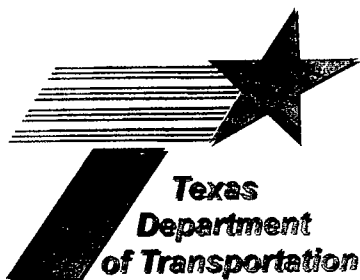
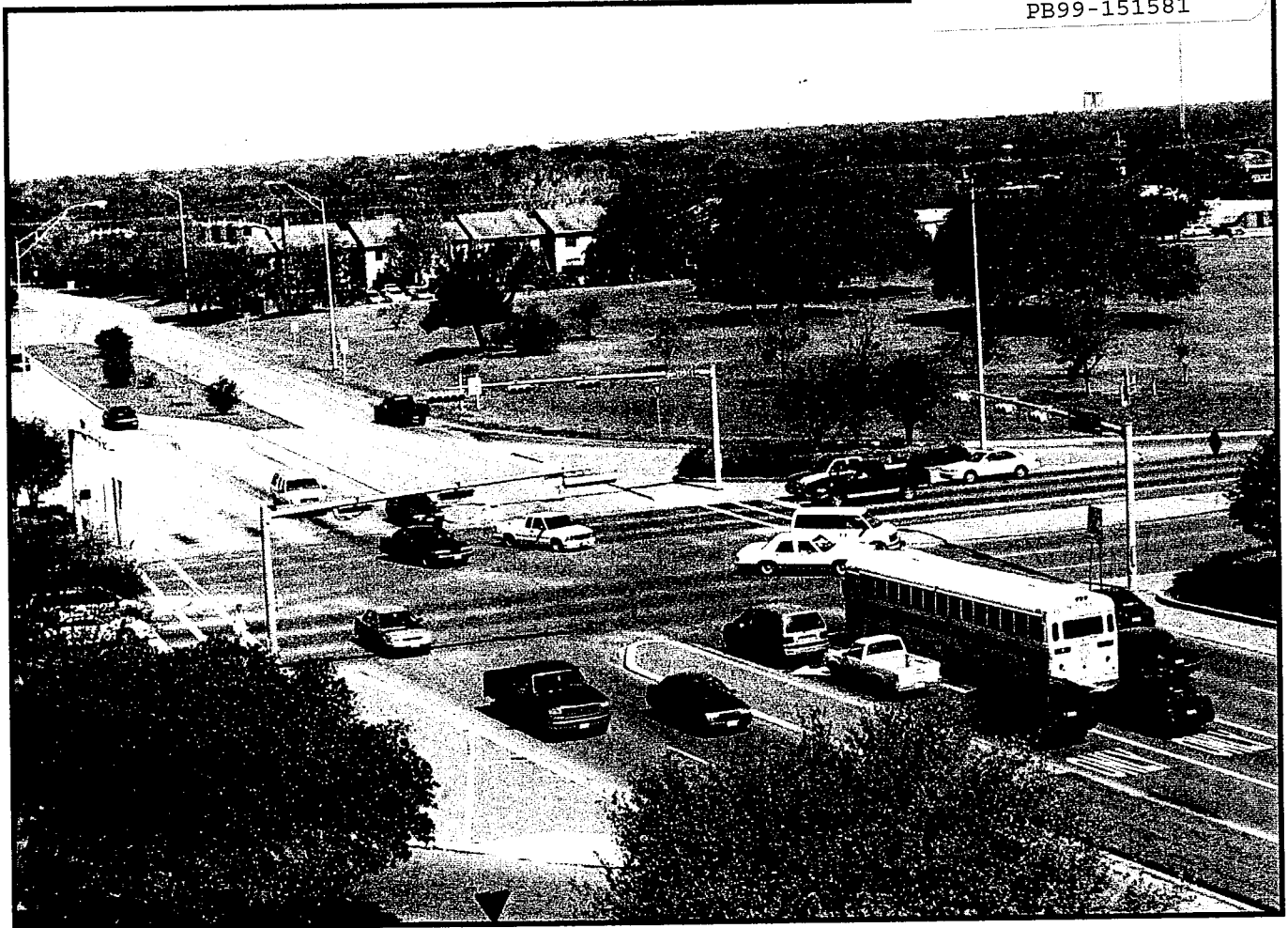


TRAFFIC SIGNAL WARRANTS

Guidelines for Conducting a Traffic Signal Warrant Analysis



PB99-151581



Report Number 3991-2

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE

TRAFFIC SIGNAL WARRANTS

Guidelines for Conducting a Traffic Signal Warrant Analysis

Report Number 3991-2
Project Number 7-3991

Sponsored by the
Texas Department of Transportation

Research Conducted by
Texas Transportation Institute
The Texas A&M University System

Authors
H. Gene Hawkins, Jr.
Paul J. Carlson

TxDOT Project Committee

Project Director
J. Dan Maupin

Project Advisor
Allison C. Meadors

DISCLAIMER

The contents of this document reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was H. Gene Hawkins, Jr., P.E. #61509.

ACKNOWLEDGMENTS

This document represents the implementation phase of a research project evaluating factors influencing traffic signal warrants. The research project was sponsored by the Texas Department of Transportation.

Special thanks are due to the many TxDOT engineers who reviewed various drafts of this document and provided commendable comments. Personnel from FHWA have also provided support through critical reviews of this document.

Grateful appreciation is expressed to members of the Signals Technical Committee of the National Committee on Uniform Traffic Control Devices who reviewed a draft of this document and provided valuable input on its content.

TABLE OF CONTENTS

INTRODUCTION	1
TRAFFIC SIGNALS	1
TRAFFIC SIGNAL WARRANTS	5
ORDER OF WARRANT PRESENTATION	8
DATA COLLECTION PROCEDURES	11
FIRST PHASE – VEHICULAR VOLUME WARRANTS	11
SECOND PHASE – ACCIDENT WARRANT	16
THIRD PHASE – SIGNAL OPERATION WARRANTS	17
FOURTH PHASE – DELAY WARRANT	18
FIFTH PHASE – PEDESTRIAN RELATED WARRANTS	19
WARRANT ANALYSIS GUIDELINES	23
FIRST PHASE – VEHICULAR VOLUME WARRANTS	23
SECOND PHASE – ACCIDENT EXPERIENCE WARRANT	33
THIRD PHASE – SIGNAL OPERATION WARRANTS	35
FOURTH PHASE – DELAY WARRANT	37
FIFTH PHASE – PEDESTRIAN WARRANTS	37
BIBLIOGRAPHY	43
APPENDIX A – MUTCD BACKGROUND	45
NATIONAL AND STATE VERSIONS OF THE MUTCD	45
NEXT EDITION OF THE MUTCD	45
MUTCD AS A LEGAL DOCUMENT	46
MUTCD STANDARDS AND WARRANTS	46
APPENDIX B – WARRANTS FROM THE TEXAS MUTCD	49
APPENDIX C – EXAMPLES OF WARRANT ANALYSIS	57
ANALYSIS EXAMPLE FOR WARRANTS 1 AND 2	57
ANALYSIS EXAMPLE FOR WARRANTS 9, 11, AND 12	57
BLANK WARRANT TABLE	57

LIST OF FIGURES

Figure 1. Eight High Hours – Reduced Warrant Volume	27
Figure 2. Four High Hours – Reduced Warrant Volume	27
Figure 3. Two High Hours – Reduced Warrant Volume	28
Figure 4. Peak Hour – Reduced Warrant Volume	28
Figure 5. Eight High Hours – Normal Warrant Volume	29
Figure 6. Four High Hours – Normal Warrant Volume	29
Figure 7. Two High Hours – Normal Warrant Volume	30
Figure 8. Peak Hour – Normal Warrant Volume	30
Figure 9. Example of Warrant 12, 8 High Hours, Normal Volumes	59
Figure 10. Example of Warrant 9, 4 High Hours, Normal Volumes	59

LIST OF TABLES

Table 1. Texas MUTCD Traffic Signal Warrants	5
Table 2. FHWA Change Regarding Post-Warrant Analysis	7
Table 3. Relative Use of Texas Signal Warrants	9
Table 4. Order of Warrant Analysis Process	9
Table 5. Suggested Data Collection Phases	12
Table 6. FHWA Interpretation Warrants for Wide Median Intersections	13
Table 7. FHWA Interpretation on Speed for Reduction of Volume Warrant	13
Table 8. FHWA Interpretation on Lane Count and Turn Volume	15
Table 9. FHWA Interpretation on Average Day	15
Table 10. Types of Accidents Susceptible to Correction by a Traffic Signal	17
Table 11. Definition of a Major Route for Use with Systems Warrant	18
Table 12. Vehicular Volume Based Traffic Signal Warrants	23
Table 13. Reduced Warrant Volume Criteria	26
Table 14. Normal Warrant Volumes	26
Table 15. FHWA Interpretation on Combination Warrant Terminology	31
Table 16. Combination Warrant and Accident Experience Warrant Volumes	31
Table 17. FHWA Interpretation on Accident Experience Warrant Terminology	33
Table 18. Minimum Vehicular Volumes for Warrant 1	49
Table 19. Minimum Vehicular Volumes for Warrant 2	50
Table 20. Example of Volume Analysis for Warrants 1 and 2	58
Table 21. Blank Form for Volume Warrant Analysis	60

INTRODUCTION

Traffic signals are electronically controlled traffic control devices that are used to 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 traffic signal with red-yellow-green indications as used today was established as the standard appearance of a 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, a series of traffic signal warrants has been developed to define the minimum traffic conditions that must be present before signal installation can be considered. Installation of a traffic signal should not be considered if the traffic conditions do not meet the minimum criteria established by at least one of the warrants.

The use of traffic signals and the related signal warrants can be complicated. The general public, elected and government officials, and even some practitioners, often misunderstand the signal warrants. Furthermore, there is no recent document that provides a step-by-step description of the warranting process. This document provides transportation officials with detailed information about conducting a traffic signal warrant analysis. It addresses many of the issues that have typically been left to interpretation and is intended to improve the consistency of the warranting process.

TRAFFIC SIGNALS

The intersection of two or more roadways provides one of the more significant challenges to the governing 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.

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. A series of guidelines and standards have been developed to ensure that traffic signals are used in a uniform manner.

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 U.S. As such, the Federal Highway Administration (FHWA) is responsible for the national MUTCD. States have the option of adopting the national MUTCD or developing a state MUTCD 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 current Texas MUTCD has been revised six times since its original publication in 1980.

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. 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. However, even though the MUTCD provides guidelines and standards for traffic signals and other traffic control devices, the application of these guidelines and standards should be exercised only by a competent traffic engineer and only after a thorough study of the critical factors.

The FHWA is in the process of revising the national MUTCD. The new edition, which is expected to be available in 2000 or later, is a complete rewrite of the Manual. The information in the MUTCD has been significantly reorganized and much of it has been rewritten as well. In January 1997, FHWA published a *Federal Register* notice of proposed rulemaking that presented the proposed "Part 4—Signals" to the public for comment. The proposed "Part 4" clarifies many of the warrant questions that have been subject to interpretation in the past. These clarifications are used throughout this warrant guideline document where the clarifications do not conflict with the warrants contained in the 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-6 of the 1988 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 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.
- It can reduce the frequency of certain types of accidents, 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. The disadvantages that may be associated with a properly justified, designed, and installed traffic signal include:

- It can increase the delay experienced by the major traffic movements.
- It can increase the frequency of certain types of accidents (primarily rear-end accidents).
- It can reduce the freedom of road users to control their own progress.

