:

- Intersection limits (see page 13).
- Speed on the major roadway (see page 13).
- Population of the area (see page 14).
- Typical weekday hourly vehicular approach volumes (see page 14).
- Number of lanes per approach (see page 16).

Warrant Criteria

Warrants 1, 2, and 3 can be analyzed by answering the following questions:

1. Do the reduced volume criteria apply?
   a. Is the posted or 85th percentile speed on the major road greater than 40 mph (see page 13 and Table 8)? If yes, the 70 percent volume warrant criteria apply. Go to Question 2. If not, go to Question 1b.
   b. Is the intersection located within the built-up area of an isolated community having a population of less than 10,000 (see page 14)? If yes, the 70 percent volume warrant criteria apply. Go to Question 2. If not, go to Question 4.
2. Analyze the eight-hour reduced volume warrant criteria using the reduced volume warrant column.
   a. Are there 8 hours where both the major and minor street volumes meet the 70 percent criteria in Table 14 (for Condition A – Minimum Vehicular Volume) or Table 15 (Condition B – Interruption of Continuous Traffic)? See Appendix C for guidance and an example of how to use the tables. If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 3.
3. Analyze the four-hour and one-hour reduced volume warrant criteria using the reduced volume warrant curves.
   a. Are there 4 hours where the major and minor street volumes are above the applicable curve in Figure 1 (Warrant 2)? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 3b.
   b. Is there 1 hour where the major and minor street volumes are above the applicable curve in Figure 2 (Warrant 3)? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 6.
4. Analyze the normal volume warrant criteria using the 100 percent volume warrant column:
   a. Are there 8 hours where both the major and minor street volumes meet the 100 percent criteria in Table 14 (for Condition A – Minimum Vehicular Volume) or Table 15 (Condition B – Interruption of Continuous Traffic)? See Appendix C for guidance and an example of how to use the tables. If yes, this warrant has been satisfied. Other

engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 5.

Table 14. Eight-Hour Vehicular Volume; Condition A (Table 4C-1 in MUTCD)

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

[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 is 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 is in an isolated community with a population of less than 10,000.

Table 15. Eight-Hour Vehicular Volume; Condition B (Table 4C-1 in MUTCD)

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 is 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 is in an isolated community with a population of less than 10,000.

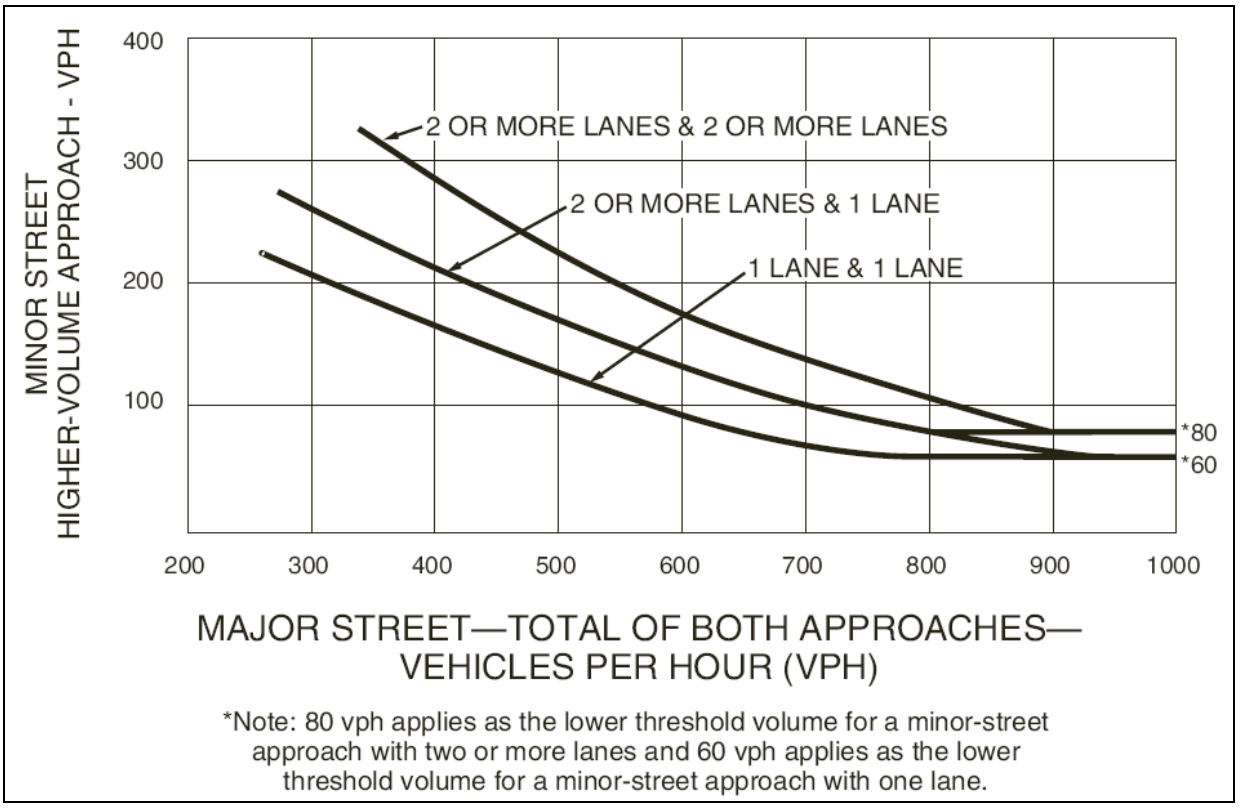


Figure 1. Warrant 2, Four-Hour Vehicular Volume (70 Percent Factor)

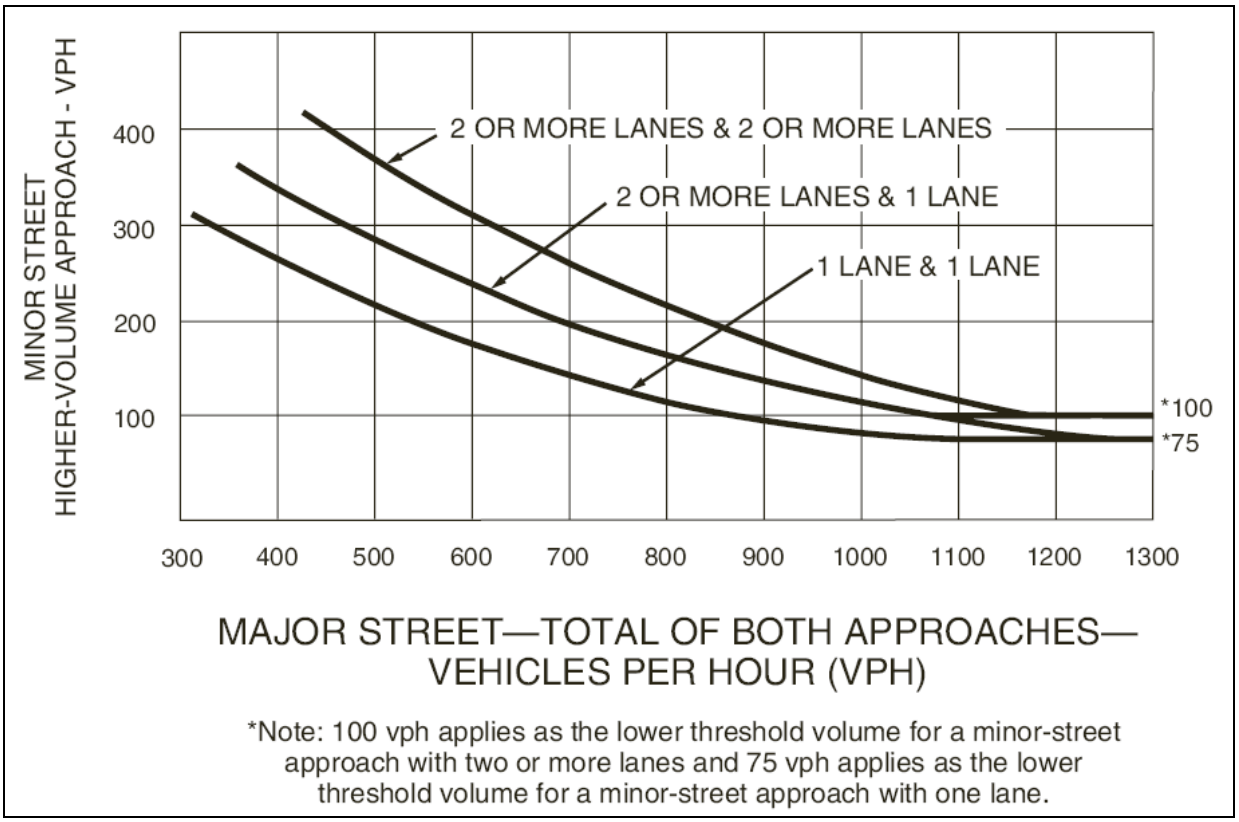


Figure 2. Warrant 3, Peak Hour (70 Percent Factor)

5. Analyze the four-hour and one-hour normal volume warrant criteria using the normal volume warrant curves.
    a. Are there 4 hours where the major and minor street volumes are above the applicable curve in Figure 3 (Warrant 2)? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 5b.
    b. Is there 1 hour where the major and minor street volumes are above the applicable curve in Figure 4 (Warrant 3)? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, go to Question 6.
6. Analyze the vehicular volumes of the Combination of Conditions A and B of the Eight-Hour Warrant.
    a. Has there been an adequate trial of other alternatives that could cause less delay and inconvenience to traffic, and these alternatives have failed to solve the traffic problem? See Table 16 for an FHWA interpretation on the meaning of "remedial measures." If the answer is yes, go to Question 6b. If not, this warrant cannot be satisfied.
    b. Is the posted or 85th percentile speed on the major road greater than 40 mph (see page 13 and Table 8)? If yes, the 56 percent volume warrant criteria apply. Go to Question 6d. If not, go to Question 6c.
    c. Is the intersection located within the built-up area of an isolated community having a population of less than 10,000 (see page 14)? If yes, the 70 percent volume warrant criteria apply. Go to Question 6d. If not, go to Question 6e.
    d. Are there 8 hours where both the major and minor street volumes meet the 56 percent criteria in Table 14 (for Condition A – Minimum Vehicular Volume) AND Table 15 (Condition B – Interruption of Continuous Traffic)? The volumes must meet the 56 percent criteria for BOTH Condition A and Condition B. See Appendix C for guidance and an example of how to use the tables. If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, none of the volume warrant can be met.
    e. Are there 8 hours where both the major and minor street volumes meet the 80 percent criteria in Table 14 (for Condition A – Minimum Vehicular Volume) AND Table 15 (Condition B – Interruption of Continuous Traffic)? The volumes must meet the 80 percent criteria for BOTH Condition A and Condition B. See Appendix C for guidance and an example of how to use the tables. If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, none of the volume warrant can be met.

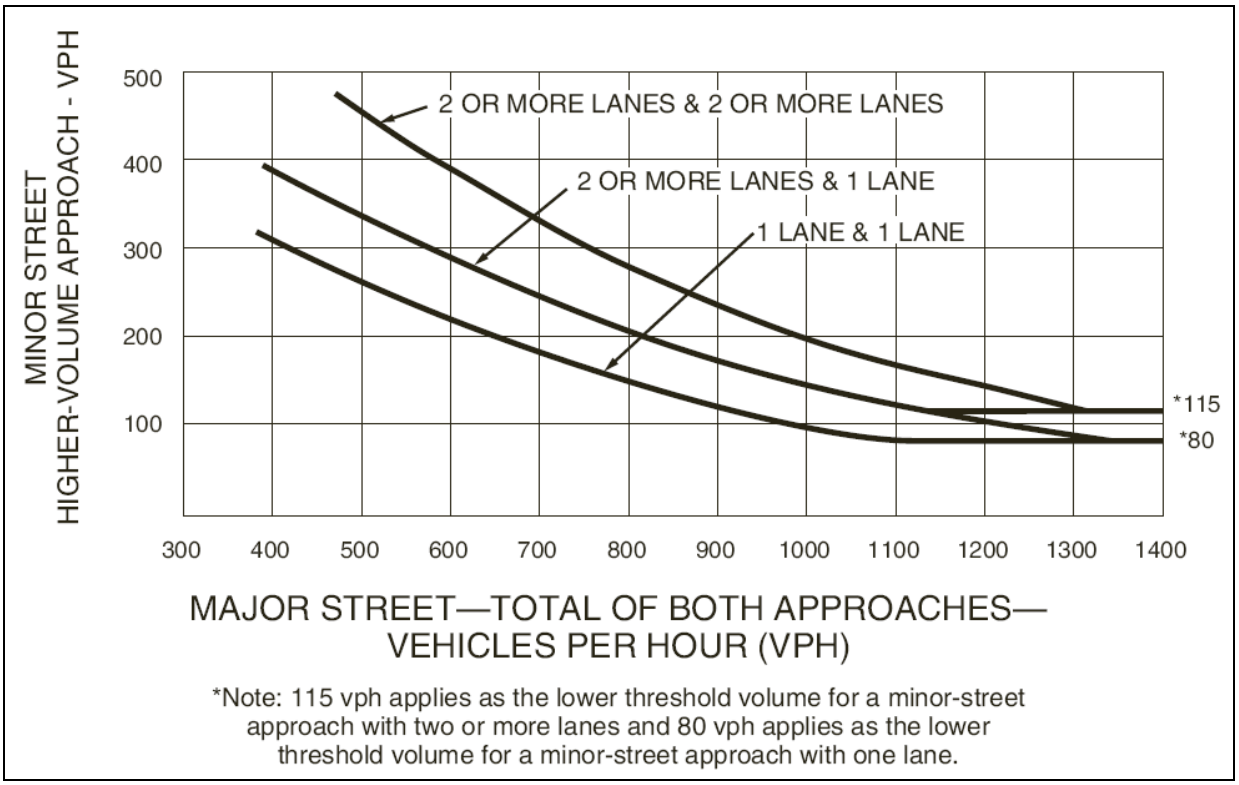


Figure 3. Warrant 2, Four-Hour Vehicular Volume

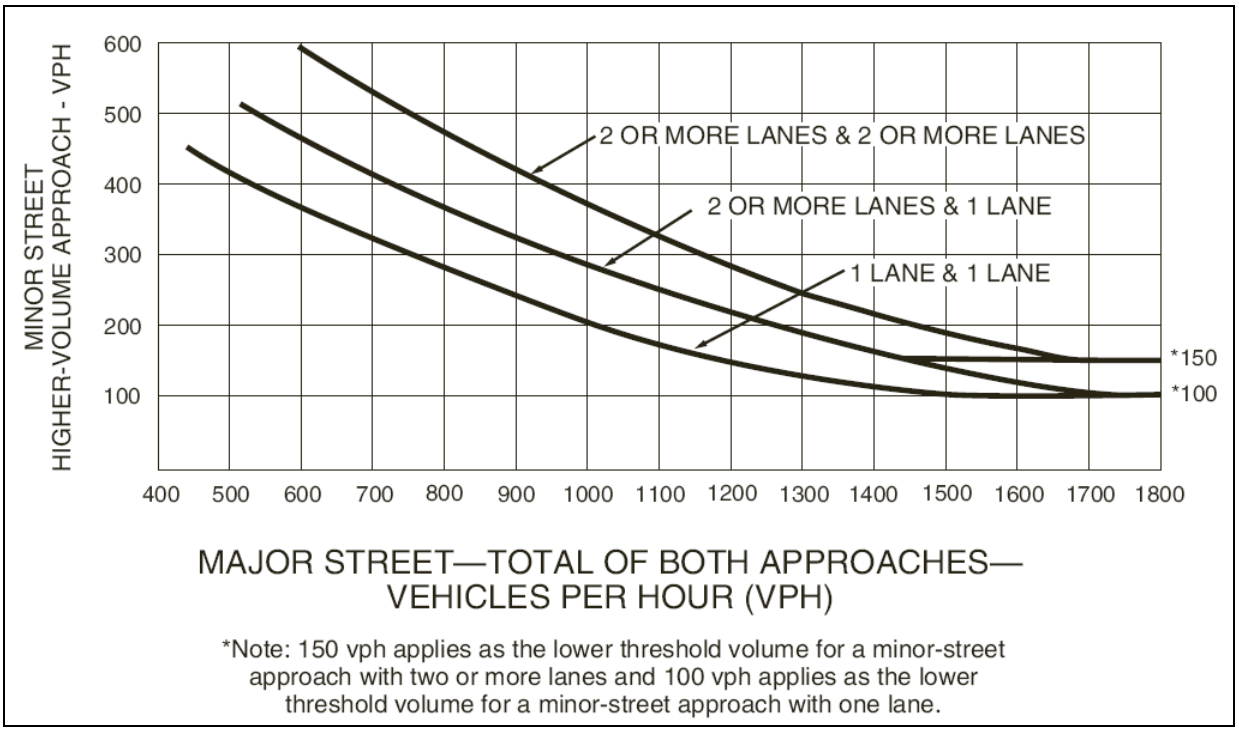


Figure 4. Warrant 3, Peak Hour

Table 16. Interpretation on Remedial Measures

Sg-61 (Change)	**Combination Warrant**
A request was made to define the "remedial measures" described in the warrant and that warrants be established for the "remedial measures." It was concluded that the guidelines for some of the other remedial measures already exist and that guidelines and warrants for the use of all possible remedial measures are neither needed nor desirable inasmuch as they will vary from location to location and will have to be determined partly through the exercise of professional judgment.	