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 accidents at the intersection.
- 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 accidents 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 accidents, most notably rear-end collisions. However, the accidents that typically result from signal installation are typically less severe than the accidents 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 MUTCD Section 2B-8 for Yield sign warrants).
- Manual traffic control by a police officer or other official.
- Two-way stop control with Stop sign only (see MUTCD Section 2B-5 for Stop sign warrants).
- Two-way stop control with Stop sign and stop sign beacon (see MUTCD Section 4E-4 for stop sign beacon).
- Two-way stop control with Stop sign and red/yellow intersection beacon (see MUTCD Section 4E-3 for intersection control beacon).
- Multiway stop control with Stop sign only (see MUTCD Section 2B-6 for Multiway Stop sign warrants).
- Multiway stop control with Stop sign and stop sign beacon (see MUTCD Section 4E-4 for stop sign beacon).
- Multiway stop control with Stop sign and red/red intersection beacon (see MUTCD Section 4E-3 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, Pedestrian Crossing).
- Increasing the size of regulatory and/or warning signs on the intersection approach.
- Installing hazard identification beacons on warning signs in advance of the intersection (see MUTCD Section 4E-1 for hazard identification 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 accidents occur at night.
- Restricting one or more turning movements (perhaps on a time-of-day basis) if alternate routes are available.
- 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 twelve traffic signal warrants. Table 1 lists these warrants, which address a variety of intersection conditions such as vehicular volume, pedestrian volume, accidents, progression, and delay. The specifics associated with these warrants are described in detail in the analysis guidelines chapter (see page 23). The warrants in the MUTCD 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
1	Minimum Vehicular Volume	8-hour vehicular volume
2	Interruption of Continuous Traffic	8-hour vehicular volume
3	Minimum Pedestrian Volume	Pedestrian volumes and gaps
4	School Crossing	Number of school children and gaps
5	Progressive Movement	Signal progression
6	Accident Experience	Accidents and Warrants 1, 2 or 3
7	Systems	Vehicular volumes and road classification
8	Combination of Warrants	Vehicular volumes and pedestrians
9	Four Hour Volumes	4-hour vehicular volume
10	Peak Hour Delay	Vehicular volume and delay on minor street
11	Peak Hour Volume	1-hour vehicular volume
12	Volumes for Traffic Actuated Signals ¹	2- or 8-hour vehicular volumes

Note: ¹This warrant is in the Texas MUTCD, but not the national MUTCD. It is similar to Warrants 9 and 11, but provides for analysis of the two high hours and eight high hours.

It is worth noting that the numerical order in which the warrants are listed does not imply an ordered relationship between the warrants. For example, Warrants 1, 2, 9, 11, and 12 are based solely on vehicular volumes. Warrants 6 and 8 consider relationships between multiple warrants. Warrants 3 and 4 are related to pedestrian volumes. Warrants 5 and 7 include operational and functional aspects. Finally, Warrant 10 considers delay and volumes. 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.

Traffic Signal Warrants

The traffic signal warrants have been developed 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 twelve 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 only 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 traffic control at the intersection.

- 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.

The FHWA changed the first paragraph of Section 4C-2 in the 1988 MUTCD to emphasize the need for post-warrant analysis. Table 2 describes 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 2. FHWA Change Regarding Post-Warrant Analysis

IV-66 (Change)	Warrants for Traffic Signal Installation
<p>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.</p>	

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. Neither the Texas nor the national MUTCD contain specific warrants for the removal of traffic signals. The only MUTCD guidance relative to signal removal is a statement that a signal should not continue in operation if it does not meet any of the warrants. 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 accidents, delay, or traffic patterns). Therefore, the removal of a traffic signal requires engineering judgement.

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.

- The traffic signal should be placed in flashing operation reflecting two-way or multiway stop control, as appropriate.
- If, after an extended period of flashing operation, intersection operation and safety are acceptable, the signal should be deactivated and Stop signs should be installed on the appropriate approaches. 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 should be left in place.
- After an extended period of acceptable sign control operation, the signal poles, mast arms, and/or span wire should be removed.

The Traffic Signal 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 is 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 the chapter on 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).
- Accident reports (number, type, and date of accidents).

ORDER OF WARRANT PRESENTATION

Using information gathered as part of a TxDOT/TTI research project on traffic signal warrants¹, 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 3 indicates the relative frequencies that the twelve TxDOT warrants are used in the process of analyzing the need for a traffic signal.

Based on the order of the information in Table 3, this document presents the warrant analysis procedure as a five phase process. Table 4 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.

¹Carlson, 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 3. Relative Use of Texas Signal Warrants

Warrant Number and Title		Percent of Use for Signal Installation
1	Minimum Vehicular Volume	28%
12	Warrant Volumes for Traffic Actuated Signals	19%
2	Interruption of Continuous Traffic	16%
11	Peak Hour Volume	12%
6	Accident Experience	7%
7	Systems	4%
8	Combination of Warrants	4%
5	Progressive Movement	3%
9	Four Hour Volumes	3%
10	Peak Hour Delay	2%
4	School Crossing	2%
3	Minimum Pedestrian Volume	0%

Source: Based on a survey of 32 TxDOT Districts. The survey and responses are described in more detail in TxDOT Research Report 3991-1.

Table 4. Order of Warrant Analysis Process

Phase	Warrant Number and Title		Described on Page	
			Data Collection	Analysis Guidelines
1 st Phase: Volumes	1	Minimum Vehicular Volume	11	23
	2	Interruption of Continuous Traffic		
	9	Four Hour Volumes		
	11	Peak Hour Volume		
	12	Warrant Volumes for Traffic Actuated Signals		
	8	Combination of Warrants		
2 nd Phase: Accidents	6	Accident Experience	16	33
3 rd Phase: Signal Operation	5	Progressive Movement	17	35
	7	Systems		
4 th Phase: Delay	10	Peak Hour Delay	18	37
5 th Phase: Pedestrians	4	School Crossing	19	37
	3	Minimum Pedestrian Volume		

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 the measurement of the size of 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 most reasonably be collected 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 intersection 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 5 indicates the data that needs to be collected with each of the warrant phases identified in Table 4. Table 5 is followed by specific instruction on how to collect each type of data needed in the various warrant analysis phases.

FIRST PHASE – VEHICULAR VOLUME WARRANTS

There are six different warrants that are based solely on the vehicular volume at the intersection. These warrants include: the Minimum Vehicular Volume Warrant (Warrant 1), the Interruption of Continuous Traffic Warrant (Warrant 2), the Four Hour Volumes Warrant (Warrant 9), the Peak Hour Volume Warrant (Warrant 11), the Traffic Actuated Signals Warrant (Warrant 12), and the Combination of Warrants Warrant (Warrant 8). The basic differences between these warrants are the threshold criteria and the number of hours that must meet the threshold. Four types of data are used in the first phase of analysis. The specific data and the related purpose are described below. The following paragraphs provide specific details on collecting the data.

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

Intersection Limits

For most intersections, the 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 9.1 m (30 ft) apart are treated as separate intersections by definition. However, Table 6 presents an FHWA interpretation that 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 5. Suggested Data Collection Phases

Phase	Data	See Page	Warrant Categories				
			Vehicular Volume	Signal Operation	Accident	Delay	Pedestrian Related
First: Vehicular Volume	Intersection limits	11	X	X	X	X	X
	Speed on the major roadway	13	X	X	X		
	Population of the area	13	X		X		
	Typical weekday hourly vehicular approach volumes	14	X	X	X	X	
	Number of lanes per approach	15	X		X		
Second: Accident	Accident history	16			X		
	Type of each accident	16			X		
	Distance between existing signals	17		X			
Third: Signal Operation	Information on platoon dispersion	?		X			
	Roadway characteristics	18		X			
	Hourly volumes for a typical non-business day	18		X			
	Five-year projected hourly traffic volumes	18		X			
	Peak hour vehicular delay on minor road	19				X	
Fourth: Delay	Distance to nearest existing signal	19					X
	Distance to nearest crosswalk	20					X
Fifth: Pedestrian Related	Pedestrian walking speed	20					X
	Hourly pedestrian volume	20					X
	Storage capacity of median	20					X
	Size of adequate gap	20					X
	Number of gaps of adequate size	21					X
	School crossing plan	21					X
	Presence of school children	21					X

Table 6. FHWA Interpretation Warrants for Wide Median Intersections

Sg-25 (Interpretation)	Clarification on Computing Signal Warrants for Wide Median Intersections
<p>Interpretation of the following question 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?</p> <p>It was ruled that traffic signal warrants were established to identify those conditions which present a high potential for traffic conflict with resultant accidents, 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.</p>	

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 64 km/h (40 mph). Both the current national and Texas MUTCDs indicate that this is the 85th percentile speed. However, the proposed language for the next edition of the national MUTCD indicates that the speed can be the posted, statutory, or 85th percentile speed. Since the posted speed should be based on the 85th percentile speed, either speed can be used for the 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. Table 7 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 7. FHWA Interpretation on Speed for Reduction of Volume Warrant

Sg-94 (Interpretation)	Reduction of Volume Warrant
<p>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.</p> <p>The FHWA response stated that the reduction can be applied to both rural and urban intersections.</p>	

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 criteria 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 the 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 only vehicles approaching the intersection are counted. (In other words, count only one direction of traffic on each approach).
- The count locations should not include turning vehicles if the traffic using the turn lane is minor. Table 8 presents the text of an FHWA interpretation that indicates the need to apply engineering judgement in determining whether turning volumes should be included in the approach volume count.
- 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 vehicles¹.
- 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.
- 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 a 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,

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

with one exception. It may be appropriate to subtract the volume of right or left turns from the approach volume before conducting the analysis as described in Table 8.

Table 8. FHWA Interpretation on Lane Count and Turn Volume

IV-65 (Interpretation)	Signal Warrants, Determining Number of Approach Lanes
<p>Considerable engineering judgement 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 judgement 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, judgement 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 a two-lane approach if the lane split approached 50/50.</p> <p>A similar rationale could be applied to a minor street approach with one lane plus a right-turn lane. Judgement, 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.</p>	

Table 9. FHWA Interpretation on Average Day

Sg-7 (Interpretation)	Interpretation of Signal Warrants as Applied to Rural Locations
<p>The request was for clarification of the term “an average day” as used in the Minimum Vehicular Warrant (Warrant 1). 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 a weekday representing traffic volumes normally and repeatedly found at the location.</p>	

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. In addition to addressing the turning volume, the FHWA interpretation presented in Table 8 also indicates the need to exercise engineering judgement in determining whether to include a turning lane in the approach lane count.

SECOND PHASE – ACCIDENT WARRANT

The data needs for the Accident Experience Warrant (Warrant 6) build upon those used in the vehicular volume warrants. One portion of the Accident Experience Warrant requires the intersection to have at least 80 percent of the volumes required for the Minimum Vehicular Volume Warrant (Warrant 1) or the Interruption of Continuous Traffic Warrant (Warrant 2). In addition to the vehicular volume data, this warrant requires accident 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:
 - ▶ Accident history.
 - ▶ Type of each accident.
 - ▶ Date of each accident.