Frequently Asked Questions about the Volume Warrants

Practitioners analyzing the vehicular volume warrants often ask the following questions.

- What if there are two lanes on one major street approach and one lane on the other major street approach?
  - There is no official interpretation on this issue. Engineering judgment should be used to determine the appropriate volume to use for the analysis. One possibility is to add half of the one-lane volume criterion and half of the two-lane volume criterion. For example, in Condition A – Minimum Vehicular Volume warrant, the warranting volume would be 250 (½ of 500) plus 300 (½ of 600), or 550 vph.
- What if there are more than two intersecting roadways?
  - There is no official interpretation on this issue. The road with the highest total volume should be classified as the major road. Any of the remaining approaches can be classified as the minor road approach. This approach can change from one hour to the next to obtain the high volume minor road approach. The high-volume approach does not need to be on the same road for each hour if there is more than one minor road at the intersection.
- How do you treat left-turn lanes?
  - MUTCD Section 4C.01 states that "engineering judgment should 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 dictate whether an approach should be 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, engineering judgment could indicate that it should be considered a one-lane approach if the traffic using the left-turn lane is minor. In such a case, 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." Table 10 presents the text of an FHWA interpretation that indicates the need to apply engineering judgment in determining whether turning volumes should be included in the approach volume.

SECOND PHASE – CRASH EXPERIENCE WARRANT

When there is a history of crashes at an intersection, the Crash Experience Warrant (Warrant 7) can be used to justify further consideration of a traffic signal installation. The following factors should be considered in the application of this warrant:

- Only certain types of crashes are susceptible to being corrected by a traffic signal, and only those types of crashes should be considered in the application of the crash warrant.
- Although the basis for this warrant is an anticipated reduction in crashes, the installation of a signal using this warrant may merely result in a shift of crashes from one type to another.
- While this warrant considers the frequency of certain types of crashes, there is at present no means for considering the severity of those crashes in the warrant analysis.

Data Requirements

To conduct an analysis of the Crash Experience Warrant, the following data should be collected:

- Data required to analyze Warrant 1, Eight-Hour Vehicular Volume (see page 11).
- Crash history at the intersection for the most recent 12-month period.
    - Reported crashes – Only crashes that are included in an agency's database can be used for the Crash Experience Warrant. This typically means that crashes that are not investigated by the police do not qualify for consideration as part of the crash warrant.
    - Susceptible to correction by a traffic signal – This generally means right-angle crashes, crashes between left-turning and oncoming vehicles, or crashes involving pedestrians. It does not include rear-end crashes. See Table 11 for more detail.

Warrant Criteria

The Crash Experience Warrant can be analyzed by answering the following questions:

1. Have other traffic control alternatives been given an adequate opportunity, with satisfactory observation and enforcement, to reduce the crash frequency? Table 17 presents an FHWA response to an interpretation request on the MUTCD language "adequate trial of less restrictive remedies" [the term used in the 1980 Texas MUTCD]. If yes, proceed to Question 2. If not, try other traffic control alternatives before considering traffic signal installation (note that the traffic control alternative may need to be in place for a period of months before sufficient crash data may be available to conduct a crash warrant analysis that accounts for the newer form of traffic control).
2. Have there been five or more reported crashes in a 12-month period that are susceptible to correction by a traffic signal (each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash)? Table 11 lists the types of crashes that are susceptible to correction by a traffic signal. If yes, proceed to Question 3. If no, this warrant is not satisfied.

Table 17. Interpretations on the Crash Experience Warrant

Sg-60 (Change)	**Crash Experience Warrant**
A request was made to define the terms "adequate trial" and "remedies" as used in the first criteria of the crash warrant. Adequate trial of less restrictive remedies with satisfactory observance and enforcement has failed to reduce the crash frequency. It also included a request for the establishment of guidelines for the use of "less restrictive measures" as used in the warrant. It was determined that guidelines for the use of "less restrictive remedies" and a definition of the term "adequate trial" are unnecessary as the remedies to be applied would vary greatly from situation to situation, as would the length of period which would be adequate for a trial of these remedies. Application of this warrant is a matter for professional judgment, and no useful purpose would be served by attempting to minutely define either of the terms.	

3. Do the reduced volume criteria apply?
   a. Is the posted or 85th percentile speed on the major road greater than 40 mph (see page 13 and Table 8)? If yes, the 56 percent volume warrant criteria apply. Go to Question 4. If not, go to Question 3b.
   b. Is the intersection located within the built-up area of an isolated community having a population of less than 10,000 (see page 14)? If yes, the 56 percent volume warrant criteria apply. Go to Question 4. If not, go to Question 5.
4. Are there 8 hours of an average day where both the major (sum of both approaches) and minor street (high volume approach) volumes are greater than the 56 percent values for Condition A (Table 14) OR Condition B (Table 15) in Warrant 1? If yes, this warrant is satisfied. If not, proceed to Question 5.
5. Are there 8 hours of an average day where both the major (sum of both approaches) and minor street (high volume approach) volumes are greater than the 80 percent values for Condition A (Table 14) OR Condition B (Table 15) in Warrant 1? If yes, this warrant is satisfied. If not, proceed to Question 6.
6. The pedestrian related aspects of the crash warrant analysis are described in the pedestrian warrants on page 34.

Frequently Asked Questions about the Crash Experience Warrant

The following questions are often asked by practitioners analyzing the Crash Experience Warrant:

- How does the severity of the crashes impact the analysis of this warrant?
  - Crash severity is not a factor in the current warrant. Fatal, injury, and non-injury crashes are all considered equal in the warrant analysis. However, a recent NCHRP project[1] has proposed changes to the Crash Experience Warrant that would require that crashes used to satisfy this warrant be injury crashes.

[1]McGee, H., and S. Taori. Crash Experience Warrant for Traffic Signals. NCHRP Report 491, National Cooperative Highway Research Program, Washington, D.C., 2003.

- Will the NCHRP recommendations be incorporated into a future edition of the MUTCD?
  - Any proposed changes to the national MUTCD must be approved through the federal rulemaking process, which includes publication in the *Federal Register* and comment by the public. Therefore, it is not possible to predict future changes in the national MUTCD. If incorporated into the national MUTCD, it may then be incorporated into a later edition of the Texas MUTCD. However, the Signals Technical Committee of the NCUTCD determined that the NCHRP recommended warrant revisions should not be incorporated into the MUTCD.

THIRD PHASE – SIGNAL OPERATION WARRANTS

Two of the signal warrants address factors associated with the operation of a traffic signal. The Coordinated Signal System Warrant (Warrant 6) is used to justify further consideration of a signal installation if needed to maintain proper grouping or platooning of vehicles in a coordinated signal system and to effectively regulate group speed. The Roadway Network Warrant (Warrant 8) is used to justify further consideration of a signal installation at the intersection of two or more major routes to encourage concentration and organization of traffic flow on a roadway network.

Data Requirements

The following data should be collected to conduct an analysis of the Coordinated Signal System Warrant:

- Information on platoon dispersion between existing traffic signals.
- Distance between traffic signals.
- 85th percentile speed. The 85th percentile speed should be used for the analysis of platoon dispersion unless an engineering study indicated that another speed is more desirable.

The following data should be collected to conduct an analysis of the Roadway Network Warrant:

- Peak hour volume for a typical weekday. The typical weekday volumes may be an average of hourly volumes for more than 1 day.
- Volumes for five highest hours for a typical non-business day (Saturday or Sunday). The hourly non-business day volumes may be an average of more than 1 day.
- Five-year projected hourly traffic volumes based on a documented engineering study.

Criteria for Coordinated Signal Systems Warrant

The Coordinated Signal Systems Warrant can be analyzed by answering the following questions:

1. If a signal were to be installed on the basis of this warrant, would the resulting spacing from this signal to any adjacent signal be less than 1,000 ft? If yes, this warrant cannot be satisfied. If no, go to Question 2.
2. If a signal were to be installed on the basis of this warrant, would the resulting spacing from this signal to any other signal be greater than 0.5 mi? If yes, an efficient progression platoon may be more difficult to maintain and the benefits to be gained from signalization on the basis of this warrant should be carefully evaluated. If such an evaluation indicates that roadside friction, low speeds, intersections, and driveway access limit efficient progression, this warrant cannot be satisfied. If efficient progression can be maintained, go to Question 3.
3. Is the major road one-way or have predominately unidirectional traffic flow? If yes, go to Question 4. If no, go to Question 5.
4. Based on the 85th percentile speed (unless an engineering study indicated that another speed is more desirable), are the adjacent signals so far apart that they do not provide the necessary degree of vehicle platooning and speed control? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If no, go to Question 5.
5. Based on the 85th percentile speed (unless an engineering study indicated that another speed is more desirable), do the adjacent signals provide the necessary degree of platooning and speed control? If yes, this warrant cannot be satisfied. If no, go to Question 6.
6. Could the proposed and existing adjacent signals constitute a progressive signal system? If yes, this warrant has been met. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If no, this warrant cannot be satisfied.

Criteria for Roadway Network Warrant

The Roadway Network Warrant can be analyzed by answering the following questions:

1. Do at least two of the roadways at the intersection each meet one or more of the criteria in Table 12? Note that each roadway must meet at least one criterion. If yes, continue to Question 2. If no, this warrant cannot bet met.
2. For a typical weekday, is the existing or immediately projected peak hour entering volume equal to or greater than 1,000 vph? If yes, continue to Question 3. If no, go to Question 4.
3. For a typical non-business day, are there 5 hours where the existing or immediately projected hourly entering volumes are 1,000 vph or greater? (The entering volume for each of the 5 hours must be 1,000 vehicles or higher). If yes, this warrant has been met. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If no, go to Question 4.
4. Do the 5-year projected hourly entering volumes satisfy any of the traffic volume warrants (Warrant 1, 2, or 3)? If yes, this warrant has been met. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If no, this warrant cannot be met.

Installation Requirements

If the Coordinated Signal System Warrant is used as the basis for installing a traffic signal, the signal should be coordinated with the adjacent traffic signal(s) on the major roadway(s).

FOURTH PHASE – DELAY WARRANT

The peak hour warrant (Warrant 3) used at locations where traffic conditions are such that for a minimum of 1 hour of a typical or average day, the minor-roadway traffic suffers undue delay when entering or crossing the major roadway. This warrant is used only in unusual cases. Examples of circumstances where this warrant may be applicable 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.

Data Requirements

- Peak hour volume on each intersection approach (see page 14).
- Peak hour vehicular delay on minor street approach(es).

Criteria for Peak Hour Warrant

The Peak Hour Warrant can be analyzed by answering the following questions:

1. Is the total entering volume during the peak hour equal to or greater than 650 vph for an intersection with three approaches or 800 vph for an intersection with four or more approaches? If yes, go to Question 2. If no, this warrant cannot be satisfied.
2. Is the volume on one minor roadway approach (one direction only) equal to or greater than 100 vph for approaches with one moving lane of traffic or 150 vph for approaches with two moving lanes? If yes, go to Question 3. If no, this warrant cannot be satisfied.
3. Is the total delay experienced by the traffic on the same minor-roadway approach (one direction only) controlled by a Stop sign equal to or greater than 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach? If yes, this warrant has been met. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If no, this warrant cannot be satisfied.

Installation Requirements

If a signal is installed solely on the basis of this warrant, a fully actuated traffic signal should be installed.

FIFTH PHASE – PEDESTRIAN WARRANTS

The presence of sufficient pedestrians at an intersection may provide justification for further analysis of traffic signal installation. Two warrants specifically address pedestrians at intersections: the Pedestrian Volume Warrant (Warrant 4) and the School Crossing Warrant (Warrant 5). In addition, the Crash Experience Warrant (Warrant 7) includes provisions for

pedestrians as an element in the warranting process. Intersections that will meet either the pedestrian or school warrants are few, and it should be readily apparent whether these warrants should be included in the analysis procedure.

Data Requirements

To conduct an analysis of the Pedestrian Volume Warrant, the following data should be collected:

- Hourly pedestrian volumes (see page 21).
- The average pedestrian walking speed (see page 20).
- The width of a median, if any (see page 21).
- The number of gaps of adequate size (see page 21).
- Distance to adjacent traffic signals (see page 20).

To conduct an analysis of the School Crossing Warrant, the following data should be collected as part of a traffic engineering study:

- Times of the day when school children are present at the crossing.
- Frequency and size of adequate gaps in the vehicular traffic stream during the times that school children are present at the crossing.

To conduct an analysis of the pedestrian element of the Crash Experience Warrant, the following data should be collected:

- Hourly pedestrian volumes (see page 21).
- The average pedestrian walking speed (see page 20).
- The width of a median, if any (see page 21).
- The number of gaps of adequate size (see page 21).
- Distance to adjacent traffic signals (see page 20).
- Crash history at the intersection for the most recent 12-month period.
    - Reported crashes – Only crashes that are included in an agency's database can be used for the Crash Experience Warrant. This typically means that crashes that are not investigated by the police do not qualify for consideration as part of the crash warrant.
    - Susceptible to correction by a traffic signal – This generally means right-angle crashes, crashes between left-turning and oncoming vehicles, or crashes involving pedestrians. It does not include rear-end crashes. See Table 11 for more detail.

Pedestrian Warrant Criteria

The Pedestrian Volume Warrant can be applied to both intersection and midblock crossing locations by answering the following questions:

1. Is there a traffic signal along the major street within 300 ft of the crossing under study? If yes, go to Question 2. If no, go to Question 3.

2. If a signal is installed at the crossing location, will it restrict progressive movement of traffic? If yes, a signal should not be installed at this location on the basis of this warrant. If no, go to Question 3.
3. Is the average walking speed of pedestrians crossing the major street less than 4 ft/sec? If yes, go to Question 4. If no, go to Question 5.
4. Are there 50 pedestrians or more per hour crossing the major street for each of 4 hours or 95 pedestrians or more during any 1 hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
5. Are there 100 pedestrians or more per hour crossing the major street for each of 4 hours or 190 pedestrians or more during any 1 hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
6. Is there a median of sufficient width for pedestrians to wait while crossing traffic? If yes, go to Question 7. If no, go to Question 8.
7. For each direction of traffic, are there less than 60 gaps per hour of adequate size for pedestrians to cross during the same period that the pedestrian volume criterion is satisfied? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, this warrant cannot be satisfied.
8. For both directions of traffic, are there fewer than 60 gaps per hour of adequate size for pedestrians to cross during the same period that the pedestrian volume criterion is satisfied? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, this warrant cannot be satisfied.

Pedestrian Warrant Signal Installation Requirements

The following criteria apply to a traffic signal installation that is justified solely on the basis of the Pedestrian Volume Warrant:

- The signal installation shall have pedestrian signal heads.
- The signal should be pedestrian actuated (pedestrian pushbuttons or pedestrian detectors).
- If the signal is installed at an intersection, it should be traffic actuated.
- If the signal is installed within a signal system, it should be coordinated.
- If the crossing is at a non-intersection location, curbside parking should be prohibited 100 ft in advance of the crosswalk and 20 ft beyond the crosswalk. Stop lines should be placed at least 40 ft in advance of the nearest signal indication (see Section 4D.15 for other signal head location criteria).
- Because Section 3B-17 of the Texas MUTCD recommends crosswalks for intersections where there is substantial conflict between vehicle and pedestrian movements, signal installations that are justified solely on the basis of the Pedestrian Volume Warrant should have crosswalk markings.
- If there is a median that allows pedestrians to complete the crossing maneuver using two separate “Walk” pedestrian signal indications, then the median should provide pedestrian pushbuttons or other pedestrian-actuation.