Accident History

A list of all accidents that have occurred at the intersection should be obtained from the agency responsible for maintaining the accident 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 accidents off the state system. Only those accidents that have occurred during the most recent 12-month period (in which data are available) should be used in analyzing the Accident Experience Warrant.

Type of Accidents

Only those accidents that are susceptible to correction by a traffic control signal are used in the Accident Experience Warrant. Table 10 provides examples of the types of accidents that are, and are not, susceptible to correction by a traffic control signal.

Table 10. Types of Accidents Susceptible to Correction by a Traffic Signal

Examples of Accidents that may be Susceptible to Correction by a Traffic Control Signal	Examples of Accidents that may not be Susceptible to Correction by a Traffic Control Signal
<ul style="list-style-type: none"> • Accidents between vehicles on conflicting approaches to the intersection. • Accidents between left-turning vehicles and through vehicles on the opposite approach. • Accidents involving pedestrians. 	<ul style="list-style-type: none"> • Rear-end accidents. • Accidents between vehicles moving in the same direction.
<p>Note: The examples above represent typical situations. Engineering judgement should be used on a case-by-case basis to determine whether a particular accident is susceptible to correction by a traffic signal.</p>	

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 Progressive Movement Warrant (Warrant 5) and the Systems Warrant (Warrant 7). 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.

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

Distance Between Existing Signals

The distance between the proposed signal and existing signals is used in analyzing the Progression 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 Systems Warrant can only be applied to the intersection of two or more major routes. Table 11 identifies the characteristics of a major routes as used in this warrant.

Table 11. Definition of a Major Route for Use with Systems Warrant

For purposes of the Systems Warrant, a major roadway has one or more of the following characteristics:
It is part of the roadway or highway system that serves as the principal network for through traffic flow.
It connects areas of principal traffic generation.
It includes rural or suburban highways outside, entering, or traversing a city.
It has surface street freeway or expressway ramp terminals, or
It appears as a major route on an official plan, such as a major roadway 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 (see page 14), except that they are collected on a 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 Traffic 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 Delay Warrant (Warrant 10) 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 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 9, Appendix III. Although this chapter applies to signalized intersections, the procedure for measuring delay can be applied to approaches controlled by a Stop sign. Procedures for calculating delay at unsignalized intersections are contained in Chapter 10.

FIFTH PHASE – PEDESTRIAN RELATED WARRANTS

The Minimum Pedestrian Volume Warrant (Warrant 3) and the School Crossing Warrant (Warrant 4) 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 is 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. 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 (Minimum Pedestrian Volume Warrant).
 - ▶ Distance to nearest crosswalk (Minimum Pedestrian Volume Warrant).
 - ▶ Pedestrian walking speed (Minimum Pedestrian Volume Warrant).
 - ▶ Hourly pedestrian volume (Minimum Pedestrian Volume Warrant).
 - ▶ Width of median (Minimum Pedestrian Volume Warrant).
 - ▶ Size of adequate gap (Minimum Pedestrian Volume Warrant).
 - ▶ Number of gaps of adequate size (Minimum 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. As with the distance between intersections (see page 17), this is the distance from center-of-intersection to center-of-intersection.

¹*Special Report 209, Highway Capacity Manual, 3rd Edition.* Transportation Research Board, National Research Council, Washington, D.C., 1994. (Note: A new edition of the *Highway Capacity Manual* is scheduled for publication in 2000).

Distance to Nearest Crosswalk

If the signal under consideration is a mid-block 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 no specific guidelines for measuring this speed. It can be determined from the equation below.

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

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.

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 1.2 m (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 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, seconds,
W = crossing distance or width of roadway, feet,
S = walking speed, feet / second,
N = predominant number of rows (group size),
H = time headway between rows, seconds, and
R = pedestrian startup time, seconds.

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.

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.

¹Robertson, H.D, J.E. Hummer, D.C. Nelson. *Manual of Transportation Engineering Studies*, Institute of Transportation Engineers, Prentice Hall, Englewood Cliffs, New Jersey, 1994.

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 4, 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

Six of the twelve warrants are based solely on hourly vehicular approach volumes at the intersection. Table 12 shows these warrants. Based on the findings of a recent TxDOT/TTI research project (see Table 3), 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 succeeding analysis phases.

Table 12. Vehicular Volume Based Traffic Signal Warrants

Number and Title		Hours ¹	Application
1	Minimum Vehicular Volume	8	Where a large volume of intersecting traffic is the principle reason to consider installing a signal.
2	Interruption of Continuous Traffic	8	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
8	Combination	8	Where 80 percent or more of the criteria are met for any two of the following warrants: 1, 2, or 3.
9	Four Hour Volumes	4	Where the volume of intersecting traffic is the principle reason to consider installing a signal.
11	Peak Hour Volume	1	Where minor street traffic suffers undue delay entering or crossing the major street during one hour of the day.
12	Traffic Actuated Signals (2 or 8 hours)	2 and 8	Where the volume of intersecting traffic may not completely satisfy other warrants, but where unpredictable peak hours may occur during the two or eight high hours.

Notes: ¹Number of hours for which volume criteria must be satisfied.

Other than the actual volume thresholds, the analysis of these six warrants are essentially the same. One aspect of these warrants is that the threshold volumes can be reduced if the major roadway speeds are high or 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 11).
- Speed on the major roadway (see page 13).
- Population of the area (see page 13).
- Typical weekday hourly vehicular approach volumes (see page 14).
- Number of lanes per approach (see page 15).

Warrant Criteria

Warrants 1, 2, 9, 11, and 12 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 64 km/h (40 mph) (see page 13 and Table 7)? If yes, the reduced 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 13)? If yes, the reduced volume warrant criteria apply. Go to Question 2. If not, go to Question 4.
2. Analyze the reduced volume warrant criteria using the reduced volume warrant table:
 - a. Are there 8 hours where both the major and minor street volumes meet the criteria in Table 13 for either Warrant 1 OR Warrant 2? See Appendix C for guidance and an example of how to use the table. 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 reduced volume warrant criteria using the reduced volume warrant curves.
 - a. Are there 8 hours where the major and minor street volumes are above the applicable curve in Figure 1 (Warrant 12)? 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. Are there 4 hours where the major and minor street volumes are above the applicable curve in Figure 2 (Warrant 9)? 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 3c.
 - c. Are there 2 hours where the major and minor street volumes are above the applicable curve in Figure 3 (Warrant 12)? 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 3d.
 - d. Is there 1 hour where the major and minor street volumes are above the applicable curve in Figure 4 (Warrant 11)? 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 normal volume warrant table:
 - a. Are there 8 hours where both the major and minor street volumes meet the criteria in Table 14 for either Warrant 1 OR Warrant 2? See Appendix C for guidance and an example of how to use the table. 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.

5. Analyze the normal volume warrant criteria using the normal volume warrant curves.
 - a. Are there 8 hours where the major and minor street volumes are above the applicable curve in Figure 5 (Warrant 12)? 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. Are there 4 hours where the major and minor street volumes are above the applicable curve in Figure 6 (Warrant 9)? 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 5c.
 - c. Are there 2 hours where the major and minor street volumes are above the applicable curve in Figure 7 (Warrant 12)? 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 5d.
 - d. Is there 1 hour where the major and minor street volumes are above the applicable curve in Figure 8 (Warrant 11)? 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 volume portion of the Combination Warrant (Note: the pedestrian related portions of the Combination Warrant are analyzed in the “Fifth Phase – Pedestrian Related Warrants”).
 - a. Has there been an adequate trail of other remedial measures which cause less delay and inconvenience to traffic? See Table 15 for an FHWA interpretation on the meaning of “remedial measures.” If the answer is yes, go to Question 2. If not, this warrant cannot be satisfied.
 - b. Are there 8 hours where both the major and minor street volumes meet the criteria in Table 16? The criteria must be met for BOTH Warrants 1 and 2. See Appendix C for guidance and an example of how to use the table. 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.

Table 13. Reduced Warrant Volume Criteria

Number of approach lanes of moving traffic		Warrant 1 – Minimum Vehicular Volume		Warrant 2 – Interruption of Continuous Traffic	
Major Rd	Minor Rd	Major Rd – total of both approaches	Minor Rd – one approach only	Major Rd – total of both approaches	Minor Rd – one approach only
1	1	350	105	525	53
2 or more	1	420	105	630	53
2 or more	2 or more	420	140	630	70
1	2 or more	350	140	525	70

Note: These volumes represent 70 percent of the volumes shown in Table 14.

Table 14. Normal Warrant Volumes

Number of approach lanes of moving traffic		Warrant 1 – Minimum Vehicular Volume		Warrant 2 – Interruption of Continuous Traffic	
Major Rd	Minor Rd	Major Rd – total of both approaches	Minor Rd – one approach only	Major Rd – total of both approaches	Minor Rd – one approach only
1	1	500	150	750	75
2 or more	1	600	150	900	75
2 or more	2 or more	600	200	900	100
1	2 or more	500	200	750	100

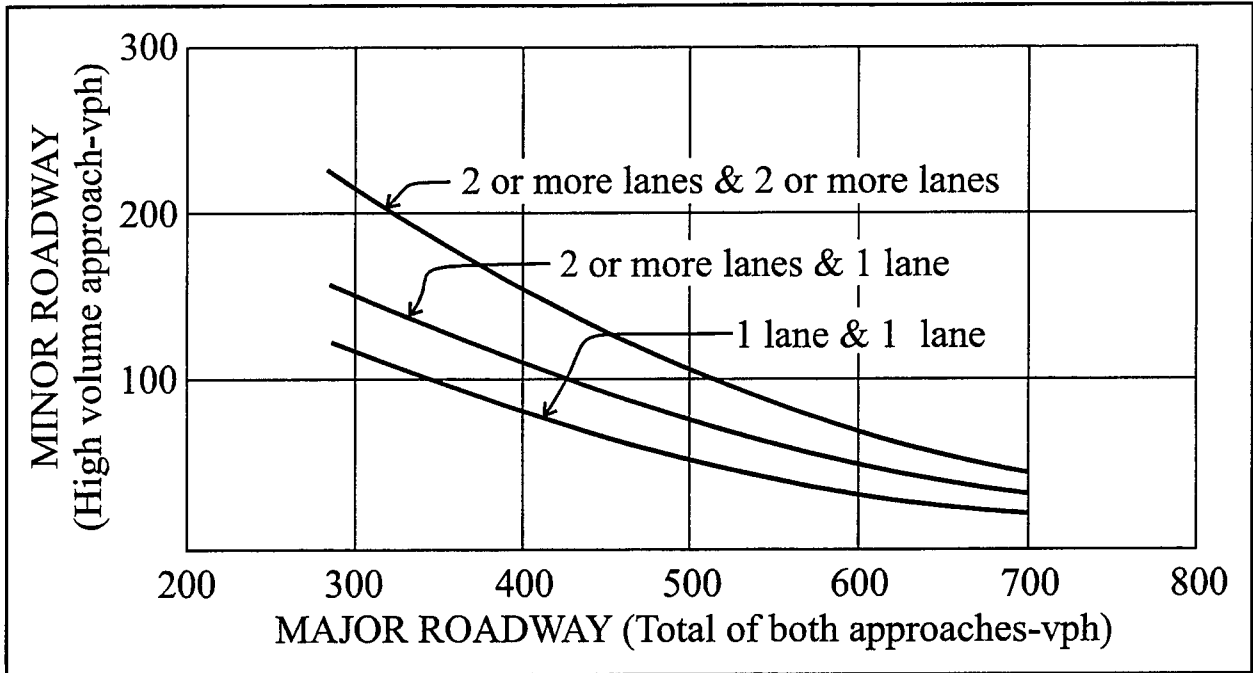


Figure 1. Eight High Hours – Reduced Warrant Volume

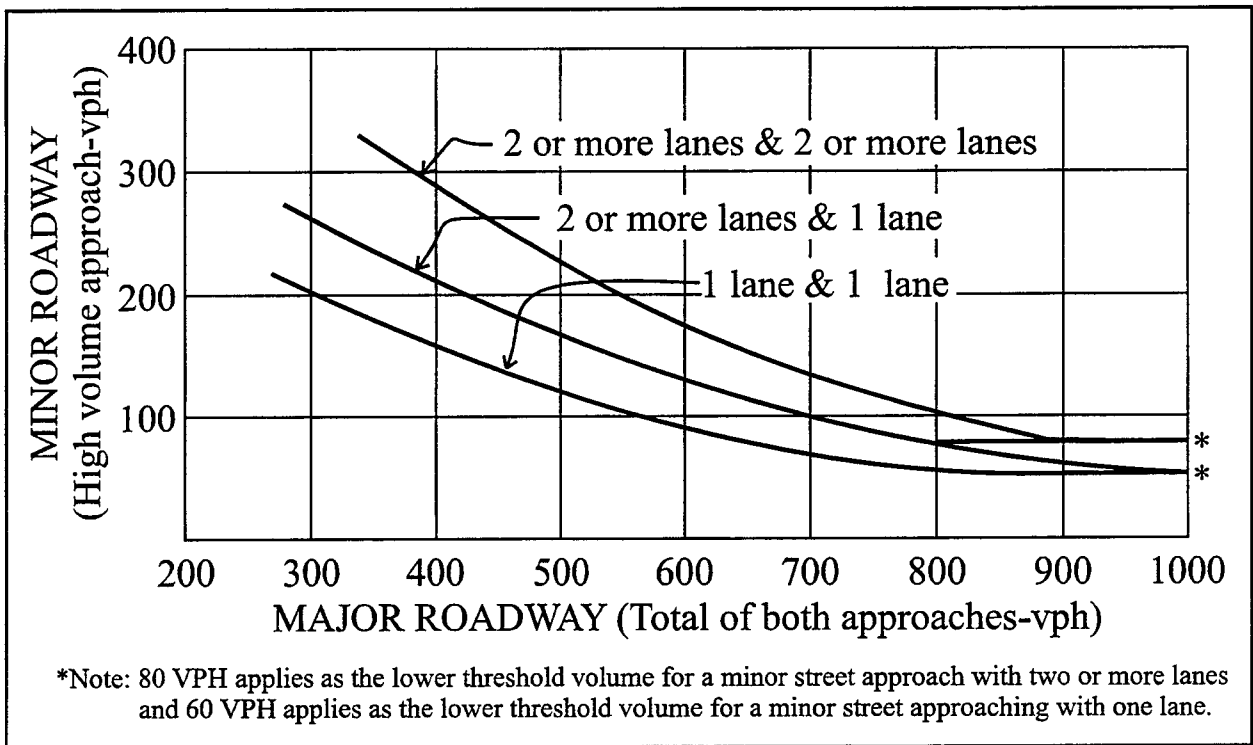


Figure 2. Four High Hours – Reduced Warrant Volume

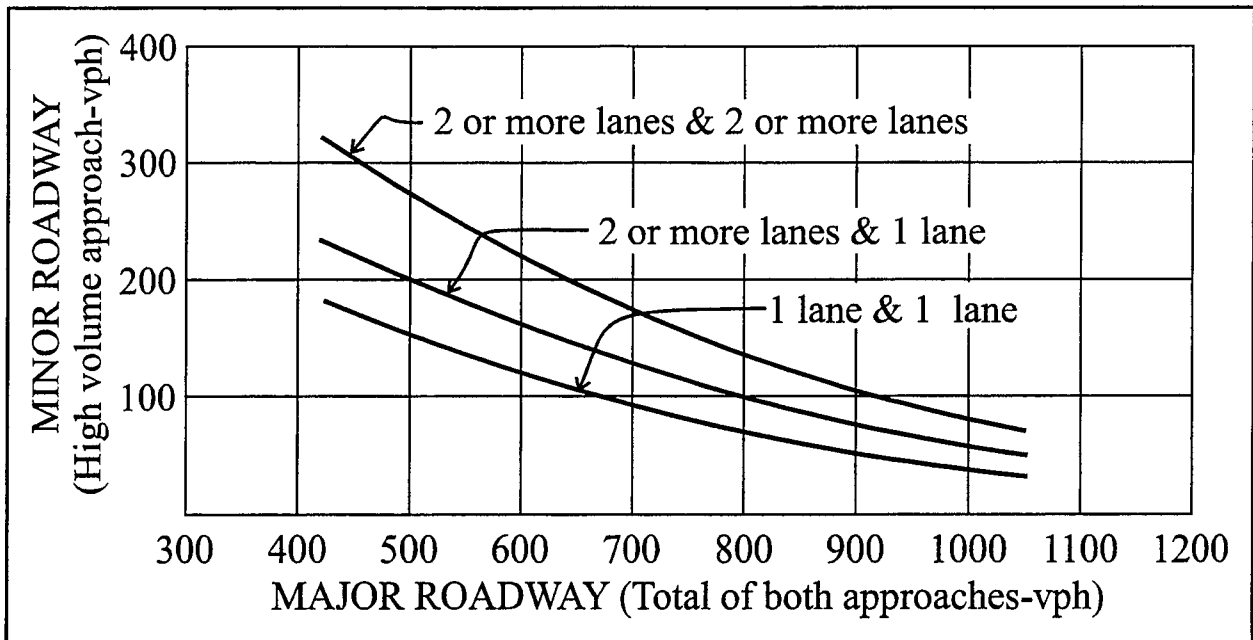


Figure 3. Two High Hours – Reduced Warrant Volume

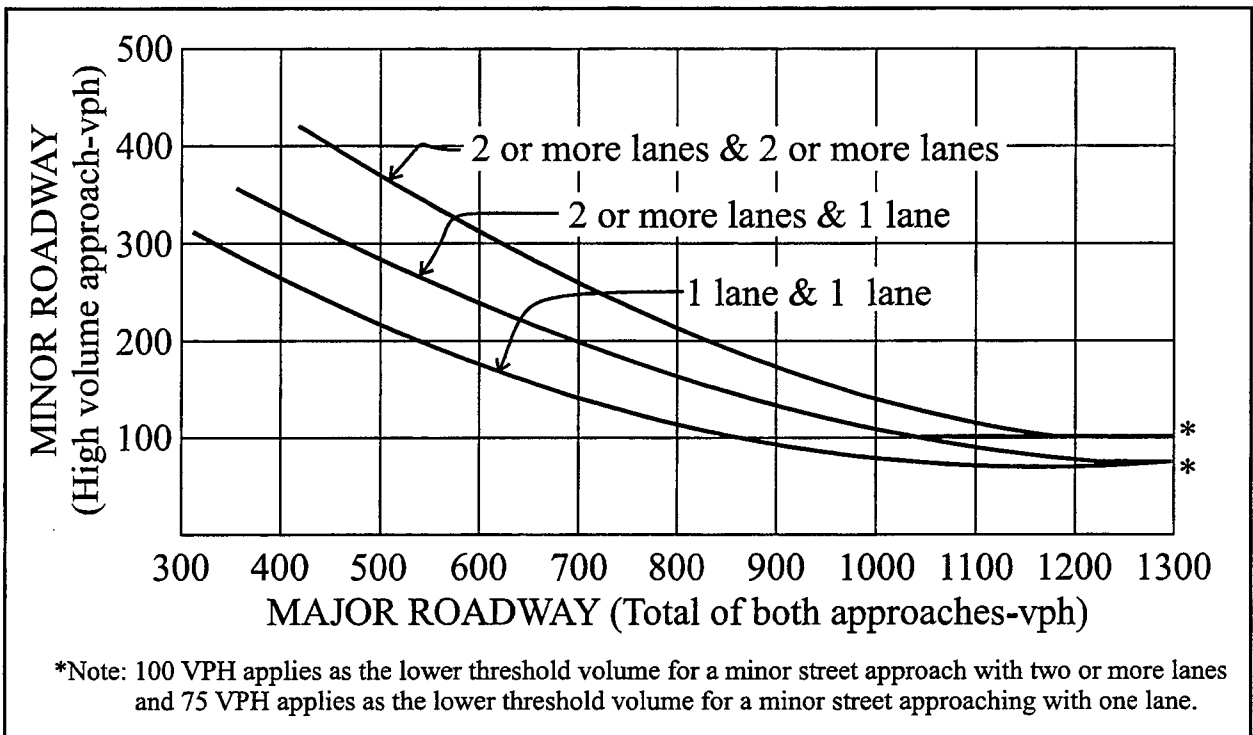


Figure 4. Peak Hour – Reduced Warrant Volume

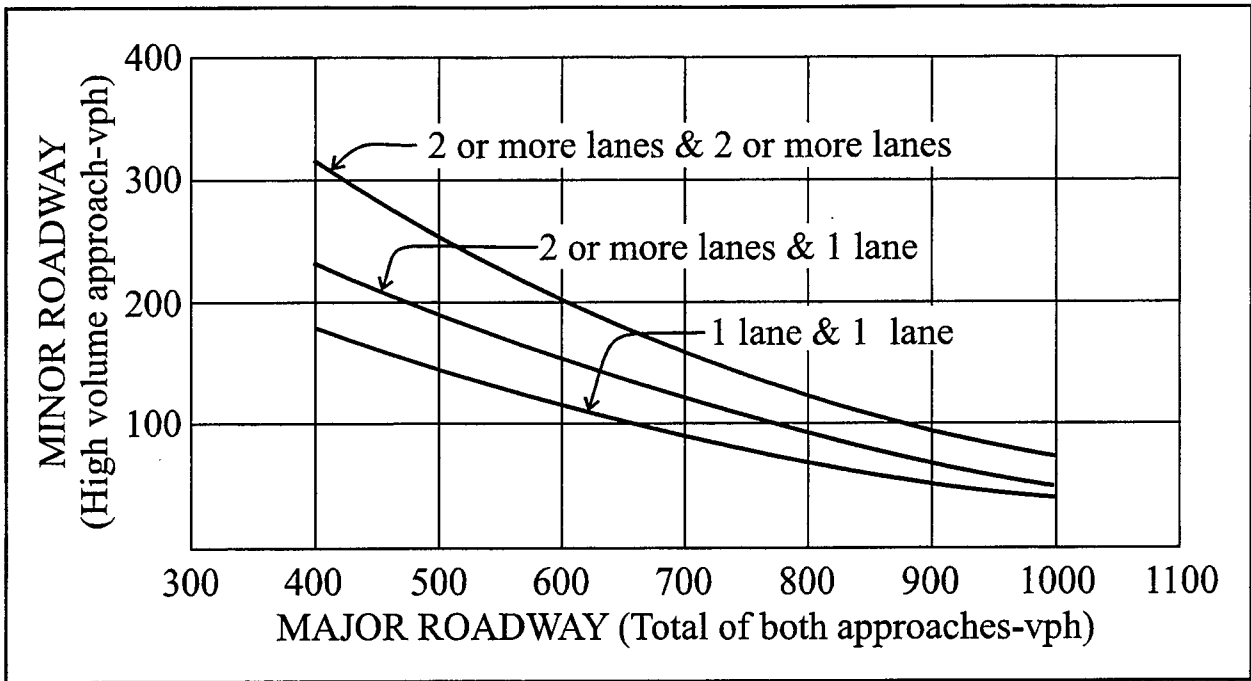


Figure 5. Eight High Hours – Normal Warrant Volume

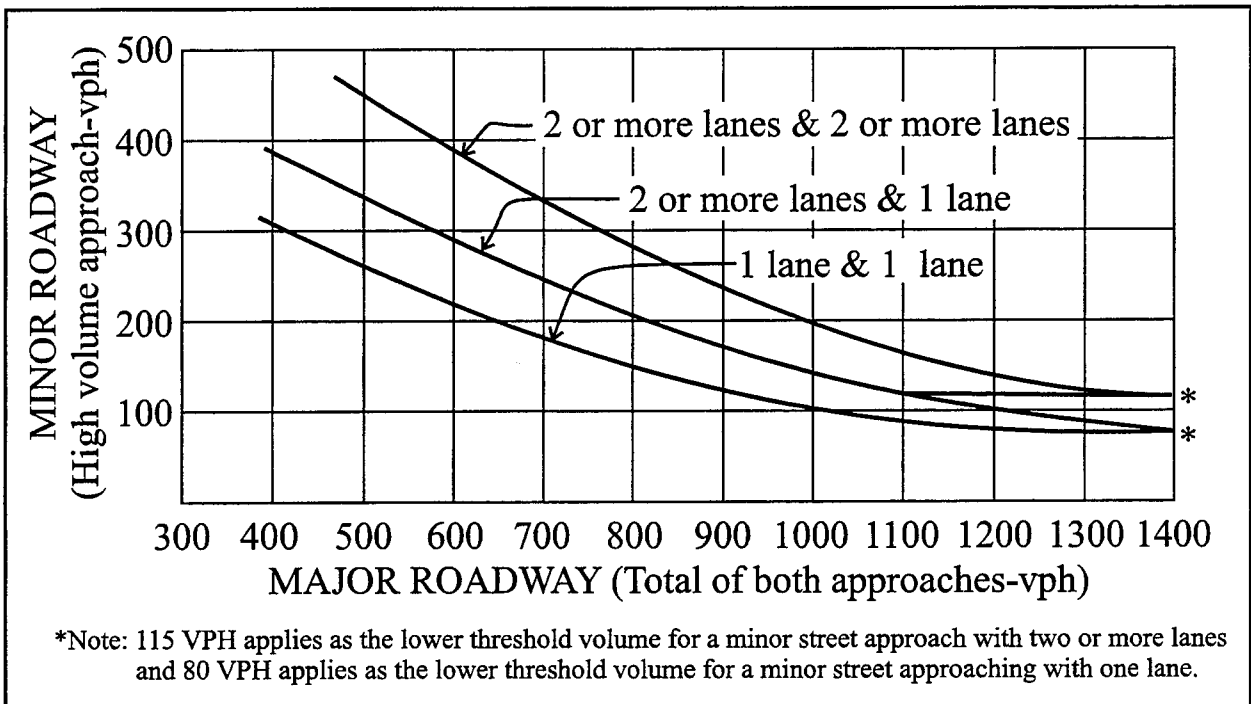


Figure 6. Four High Hours – Normal Warrant Volume

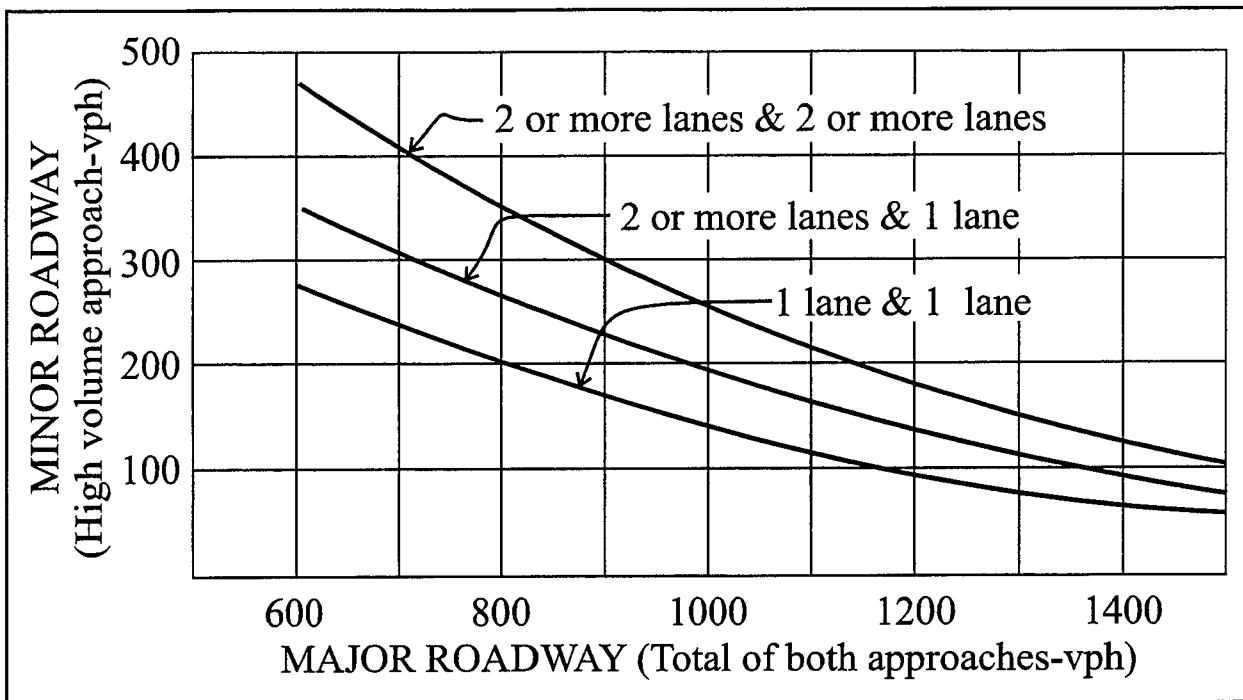


Figure 7. Two High Hours – Normal Warrant Volume

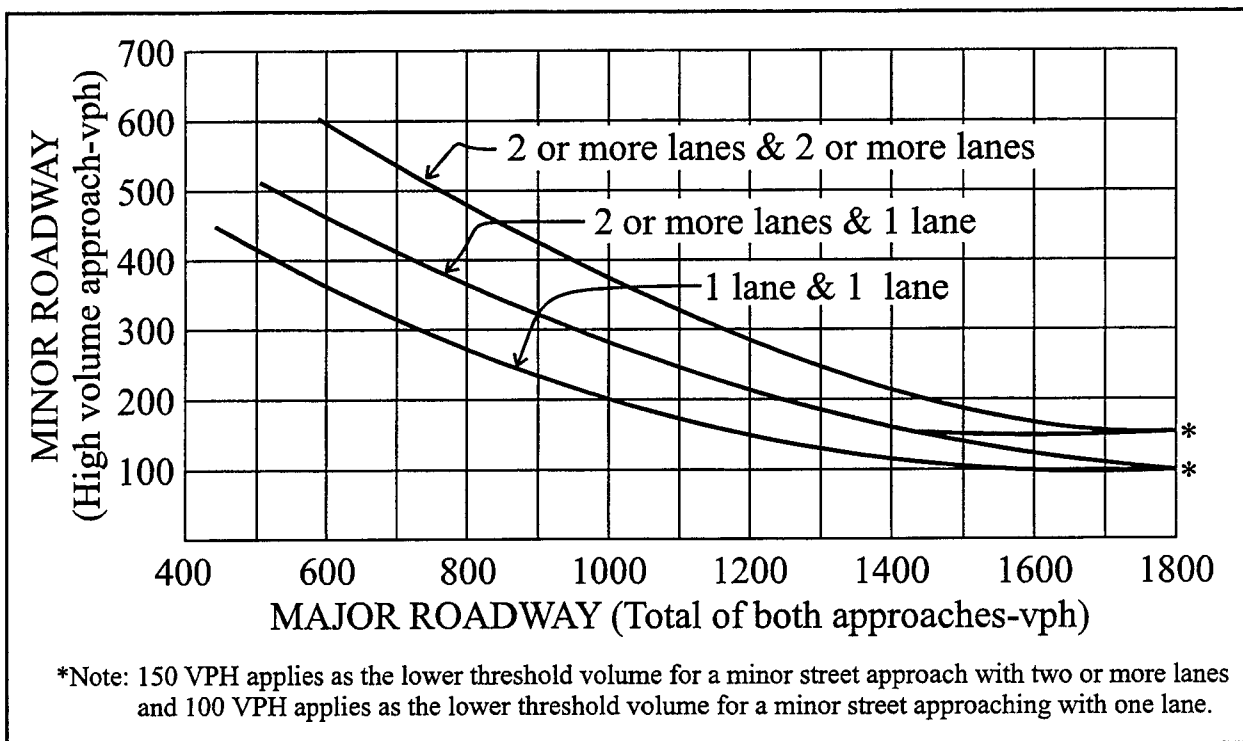


Figure 8. Peak Hour – Normal Warrant Volume

Table 15. FHWA Interpretation on Combination Warrant Terminology

Sg-61 (Change)	Combination Warrant
<p>A request was made to define the “remedial measures” described in the warrant and that warrants be established for the “remedial measures.”</p> <p>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 judgement.</p>	

Table 16. Combination Warrant and Accident Experience Warrant Volumes

Number of approach lanes of moving traffic		Warrant 1 – Minimum Vehicular Volume		Warrant 2 – Interruption of Continuous Traffic	
Major Rd	Minor Rd	Major Rd – total of both approaches	Minor Rd – one approach only	Major Rd – total of both approaches	Minor Rd – one approach only
1	1	400	120	600	60
2 or more	1	480	120	720	60
2 or more	2 or more	480	160	720	80
1	2 or more	400	160	600	80

Notes: These volumes represent 80 percent of the volumes shown in Table 14. For the Combination Warrant, the volumes indicated must be satisfied for both Warrant 1 and Warrant 2. For the Accident Experience Warrant, the volumes indicated must be satisfied for either Warrant 1 or Warrant 2. These major roadway and minor roadway volumes shall be for the same 8 hours within each warrant. However, the 8 hours satisfied in Warrant 1 are not required to be the same 8 hours satisfied in Warrant 2.

Installation Requirements

Although not required by the MUTCD, if a signal is installed on the basis of Warrants 9, 11, or 12 (plots for peak, two, four, or eight high hours), a fully-actuated traffic signal should be installed.