School Crossing Warrant Criteria

The School Crossing Warrant can be analyzed by answering the following questions:

1. During the period that school children are using the crossing, is the number of adequate gaps in the traffic stream less than the number of minutes in the same period? If yes, go to Question 2. If not, this warrant cannot be satisfied.
2. Are there at least 20 students using the crossing during the highest crossing hour? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, this warrant cannot be satisfied.

School Crossing Warrant Signal Installation Requirements

If a signal is installed solely on the basis of the School Crossing warrant, the signal should meet the signal installation requirements listed for the Pedestrian Warrant.

Pedestrian Related Criteria for the Crash Experience Warrant

The pedestrian related portion of the Crash Experience Warrant can be analyzed by answering the following questions:

1. Have other traffic control alternatives been given an adequate opportunity, with satisfactory observation and enforcement, to reduce the crash frequency? Table 17 presents an FHWA response to an interpretation request on the MUTCD language "adequate trial of less restrictive remedies" [the term used in the 1980 Texas MUTCD]. If yes, proceed to Question 2. If not, try other traffic control alternatives before considering traffic signal installation (note that the traffic control alternative may need to be in place for a period of months before sufficient crash data may be available to conduct a crash warrant analysis that accounts for the newer form of traffic control).
2. Have there been five or more reported crashes in a 12-month period that are susceptible to correction by a traffic signal (each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash)? Table 11 lists the types of crashes that are susceptible to correction by a traffic signal. If yes, proceed to Question 3. If no, this warrant is not satisfied.
3. Is the average walking speed of pedestrians crossing the major street less than 4 ft/sec? If yes, go to Question 4. If no, go to Question 5.
4. Are there 40 pedestrians or more per hour crossing the major street for each of 4 hours or 76 pedestrians or more during any 1 hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
5. Are there 80 pedestrians or more per hour crossing the major street for each of 4 hours or 152 pedestrians or more during any 1 hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
6. Is there a median of sufficient width for pedestrians to wait while crossing traffic? If yes, go to Question 7. If no, go to Question 8.
7. For each direction of traffic, are there fewer than 48 gaps per hour of adequate size for pedestrians to cross during the same period that the pedestrian volume criterion is satisfied?

If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, this warrant cannot be satisfied.

8. For both directions of traffic, are there fewer than 48 gaps per hour of adequate size for pedestrians to cross during the same period that the pedestrian volume criterion is satisfied? If yes, this warrant has been satisfied. Other engineering factors should be evaluated to determine whether a traffic signal should be installed. If not, this warrant cannot be satisfied.

Pedestrian Portion of Crash Experience Warrant Signal Installation Requirements

If a signal is installed solely on the basis of the pedestrian requirements of the Crash Experience warrant, the signal should meet the signal installation requirements listed for the Pedestrian Warrant. These installation requirements are not specifically mentioned in the MUTCD, but they are consistent with the requirements for traffic signals installed on the basis of other pedestrian-related signal warrants.

APPENDIX A – MUTCD BACKGROUND

There was no consistency in the appearance or use of traffic signals in the early 1920s. Signals came in a wide variety of appearances and operational modes. However, traffic and highway engineers soon realized that consistency or uniformity in traffic signals was a desirable practice. As a result, they initiated efforts to establish a uniform system of traffic control devices. Their efforts led to the development of the first national manual addressing the appearance and application of traffic control devices. Through the years, that manual has evolved into the 2003 national MUTCD, which serves as the basis for the 2006 Texas MUTCD. The standards and warrants contained in the MUTCD are intended to promote national uniformity of traffic control devices.

The MUTCD is one of the key documents in the field of transportation engineering because it contains guidelines and warrants for the design and application of traffic control devices. The MUTCD is also a complex document. Although standards for certain aspects of traffic control devices are included in the MUTCD, it does not contain standards which require the traffic engineer to use a traffic control device. This provides the traffic engineer with a great deal of discretion when deciding whether a traffic control device should be used. The MUTCD is also the focal point of many tort claims, which further increases its importance as a traffic engineering document. The relationship between the MUTCD and the concept of traffic control is a significant one, and it must be understood before any evaluation of traffic control devices can be properly conducted.

NATIONAL AND STATE VERSIONS OF THE MUTCD

The MUTCD issued by the Federal Highway Administration is referred to as the national MUTCD, and it is intended to promote national uniformity of traffic control devices. The national MUTCD is available on-line at http://mutcd.fhwa.dot.gov. Federal and state laws require each state to adopt a traffic control device manual which meets or exceeds the requirements of the national manual. These state manuals can take one of three different forms: the national MUTCD, the national MUTCD with a state supplement, or a state manual. The manual adopted by a particular state governs the use of traffic control devices within that state.

MUTCD AS A LEGAL DOCUMENT

The MUTCD and its provisions are often the focus of tort claim lawsuits. Typically, these lawsuits allege that a particular traffic control device was used improperly or was not used when it should have been. The role of the MUTCD in the legal environment is unique. Although it is not a statute, it is the only traffic engineering document that carries the power of a statute in defining standards for traffic control devices.

The MUTCD has been adopted as a national standard pursuant to the authority of Title 23 of the U.S. Code. This code has the full force and effect of the law. Various Federal Aid Highway Acts authorize the FHWA to require traffic control devices on Federal-aid highway to conform to the MUTCD standards. Most states have also established statutes requiring traffic control devices placed and maintained by state and local governmental agencies to conform to a state

manual in substantial conformance with the national MUTCD. The Uniform Vehicle Code (UVC) contains suggested language for state laws on the adoption of a state manual. The suggested laws state that "the State highway commission shall adopt a manual for a uniform system of traffic control devices" ... "which shall correlate with and so far as possible conform" to the national MUTCD (Section 15-104). All traffic control devices placed by state and local authorities shall conform to the state manual.

Definition of "Shall," "Should," and "May"

The words "shall," "should," and "may" are used in the MUTCD to describe specific conditions concerning the design and application of traffic control devices. The MUTCD Introduction defines the terms "shall," "should," and "may" as indicating standard, guidance, and optional conditions, respectively, for the application of principles to traffic control devices. Each paragraph in the MUTCD is labeled with a standard, guidance, option, or support heading. Table 18 below provides additional information on these terms.

Table 18. MUTCD Terminology

Text Headings	Operative Word	Description
Standard	Shall	A statement of required, mandatory, or specifically prohibitive practice regarding a traffic control device. All standards are labeled, and the text appears in bold type. The verb shall is typically used. Standards are sometimes modified by Options.
Guidance	Should	A statement of recommended, but not mandatory, practice in typical situations, with deviations allowed if engineering judgment or engineering study indicates the deviation to be appropriate. All Guidance statements are labeled, and the text appears in unbold type. The verb should is typically used. Guidance statements are sometimes modified by Options.
Option	May	A statement of practice that is a permissive condition and carries no requirement or recommendation. Options may contain allowable modifications to a Standard or Guidance. All Option statements are labeled, and the text appears in unbold type. The verb may is typically used.
Support	Shall, should, or may are not used	An informational statement that does not convey any degree of mandate, recommendation, authorization, prohibition, or enforceable condition. Support statements are labeled, and the text appears in unbold type. The verbs shall, should, and may are not used in Support statements.

MUTCD GUIDELINES AND WARRANTS

The MUTCD functions as both a legal document and as an engineering document. This situation sometimes confuses the fact that not everything in the MUTCD is a standard. Many of the principles contained in the MUTCD can be categorized as warrants, which provide the engineer with criteria to define the relative need for a traffic control device. Other MUTCD

principles are categorized as guidelines (standards, guidance, or option statements), which establish requirements for the design and application of a traffic control device. The differences between MUTCD guidelines and warrants can be confusing and are a potential source of conflict in lawsuits related to traffic control devices. The differences between the two can also be confusing to the administrators and elected officials of governmental agencies.

In general, the difference between warrants and guidelines is that warrants apply to the process of deciding whether or not to use a device. Once that decision has been made, guidelines apply to the design, application, installation, and maintenance of the device. A warrant is a set of criteria used to define the relative need for, and appropriateness of, a particular traffic control device. Warrants should be viewed as advisory, not as mandates. Meeting the warranting conditions does not guarantee or imply that the device is needed. Furthermore, the fact that a warrant is not fully satisfied does not constitute absolute assurance that the device could not serve a useful purpose. In fact, the MUTCD contains few requirements for the use of a traffic control device in a given set of circumstances.