Frequently Asked Questions About the Volume Warrants

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

- What if there are 2 lanes on one major street approach and one lane on the other major street approach?
 - ▶ There is no official interpretation on this issue. The situation can be addressed by adding half of the one-lane volume and half of the two-lane volume. For example, in the Minimum Vehicular Volume warrant, the warranting volume would be 250 ($\frac{1}{2}$ of 500) plus 300 ($\frac{1}{2}$ 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?
 - ▶ The volumes used to perform the warrant analysis should not typically include turning vehicles if the traffic using the turn lane is minor. Table 8 presents the text of an FHWA interpretation that indicates the need to apply engineering judgement in determining whether turning volumes should be included in the approach volume. If the volume of turning traffic is heavy, it may be included in the approach volume used in the warrant analysis.
- Can the 80 percent volumes used in the Combination Warrant (Warrant 8) be reduced to 56 percent (80 percent times 70 percent) if the intersection is located in an isolated area or has high speed approaches?
 - ▶ There is no official interpretation on this issue. The 56 percent criterion has been used in the past. However, the proposed rule for the 2000 national MUTCD does not provide the ability to use the 56 percent criterion. Therefore, use of the 56 percent criterion is not recommended.
- If the intersection qualifies for the reduced volume warrants, can I use 70 percent of the volume criteria in the Combination Warrant (i.e., 70 percent of 80 percent or 56 percent of the normal volumes)?
 - ▶ No. The warrant section of the 2000 MUTCD recently published by FHWA as a proposed rule does not provide for that option.

Table 17. FHWA Interpretation on Accident Experience Warrant Terminology

Sg-60 (Change)	Accident Experience Warrant
<p>A request was made to define the terms “adequate trial” and “remedies” as used in the first criteria of the accident warrant. Adequate trial of less restrictive remedies with satisfactory observance and enforcement has failed to reduce the accident frequency. It also included a request for the establishment of guidelines for the use of “less restrictive measures” as used in the warrant.</p> <p>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 judgement, and no useful purpose would be served by attempting to minutely define either of the terms.</p>	

SECOND PHASE – ACCIDENT EXPERIENCE WARRANT

When there is a history of accidents at an intersection, the Accident Experience Warrant (Warrant 6) 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 accidents are susceptible to being corrected by a traffic signal, and only those types of accidents should be considered in the application of the accident warrant.
- Although the basis for this warrant is an anticipated reduction in accidents, the installation of a signal using this warrant may merely result in a shift of accidents from one type to another.
- While this warrant considers the frequency of certain types of accidents, there is at present no means for considering the severity of those accidents in the warrant analysis.

Data Requirements

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

- Data required to analyze the vehicular volume warrants (see page 11).
- Accident history at the intersection for the most recent 12 month period.
 - ▶ Reported accidents – Only accidents that are included in an agency’s database can be used for the Accident Experience Warrant. This typically means that accidents that are not investigated by the police do not qualify for consideration as part of the accident warrant.
 - ▶ Susceptible to correction by a traffic signal – This generally means right-angle accidents, accidents between left-turning and oncoming vehicles, or accidents involving pedestrians. It does not include rear-end accidents. See Table 10 for more detail.

Warrant Criteria

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

1. Have *less restrictive* means of traffic control been given an *adequate opportunity*, with appropriate observation and enforcement, to reduce the accident frequency? Table 17 presents an FHWA response to an interpretation request on the MUTCD language “adequate trial of less restrictive remedies.” If yes, proceed to Question 2. If not, try less restrictive means of traffic control before considering traffic signal installation (note that the less restrictive means of traffic control may need to be in place for a period of 12 months before sufficient accident data may be available to conduct an accident warrant analysis that accounts for the newer form of traffic control).
2. Have there been five or more *reported accidents* in a twelve month period that are *susceptible to correction by a traffic signal* (each accident involving personal injury or property damage apparently exceeding the applicable requirements for a reportable accident)? Table 10 lists the types of accidents that are susceptible to correction by a traffic signal. If yes, proceed to Question 3. If no, this warrant is not satisfied.
3. Are there 8 hours where both the major (sum of both approaches) and minor street (high volume approach) volumes are greater than the volumes shown for Warrant 1 in Table 16? If yes, this warrant is satisfied. If not, proceed to Question 4.
4. Are there 8 hours where both the major (sum of both approaches) and minor street (high volume approach) volumes are greater than the volumes shown for Warrant 2 in Table 16? If yes, this warrant is satisfied. If not, proceed to Question 5.
5. The pedestrian related aspects of the accident warrant analysis are described in the pedestrian warrants on page 37.

Installation Requirements

Any traffic signal installed solely on the basis of this warrant should be:

- Semi-actuated if installed at an intersection within a *coordinated system* (if a semi-actuated signal is installed, it should provide for proper coordination).
- Fully-actuated if installed at an *isolated intersection*.

Potential Warrant Modifications

At the time this document was being prepared, the National Cooperative Highway Research Program was sponsoring research on the accident warrant¹. That research may result in a change to the Accident Experience Warrant.

¹NCHRP Project 17-16, Accident Warrant for Traffic Signals. Scheduled for completion in 1999.

Frequently Asked Questions About the Accident Experience Warrant

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

- How do the severity of the accidents impact the analysis of this warrant?
 - ▶ Accident severity is not a factor in this warrant. Fatal, injury, and non-injury accidents are all considered equal in the warrant analysis. However, the NCHRP research study previously mentioned should include recommendations for addressing accident severity into the warrant analysis.

THIRD PHASE – SIGNAL OPERATION WARRANTS

Two of the signal warrants address factors associated with the operation of a traffic signal. The Progressive Movement Warrant (Warrant 5) 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 Systems Warrant (Warrant 7) 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 Progressive Movement 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 Systems Warrant:

- Peak hour volume for a typical weekday. The typical weekday volumes may be an average of hourly volumes for more than one 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 one day.
- Five-year projected hourly traffic volumes based on a documented engineering study.

Criteria for Progressive Movement Warrant

The Progressive Movement 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 300 m (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 780 m (2,600 ft)? If yes, an adequate progression platoon cannot be maintained through this signal and the warrant cannot be satisfied. If not, 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 Systems Warrant

The Systems 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 11? Note that each roadway must meet at least one of the criteria. If yes, continue to Question 2. If no, this warrant cannot be 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, 8, 9, or 11)? 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 Progressive 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 delay warrant (Warrant 10) 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 rarely used. 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 Minimum Pedestrian Volume Warrant (Warrant 3) and the School Crossing Warrant (Warrant 4). In addition, both the Combination Warrant (Warrant 8) and the Accident Experience Warrant (Warrant 6) include provisions for pedestrians as part of 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.

It should be noted that the use of the Minimum Pedestrian Volume Warrant in the Combination Warrant was changed in the 1988 national MUTCD, but that change has not been incorporated into the Texas MUTCD. In the national MUTCD, the Combination Warrant is used only with Warrants 1 and 2. In the Texas MUTCD, the Combination Warrant is used with Warrants 1, 2, and 3.

Data Requirements

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

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

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.

Pedestrian Warrant Criteria

The Minimum Pedestrian Volume Warrant can be applied to both intersection and mid-block crossing locations by answering the following questions:

1. Is there a traffic signal along the major street within 90 m (300 ft) of the crossing under study. If yes, this warrant cannot be satisfied. If no, go to Question 2.
2. If a signal is installed at the crossing location, will it unduly restrict platooned traffic flow? If yes, this warrant cannot be satisfied. If no, go to Question 3.
3. Is this a mid-block location? If yes, go to Question 4. If not, go to Question 5.
4. Is there an established crosswalk within 45 m (150 ft) of the mid-block crossing? If yes, this warrant cannot be satisfied. If not, go to Question 5.
5. Is the predominate walking speed less than 1.1 m (3.5 ft) per second? If yes, go to Question 6. If no, go to Question 7.
6. Are there more than 50 pedestrians or more per hour crossing the major street for each of four hours or 95 pedestrians or more during any one hour? If yes, go to Question 8. If no, this warrant cannot be satisfied.
7. Are there more than 100 pedestrians or more per hour crossing the major street for each of four hours or 190 pedestrians or more during any one hour? If yes, go to Question 8. If no, this warrant cannot be satisfied.
8. 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.

School Crossing Warrant Criteria

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

1. Is the crossing location an established school crossing? If yes, go to Question 2. If not, this warrant cannot be satisfied.
2. During the period that school children are present, are the number of adequate gaps less than the number of minutes in the same period? 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 Related Criteria for the Combination Warrant

The pedestrian aspect of the Combination Warrant is met when 80 percent of the Minimum Pedestrian Volume Warrant criteria are satisfied, along with 80 percent of the criteria for either the Minimum Vehicular Warrant or the Interruption of Continuous Traffic Warrant. The pedestrian aspect of the Combination Warrant can be analyzed by answering the following questions:

1. Is there a traffic signal along the major street within 90 m (300 ft) of the crossing under study. If yes, this warrant cannot be satisfied. If no, go to Question 2.
2. If a signal is installed at the crossing location, will it unduly restrict platooned traffic flow? If yes, this warrant cannot be satisfied. If no, go to Question 3.
3. Is this a mid-block location? If yes, go to Question 4. If not, go to Question 5.
4. Is there an established crosswalk within 45 m (150 ft) of the mid-block crossing? If yes, this warrant cannot be satisfied. If not, go to Question 5.
5. Is the predominate walking speed less than 1.1 m (3.5 ft) per second? If yes, go to Question 6. If no, go to Question 7.
6. Are there more than 40 pedestrians or more per hour crossing the major street for each of four hours or 76 pedestrians or more during any one hour? If yes, go to Question 8. If no, this warrant cannot be satisfied.
7. Are there more than 80 pedestrians or more per hour crossing the major street for each of four hours or 152 pedestrians or more during any one hour? If yes, go to Question 8. If no, this warrant cannot be satisfied.
8. Are there less 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, go to Question 9. If no, this warrant cannot be satisfied.
9. Are there 8 hours where both the major and minor street volumes meet the criteria in Table 16 for EITHER Warrant 1 or Warrant 2? See Appendix C for guidance and an example of how to use the table. 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 Related Criteria for the Accident Experience Warrant

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

1. Have less restrictive means of traffic control been given an adequate opportunity, with appropriate observation and enforcement, to reduce the accident frequency? If yes, proceed to Question 2. If not, try less restrictive means of traffic control before considering traffic signal installation (note that the less restrictive means of traffic control may need to be in place for a period of 12 months before sufficient accident data may be available to conduct an accident warrant analysis that accounts for the newer form of traffic control).
2. Have there been five or more *reported accidents* in a twelve month period that are *susceptible to correction by a traffic signal* (each accident involving personal injury or property damage apparently exceeding the applicable requirements for a reportable accident)? If yes, proceed to Question 3. If no, this warrant is not satisfied.
3. Is the predominate walking speed less than 1.1 m (3.5 ft) per second? If yes, go to Question 4. If no, go to Question 5.
4. Are there more than 40 pedestrians or more per hour crossing the major street for each of four hours or 76 pedestrians or more during any one hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
5. Are there more than 80 pedestrians or more per hour crossing the major street for each of four hours or 152 pedestrians or more during any one hour? If yes, go to Question 6. If no, this warrant cannot be satisfied.
6. Are there less 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.