Some of the confusion about the difference between standards and warrants in the MUTCD may be attributable to the fact that the FHWA has established the MUTCD as the national standard for traffic control devices on roads open to public travel. Another source of potential confusion is that the MUTCD is it is the only traffic engineering document that carries the power of a statute in defining traffic control device standards.

APPENDIX B – WARRANTS FROM THE TEXAS MUTCD

This appendix provides the actual language of the Texas MUTCD sections addressing the eight traffic signal warrants. Except for a couple of minor additions to Warrant 8 (Section 4C.09), the warrant language in the Texas MUTCD is the same as that contained in the 2003 National MUTCD. In this appendix, tables and figures retain the same numbers and titles as those used in the 2006 Texas MUTCD and are not consistent with the table and figure numbering used elsewhere in this document. Changes in MUTCD language between the national and Texas MUTCDs are indicated through the use of a sans serif font.

Section 4C.02 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 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 the criteria for Warrant 1 is satisfied and Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then the criteria for Warrant 1 is satisfied and 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 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 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.

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 is 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 is in an isolated community with a population of less than 10,000.

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**
- **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.

Section 4C.03 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.

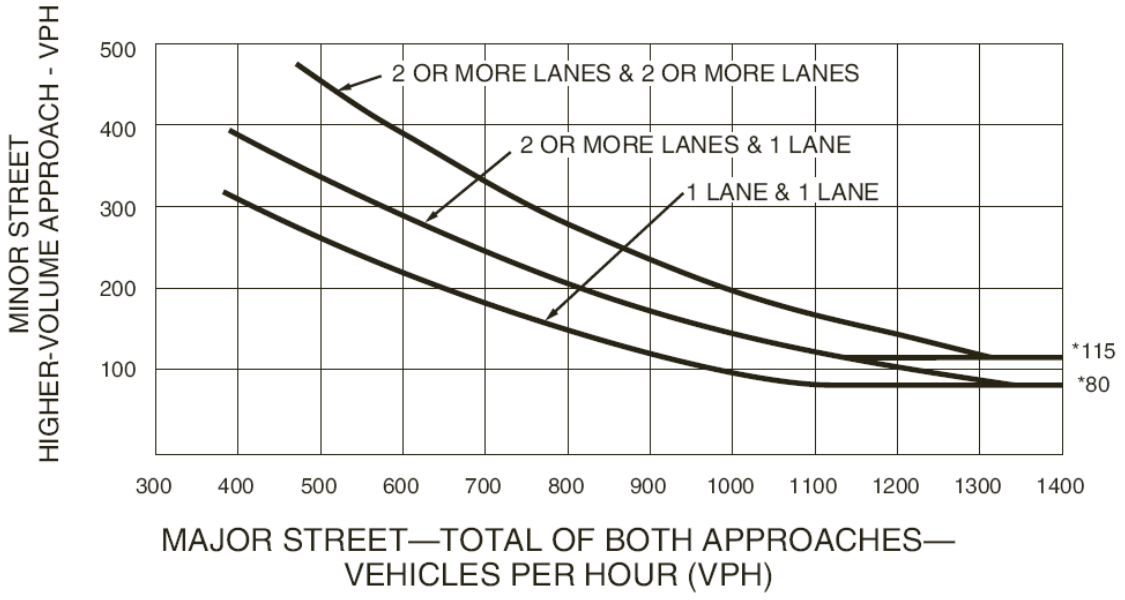
Standard:

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.

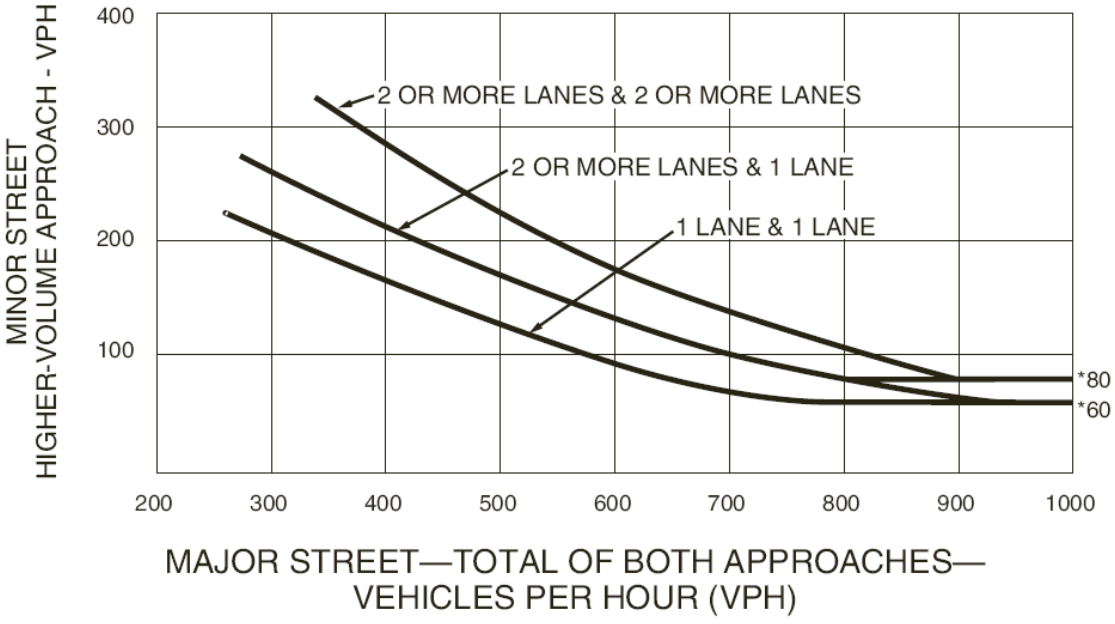
Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*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.

Section 4C.04 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 as 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

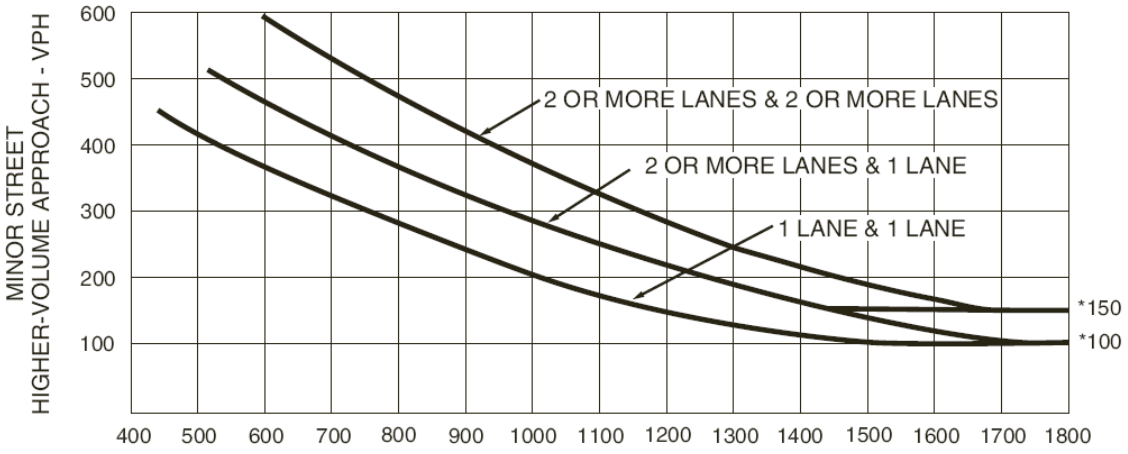
3. **The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.**

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.

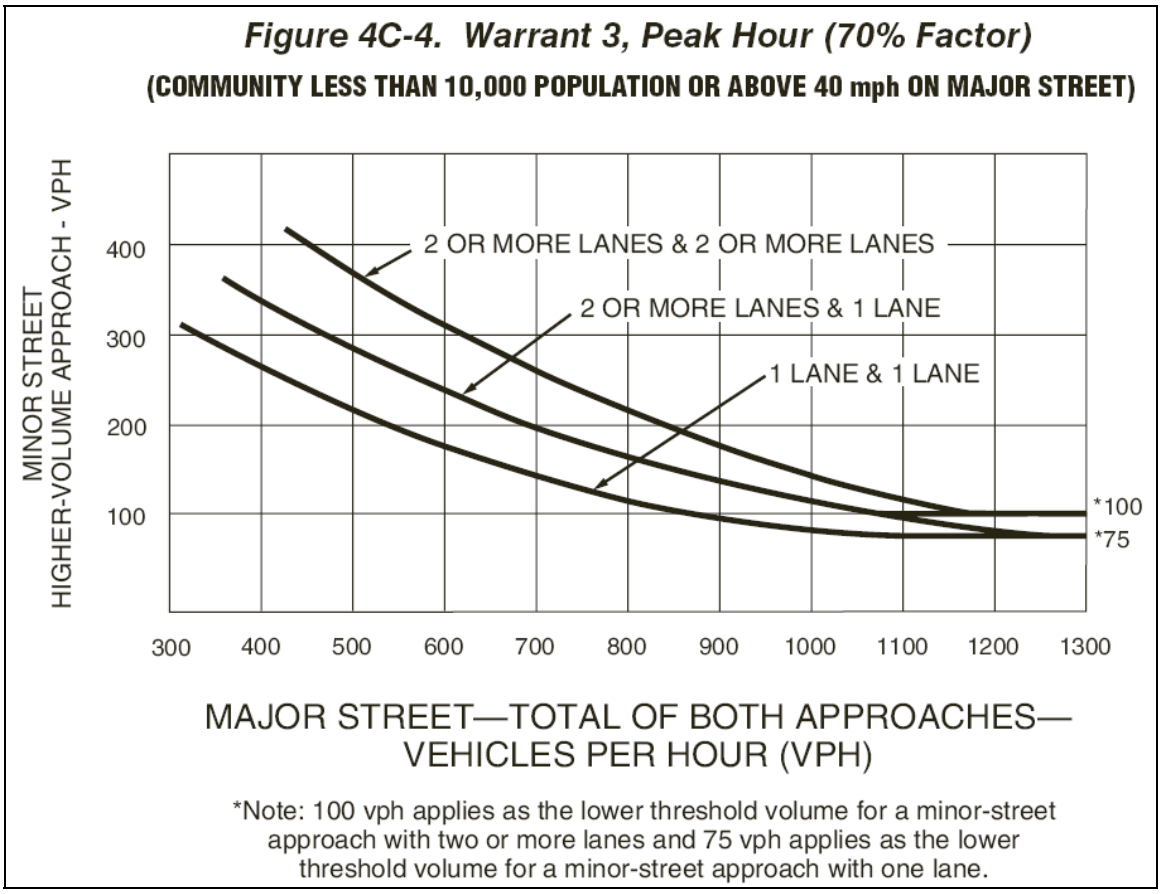
Option:

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.

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.



Section 4C.05 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 midblock crossing shall be considered if an engineering study finds that both of the following criteria are met:

- **A. The pedestrian volume crossing the major street at an intersection or midblock location during an average day is 100 or more for each of any 4 hours or 190 or more during any 1 hour; and**
- **B. There are fewer than 60 gaps per hour in the traffic stream of adequate length to allow pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for pedestrians to wait, the requirement applies separately to each direction of vehicular traffic.**

The Pedestrian Volume 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 ft, 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 conforming to requirements 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 at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 100 ft in advance of and at least 20 ft beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.
C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Option:

The criterion for the pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 4 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, even if the rate of gap occurrence is less than one per minute.

Section 4C.06 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.

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 school children 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 children 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 students during the highest crossing hour.

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 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 at an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors.
B. If at a nonintersection crossing, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 100 ft in advance

of and at least 20 ft beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.

C. Furthermore, if installed within a signal system, the traffic control signal should be coordinated.

Section 4C.07 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 ft.

Section 4C.08 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.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:

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:

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 nonnormal business day (Saturday or Sunday).**

A major route as used in this signal warrant shall have one or more 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; or**
- **D. In connects areas of principal traffic generation; or***
- **E. It has surface street freeway or expressway ramp terminals.***

*These statements appear only in the 2006 Texas MUTCD and do not appear in the 2003 national MUTCD.

APPENDIX C – EXAMPLES OF WARRANT ANALYSIS

This appendix presents information on a procedure to organize and analyze the vehicular volumes used in the first phase of a warrant analysis.

ANALYSIS EXAMPLE FOR WARRANTS 1A AND 1B

Table 19 presents a series of 16 consecutive hourly approach volumes for the four approaches to an intersection. For purposes of this example, the major road is north-south, and the minor road is east-west. The hourly volumes are shown to begin at 15 minutes past the hour, but any increment could have been used (i.e., :00 to :00, :30 to :30, etc.). For this example, the major road has two through lanes on each approach and the minor road has one through lane on each approach. The 85th percentile speed on the major road is 35 mph and the intersection is located in a large metropolitan area. Therefore, the intersection does not qualify for the reduced volume warrants. The resulting warrant criteria are shown in cells I3 and J3 for Warrant 1A and K3 and L3 for Warrant 1B.

In column I, the sum of the two major road approaches for each hour (column E) is compared to the warrant criteria (cell I3). If an hourly total volume exceeds the Warrant 1A major road criteria, a "YES" is placed in the cell. The same type of analysis is done in columns J, K, and L, except that in columns J and L, the hour volume is the higher of the two minor road approaches. If both the major and minor road columns have a "YES," then that hour meets the warrant criteria. For example, the 7:15 a.m. hour (row 6) meets both the Warrant 1A and Warrant 1B criteria. A "YES" is placed in column M or N for Warrants 1A and 1B, respectively. If there are 8 or more hours (or 'YES') in column M, then Warrant 1A is met. Likewise, column N for Warrant 1B. In this example, Warrant 1A is met, but Warrant 1B is not. Note that Warrant 1B is not met, even though there are 8 hours where the major road meets the criteria (column K) and 11 hours where the minor road meets the criteria (column L). The 8 hours must be the same hours and there are only 6 hours where both the major and minor road meets the criteria for Warrant 1B.

ANALYSIS EXAMPLE FOR WARRANT 2

The same 16 hours of volumes shown in Table 19 are plotted in Figure 5 to illustrate the application of the Four-Hour Vehicular Volume Warrant (#2). As in the previous example, the major road volume is the total of both approaches, while the minor road volume is the higher of the two approaches. The same geometric and other factors are also used. As a result, the normal volume curves are used, with the specific curve of interest being the "2 or more lanes and 1 lane." In each figure, the points representing the 16 hours are plotted. In Figure 5, there are only 3 hours that are above the curve. Four hours are required, so this warrant is not satisfied.

BLANK WARRANT TABLE

Table 20 is a blank warrant volume table that can be copied and used for the first phase warrant analysis.

Table 19. Example of Volume Analysis for Warrant 1

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Hour Beginning At:**	**Hours of volume data**	**Major Rd Volume (sum of both approaches)**			**Minor Rd Volume (high volume approach)**			**Meets Warrant 1A Criteria?**		**Meets Warrant 1B Criteria?**		**Both Major and Minor Roads Meet Criteria?**	
2			**North**	**South**	**Total**	**East**	**West**	**High**	**Major**	**Minor**	**Major**	**Minor**		
3									**∃ 500**	**∃ 150**	**∃ 900**	**∃ 75**	**Warrant 1A**	**Warrant 1B**
4	5:15 am	1	207	146	353	18	24	24	NO	NO	NO	NO		
5	6:15 am	2	327	160	487	152	167	167	NO	YES	NO	YES		
6	7:15 am	3	756	327	1083	198	195	198	YES	YES	YES	YES	YES	YES
7	8:15 am	4	812	150	962	101	137	137	YES	NO	YES	YES		YES
8	9:15 am	5	727	176	903	36	68	68	YES	NO	YES	NO		
9	10:15 am	6	526	387	913	61	51	61	YES	NO	YES	NO		
10	11:15 am	7	482	443	925	81	162	162	YES	YES	YES	YES	YES	YES
11	12:15 pm	8	458	674	1132	182	167	182	YES	YES	YES	YES	YES	YES
12	1:15 pm	9	451	468	919	153	148	153	YES	YES	YES	YES	YES	YES
13	2:15 pm	10	262	264	526	115	98	115	YES	NO	NO	YES		
14	3:15 pm	11	301	321	622	153	99	153	YES	YES	NO	YES	YES	
15	4:15 pm	12	212	483	695	148	173	173	YES	YES	NO	YES	YES	
16	5:15 pm	13	237	684	921	237	176	237	YES	YES	YES	YES	YES	YES
17	6:15 pm	14	174	431	605	158	169	169	YES	YES	NO	YES	YES	
18	7:15 pm	15	249	274	523	59	63	63	YES	NO	NO	NO		
19	8:15 pm	16	164	162	326	58	58	58	NO	NO	NO	NO		
20	No. of YES' in column								13	9	8	11	8	6