Installation Requirements

If a traffic signal installation is justified solely on the basis of the Minimum Pedestrian Volume Warrant or the pedestrian portion of the Accident Experience Warrant, the signal installation should be traffic actuated with pedestrian push buttons for pedestrians crossing the major roadway. The signal installation should also include pedestrian signal indications. If the crossing is at a non-intersection location, curbside parking should be prohibited for 30.5 m (100 ft) in advance of the crosswalk and 6.1 m (20 ft) beyond the crosswalk. Because crosswalks are recommended for intersections where there is substantial conflict between vehicle and pedestrian movements (Texas MUTCD Section 3B-18), signal installations that are justified solely on the basis of the Minimum Pedestrian Volume Warrant should have crosswalk markings across the major roadway.

When a traffic signal installation is justified solely on the basis of the School Crossing Warrant, the signal installation:

- Shall provide pedestrian indications for each crosswalk that is part of an established school crossing.

- Should be traffic-actuated unless pretimed control can be fit into progressive signal systems.
- At a non-intersection location:
 - ▶ The signal should be pedestrian actuated.
 - ▶ Parking and other sight distance obstructions should be prohibited for 30.5 m (100 ft) in advance of and 6.1 m (20 ft) after the crosswalk.
 - ▶ The installation should include suitable standard signs and pavement markings.
 - ▶ Special police supervision and/or enforcement should be provided for a new installation.

BIBLIOGRAPHY

In preparing this document, the authors used information from a variety of sources, including the following:

- *Texas Manual on Uniform Traffic Control Devices (MUTCD)*.
- *Evaluation of Potential Traffic Signal Warrant Considerations*, Texas Transportation Institute, Research Report 3991-1.
- Part 4 – Signals of the proposed Year 2000 MUTCD.
- *Manual of Transportation Engineering Studies*, Institute of Transportation Engineers.
- *Manual of Traffic Signal Design*, ITE.
- *The Traffic Signal Book*, by Fred L. Orcutt.
- *Special Report 209, Highway Capacity Manual, 3rd Edition*, Transportation Research Board.

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 1988 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 standards 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 government is referred to as the national MUTCD, and it is intended to promote national uniformity of traffic control devices. 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.

NEXT EDITION OF THE MUTCD

The next edition of the MUTCD will most likely be a significant departure from the current edition. The National Committee on Uniform Traffic Control Devices (NCUTCD) is currently in the process of reformatting and rewriting the MUTCD. The first effort is to reformat all of the material in the Manual into four categories: standards, guidance, options, and support. Once this task is completed, the NCUTCD will rewrite the reformatted MUTCD as necessary to clarify and improve its language. The revised MUTCD will then be submitted to the Federal Highway Administration (FHWA) for approval through the *Federal Register* rulemaking process. Part of the reason for revising the Manual is to eliminate phrases such as “is desirable,” “shall preferably be,” “may be required,” “may be justified,” “shall be permitted,” and “it is necessary that” which are ambiguous in their meaning.

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. Section 1A-5 of the MUTCD defines the terms “shall,” “should,” and “may” as indicating mandatory, advisory, and permissive conditions, respectively, for the application of principles to traffic control devices.

MUTCD STANDARDS 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 (or guidelines), which provide the engineer with criteria to define the relative need for a traffic control device. Other MUTCD principles are categorized as standards, which establish requirements for the design and application of a traffic control device. The differences between MUTCD standards 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 standards is that warrants apply to the process of deciding whether or not to use a device. Once that decision has been made, standards apply to the design, application, installation, and maintenance of the device. A warrant (or guideline) 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 guidelines, 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. Such flexibility is not available in the application of standards. A standard defines a minimum requirement which shall be met.

Some of the confusion about the difference between standards and warrants in the MUTCD may be attributable to the fact that the current MUTCD has been established as an American National Standard (Standard D6.1e 1989) by the American National Standards Institute (ANSI). The role of the MUTCD as a standard has a history that dates back to the first MUTCD in 1935. That edition, and every edition since then, has been designated as an American Standard. Another source of potential confusion is that the MUTCD 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 twelve traffic signal warrants. In general, the language of these warrants is the same as contained in the 1988 National MUTCD. However, the Texas MUTCD contains an additional warrant (Warrant 12), and there has been language added to some of the warrants. In this appendix, the additional language from the Texas MUTCD is presented in a different font.

Several of these warrants refer to figures containing curves with minimum volume criteria. These curves are the same as those presented previously in this document. Where these figures are mentioned in the warrant text, a cross reference to the document figures is provided in brackets [see Figure x, page y].

4C-3 Warrant 1, Minimum Vehicular Volume

The Minimum Vehicular Volume warrant is intended for application where the volume of intersecting traffic is the principal reason for consideration of signal installation. The warrant is satisfied when, for each of any 8 hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume minor street approach to the intersection. An “average” day is defined as a weekday representing traffic volumes normally and repeatedly found at the location.

Table 18. Minimum Vehicular Volumes for Warrant 1

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		
1	1	500	150
2 or more	1	600	150
2 or more	2 or more	600	200
1	2 or more	500	200

These major-street and minor-street volumes are for the same 8 hours. During those 8 hours, the direction of higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours.

When the 85-percentile speed of major-street traffic exceeds 40 mph in either an urban or a rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the Minimum Vehicular Volume warrant is 70 percent of the requirements above.

4C-4 Warrant 2, Interruption of Continuous Traffic

The Interruption of Continuous Traffic warrant applies to operating conditions where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or hazard in entering or crossing the major street. The warrant is satisfied when, for each of any 8 hours of an average day, the traffic volumes given in the table below exist on the major street and on the higher-volume minor street approach to the intersection, and the signal installation will not seriously disrupt progressive traffic flow.

Table 19. Minimum Vehicular Volumes for Warrant 2

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		
1	1	750	75
2 or more	1	900	75
2 or more	2 or more	900	100
1	2 or more	750	100

These major-street and minor-street volumes are for the same 8 hours. During those 8 hours, the direction of higher volume on the minor street may be on one approach during some hours and on the opposite approach during other hours.

When the 85-percentile speed of major-street traffic exceeds 40 mph in either an urban or a rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the Interruption of Continuous Traffic warrant is 70 percent of the requirements above.

4C-5 Warrant 3, Minimum Pedestrian Volume

A traffic signal may be warranted where the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is:

1. 100 or more for each of any four hours or
2. 190 or more during any one hour.

The pedestrian volume crossing the major street may be reduced as much as 50 percent of the values given above when the predominant pedestrian crossing speed is below 3.5 ft per second.

In addition to a minimum pedestrian volume of that stated above, there shall be less than 60 gaps per hour in the traffic stream of adequate length for 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 the pedestrian(s) to wait, the requirement applies separately to each direction of vehicular traffic.

Where coordinated traffic signals on each side of the study location provide for platooned traffic which result in fewer than 60 gaps per hour of adequate length for the pedestrians to cross the street, a traffic signal may not be warranted.

This warrant applies only to those locations where the nearest traffic signal along the major street is greater than 300 ft and where a new traffic signal at the study location would not unduly restrict platooned flow of traffic. Curbside parking at non-intersection locations should be prohibited for 100 ft in advance of and 20 ft beyond the crosswalk.

A signal installed under this warrant should be of the traffic-actuated type with push buttons for pedestrians crossing the main street. If such a signal is installed within a signal system, it should be coordinated if the signal system is coordinated.

Signals installed according to this warrant shall be equipped with pedestrian indications conforming to requirements set forth in other sections of this Manual.

Signal may be installed at non-intersection locations (mod-block) provided the requirements of this warrant are met, and provided that the related crosswalk is not closer than 150 ft to another established crosswalk. Curbside parking should be prohibited for 100 ft in advance of and 20 ft beyond the crosswalk. Phasing, coordination, and installation must conform to standards set forth in this Manual. Special attention should be given to the signal head placement and the signs and markings used at non-intersection locations to be sure drivers are aware of this special application.

4C-6 Warrant 4, School Crossing

A traffic control signal may be warranted at an established school crossing when a traffic 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 the school crossing 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 (sec. 7A-3).

When traffic control signals are installed entirely under this warrant:

- a. Pedestrian indications shall be provided at least for each crosswalk established as a school crossing.
- b. At an intersection, the signal normally should be traffic-actuated. As a minimum, it should be semi-traffic-actuated, but full actuation with detectors on all approaches may be desirable. Intersection installations that can be fitted into progressive signal systems may have pretimed control.
- c. At non-intersection crossings, the signal should be pedestrian actuated, parking and other obstructions to view should be prohibited for at least 100 ft in advance of and 20 ft beyond the crosswalk, and the installation should include suitable standard signs and

pavement markings. Special police supervision and/or enforcement should be provided for a new non-intersection installation.

4C-7 Warrant 5, Progressive Movement

Progressive movement control sometimes necessitates traffic signal installations at intersections where they would not otherwise be warranted, in order to maintain proper grouping of vehicles and effectively regulate group speed. The Progressive Movement warrant is satisfied when:

1. On a one-way street or a street which has predominantly unidirectional traffic, the adjacent signals are so far apart that they do not provide the necessary degree of vehicle platooning and speed control, or
2. On a two-way street, adjacent signals do not provide the necessary degree of platooning and speed control and the proposed and adjacent signals could constitute a progressive signal system.

The installation of a signal according to this warrant should be based on the 85-percentile speed unless an engineering study indicates that another speed is more desirable.

The installation of a signal according to this warrant should not be considered where the resultant signal spacing would be less than 1000 ft.

4C-8 Warrant 6, Accident Experience

The Accident Experience warrant is satisfied when:

1. *Adequate trial* of less restrictive *remedies* with satisfactory observance and enforcement has failed to reduce the accident frequency; and
2. Five or more reported accidents, of types susceptible to correction by traffic signal control, have occurred within a 12-month period, each accident involving personal injury or property damage apparently exceeding the applicable requirements for a reportable accident; and
3. There exists a volume of vehicular and pedestrian traffic not less than 80 percent of the requirements specified either in the Minimum Vehicular Volume warrant, the Interruption of Continuous Traffic warrant, or the Minimum Pedestrian Volume warrant; and
4. The signal installation will not seriously disrupt progressive traffic flow.

Any traffic signal installed solely on the Accident Experience warrant should be semi-traffic-actuated (with control devices which provide proper coordination if installed at an intersection within a coordinated system) and normally should be fully traffic-actuated if installed at an isolated intersection.

4C-9 Warrant 7, Systems Warrant

A traffic signal installation at some intersections may be warranted to encourage concentration and organization of traffic flow networks. The Systems Warrant is applicable when the common intersection of two or more major routes: (1) has a total existing, or immediately projected, entering volume of at least 1000 vehicles during the peak hour of a typical weekday and has five year projected traffic volumes, based on an engineering study, which meet one or more of Warrants 1, 2, 8, 9, and 11 during an average weekday; or (2) has a total existing or immediately projected entering volume of at least 1000 vehicles for each of any 5 hours of a Saturday and/or Sunday.

A major route as used in the above warrant has one or more of the following characteristics:

1. It is part of the street or highway system that serves as the principal network for through traffic flow;
2. It connects areas of principal traffic generation;
3. It includes rural or suburban highways outside, entering or traversing a city;
4. It has surface street freeway or expressway terminals;
5. It appears as a major route on an official plan such as a major street plan in an urban area traffic and transportation study.