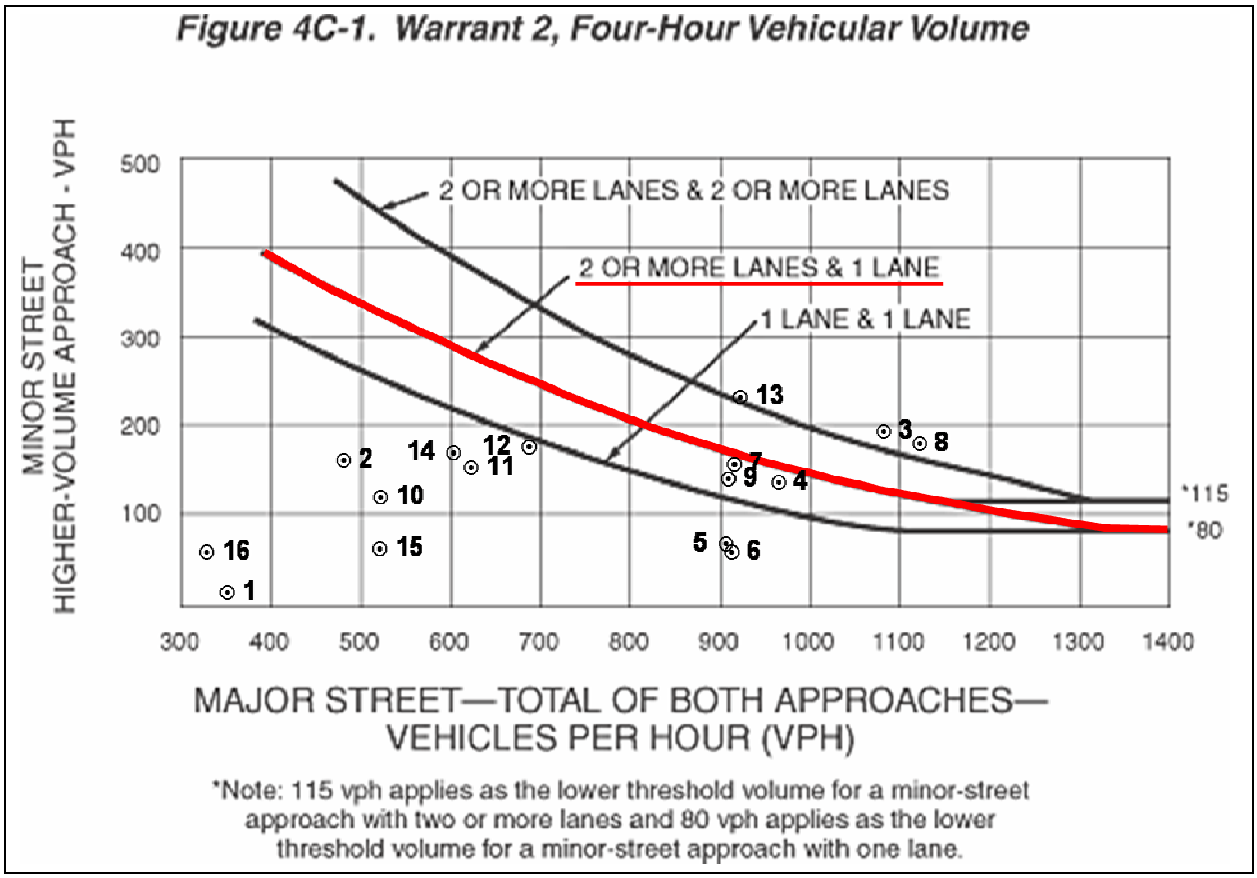


Figure 5. Example of Warrant 2, Four-Hour Vehicular Volume

Table 20. Blank Form for Volume Analysis for Warrant 1

Hour Beginning At:	Hours of volume data	Major Rd Volume (sum of both approaches)			Minor Rd Volume (high volume approach)			Meets Warrant 1A Criteria?		Meets Warrant 1B Criteria?		Both Major and Minor Roads Meet Criteria?	
		North	South	Total	East	West	High	Major	Minor	Major	Minor		
								∃	∃	∃	∃	Warrant 1A	Warrant 1B
No. of YES' in column													

APPENDIX D – EXAMPLE OF ADEQUATE GAP FOR SCHOOL CROSSING WARRANT

This appendix presents examples of how to analyze the size of an adequate gap for the school crossing warrant. The procedure consists of three elements. The first two provide the method of determining the required gap and the actual number of gaps present. The third provides a theoretical means of calculating the number of gaps of a given size.

- Calculate the size of adequate gap required.
- Count the number of gaps of adequate size.
- Predict the number of gaps of a minimum size.

Given the example values below, the size of adequate gap is calculated using the formula in Chapter 2.

Example 1:

Street width (W) = 44 ft.
School children walking speed (S) = 3.5 ft/sec (default).
Number of rows of pedestrians (N) = 8 children/4 abreast = 2 rows.
Time headway between rows (H) = 2 sec (default).
Pedestrian start up time (R) = 3 sec (default).

$$G = \frac{44}{3.5} + (2-1)2 + 3 = 17.6\,\text{sec}$$

The negative exponential function gives the probability of a headway of minimum size occurring in a traffic stream of a given volume. To utilize this formula, it is necessary to increase the headway time to account for the passage time of an automobile. Given the example values below, the gap size used in the negative exponential distribution is:

Mean speed (v) = 20 mph.
Vehicle length (L) = 19 ft (design vehicle for passenger car[1]).
Adequate gap size (G) = 17.6 sec (calculated above).

$g = 17.6 + 19/(1.47\times20) = 18.2$

This value represents the gap size to be used in the negative exponential distribution. For a road where the vehicle count was 150 vehicles in a 30 minute (1800 sec) period, the number of gaps is calculated as indicated below.

$$N_g = e^{-150/1800\times18.2}\times150 = 33 \text{ gaps} > 30$$

[1] American Association of State Highway and Transportation Officials. *A Policy on Geometric Design of Highways and Streets*, Washington, D.C., 2004.

Since the counting period was 30 minutes, the results indicate that there are more gaps of adequate length than there are minutes in the counting period. As a result, this example does not meet the criteria for the School Crossing Warrant.

Example 2:

Street width (W) = 64 ft.
School children walking speed (S) = 3.1 ft/sec.
Number of rows of pedestrians (N) = 12 children/4 abreast = 3 rows.
Time headway between rows (H) = 1 sec.
Pedestrian start up time (R) = 3 sec (default).

$$G = \frac{64}{3.1} + (3-1)1 + 3 = 25.6\,\text{sec}$$

The negative exponential function gives the probability of a headway of minimum size occurring in a traffic stream of a given volume. To utilize this formula, it is necessary to increase the headway time to account for the passage time of an automobile. Given the example values below, the gap size used in the negative exponential distribution is:

Mean speed (v) = 30 mph.
Vehicle length (L) = 16 ft.
Adequate gap size (G) = 25.6 sec (calculated above).

$g = 25.6 + 16/(1.47 \times 30) = 26.0$

This value represents the gap size to be used in the negative exponential distribution. For a road where the vehicle count was 125 vehicles in a 45 minute (2700 sec) period, the number of gaps is calculated as indicated below.

$$N_g = e^{-125/2700 \times 26.0} \times 125 = 38 \text{ gaps} < 45$$

Since the counting period was 45 minutes, the results indicate that there are fewer gaps of adequate length than there are minutes in the counting period. As a result, this example does meet the criteria for the School Crossing Warrant, based on theoretical analysis. However, it should be noted that the calculated number of gaps is close to the threshold value. As a theoretical calculation, a field study is advisable to confirm the results of the theoretical analysis before proceeding with further analysis of the benefits associated with installing a traffic signal.