4C-10 Warrant 8, Combination of Warrants

In exceptional cases, signals occasionally may be justified where no single warrant is satisfied but where two or more of Warrants 1, 2, and 3 are satisfied to the extent of 80 percent or more of the stated values.

Adequate trial of other *remedial measures* which cause less delay and inconvenience to traffic should precede installation of signals under this warrant.

4C-10.1 Warrant 9, Four Hour Volumes

The Four Hour Volume Warrant is satisfied when 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 curve in Figure 4-7 [see Figure 6, page 29] for the existing combination of approach lanes.

When the 85th percentile speed of the major street traffic exceeds 40 miles per hour or when the intersection lies within a built-up area of an isolated community having a population less than 10,000, the 4 hour volume requirement is satisfied when the plotted points referred to fall above the curve in Figure 4-8 [see Figure 2, page 27] for the existing combination of approach lanes.

4C-10.2 Warrant 10, Peak Hour Delay

The peak hour delay warrant is intended for application where traffic conditions are such that for 1 hour of the day minor street traffic suffers undue delay in entering or crossing the major street. The peak hour delay warrant is satisfied when the conditions given below exist for 1 hour (any four consecutive 15-minute periods) of an average weekday.

The peak hour delay warrant is met when:

1. The total 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 and 5 vehicle hours for a two-lane approach
2. The volume on the same minor street approach (one direction only) equals or exceeds 100 vph for 1 moving lane of traffic or 150 vph for 2 moving lanes and
3. The total entering volume serviced during the hour equals or exceeds 800 vph for intersections with 4 (or more) approaches or 650 vph for intersections with 3 approaches.

4C-10.3 Warrant 11, Peak Hour Volume

The peak hour volume warrant is also intended for application when traffic conditions are such that for one hour of the day minor street traffic suffers undue traffic delay in entering or crossing the major street.

The peak hour volume warrant is satisfied when the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicle per hour of the higher volume minor street approach (one direction only) for 1 hour (any 4 consecutive 15-minute periods) of an average day falls above the curve in Figure 4-5 [see Figure 8, page 30] for the existing combination of approach lanes.

When the 85th percentile speed of major street traffic exceeds 40 mph or when the intersection lies within a built-up area of an isolated community having a population less than 10,000, the peak hour volume requirements is satisfied when the plotted point referred to above falls above the curve in Figure 4-6 [see Figure 4, page 28] for the existing combination of approach lanes.

4C-10.4 Warrant 12, Warrant Volumes for Traffic Actuated Signals

The warrant volumes for traffic actuated signals are intended for application where the volume of intersecting traffic may not completely satisfy the requirements of Warrants 1 through 11, but where unpredictable peak hour or hours may occur either on the total of both approaches of the major street or on the high volume approach of the minor street.

Traffic actuated signal installation is considered justified if any one of the two following conditions exist:

1. For each of any 8 hours of the 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 (one direction only), all lie above the applicable curve in Figure 4-2.4 [see Figure 5, page 29]. The major street and minor street volumes are for the same eight hours.
2. For each of any 2 hours of the 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 (1 direction only), all lie above the applicable curve in Figure 4-2.6 [see Figure 7, page 30]. The major street and minor street volumes are for the same 2 hours.

When the 85th percentile speed of major street traffic exceeds 40 mph either in an urban or rural area, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000 rural warrant curves should be utilized. [see Figure 1 for 8 hours and Figure 2 for 4 hours, pages 27 and 27, respectively]

If a decision is reached to install traffic actuated control equipment, the use of full-actuated, rather than semi-actuated equipment, should be considered. The inherent design of the semi-actuated equipment tends to penalize the traffic on the major roadway, as no intelligence is transmitted to the controller relating to the vehicular volume on the major roadway.

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 1 AND 2

Table 20 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 56 km/h (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 1 and K3 and L3 for Warrant 2.

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 1 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 1 and Warrant 2 criteria. A “YES” is placed in column M or N for Warrants 1 and 2, respectively. If there are 8 or more hours (or YES’) in column M, then Warrant 1 is met. Likewise, column N for Warrant 2. In this example, Warrant 1 is met, but Warrant 2 is not. Note that Warrant 2 is not met, even though there are eight 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 meet the criteria for Warrant 2.

ANALYSIS EXAMPLE FOR WARRANTS 9, 11, AND 12

The same 16 hours of volumes shown in Table 20 are plotted in Figures 9 and 10 to illustrate the application of Warrants 9, 11, and 12. 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 9, there are 10 hours that are above the solid line curve. This warrant is satisfied because only 8 hours are required to be above the curve. In Figure 10, there are only three hours that are above the curve. Four hours are required, so this warrant is not satisfied.

BLANK WARRANT TABLE

Table 21 is a blank warrant volume table that can be copied and used for the first phase warrant analysis.

Table 20. Example of Volume Analysis for Warrants 1 and 2

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

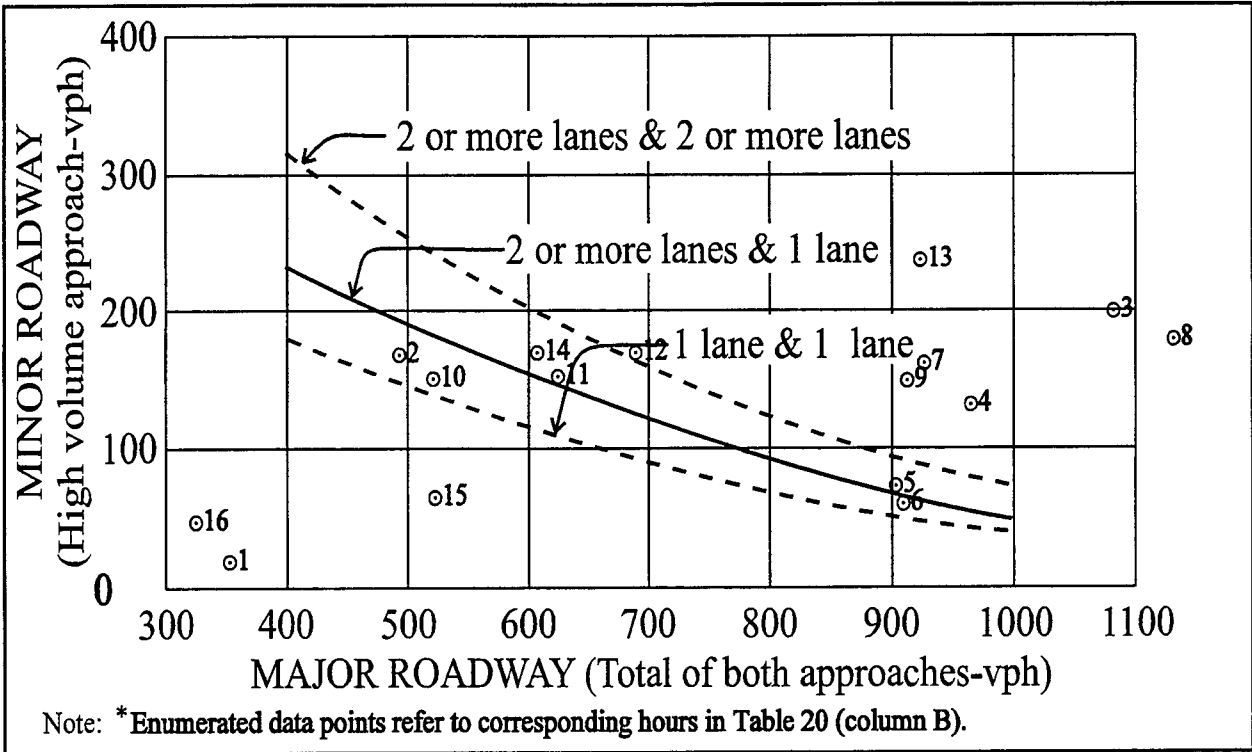


Figure 9. Example of Warrant 12, 8 High Hours, Normal Volumes

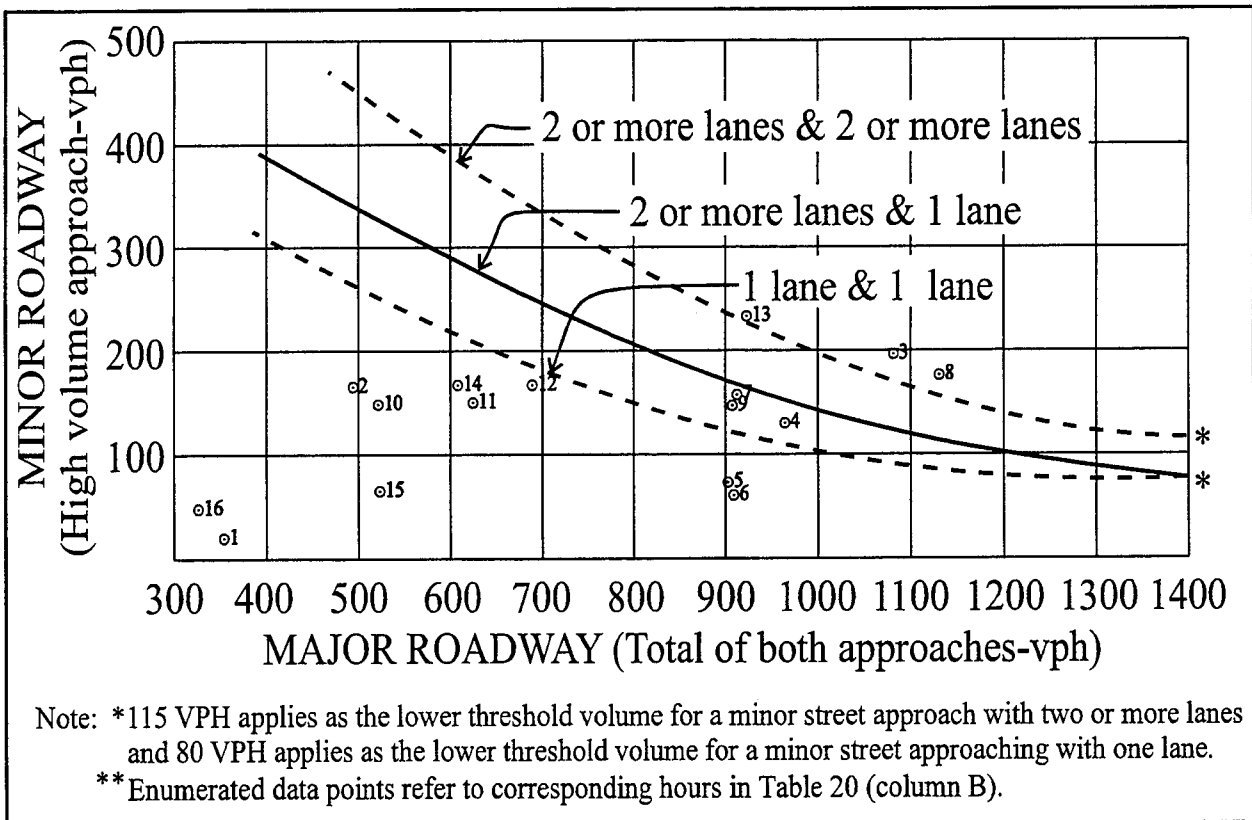


Figure 10. Example of Warrant 9, 4 High Hours, Normal Volumes

