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16. Abstract

This report documents the activities of an 11-month research project that considered various pedestrian-related factors and developed revised warrants for the installation of a traffic signal that are more sensitive to pedestrians and cyclists.

Three warrant recommendations were made as a result of this research. The recommendations are summarized below with the warrants that are affected for each recommendation. The research shows that results from warrant analyses with the revised warrants better match professional engineering judgment than the results of warrant analyses using the current warrants. The warrant recommendations should not be used until they are officially adopted by the Texas Department of Transportation.

- Include pedestrians and cyclists in the minor-street approach volumes for all warrants that currently consider only vehicles for the minor-street approach volumes (Warrants 1, 2, 9, 10, 11, and 12).
- Include a 30 percent volume reduction factor in the above warrants based upon the presence of certain types of pedestrian trip generators such as medical facilities, pedestrian transportation facilities, and activity centers serving pedestrians (Warrants 1, 2, 3, 9, 11, and 12).
- Change the existing pedestrian warrant to a mid-block only pedestrian crossing warrant, remove language about pedestrian crossing speeds, and add a reduction factor for high-speed roadways or built-up areas (Warrant 3).

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REVISING THE TRAFFIC SIGNAL WARRANTS TO BETTER ACCOMMODATE PEDESTRIANS AND CYCLISTS

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DISCLAIMER

The contents of this report 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 Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineers in charge of the project were Paul Carlson, P.E. #85402, and Shawn Turner, P.E. #82781.

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- Nelson B. "Barb" Nuckles – Freese-Nichols, Fort Worth, Texas.

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CHAPTER 1
INTRODUCTION AND SUMMARY

Traffic signals provide a very restrictive form of traffic control at intersections. A series of 12 traffic signal warrants has been developed to ensure their use is limited to only those intersections truly warranting such restrictive control. One of the 12 signal warrants is the pedestrian signal warrant which is designed to address intersections and mid-block crossings where pedestrian volume is the main concern. As shown in a subsequent section of this report, the pedestrian signal warrant is seldom used to justify the need for a traffic signal. The reasons for its limited use may be justified as intersections with significant pedestrian volumes usually have vehicular volumes satisfying other warrants. However, the reasons for its limited use may relate to the criteria of the warrant and/or the data collection and reduction requirements of the warrant. The purpose of this project is to consider pedestrian-related factors and, if appropriate, develop a revised pedestrian signal warrant or other traffic signal warrant(s) that are practical and easy to use.

INTRODUCTION

Traffic signals are a highly visible and important element of the roadway transportation network. They are often seen by the public and elected officials as a cure-all for operational and safety problems at intersections. At other times, signals are viewed as a hindrance to movement, as exemplified by the commonly used name "stop lights." The reality is that the traffic signal represents one of the most restrictive forms of right-of-way control at an intersection. Traffic signals should not be installed unless the advantages to be gained from the signal will outweigh the disadvantages of the signal.

In order to ensure that the advantages outweigh the disadvantages, that there is sufficient justification for a traffic signal, and to provide some consistency in the application of traffic signals, a series of warrants has been developed to define the ***minimum*** conditions under which further consideration of a traffic signal is appropriate. Simply meeting the warranting criteria does not mean that a signal is justified at a given location. There are many factors that impact the effectiveness of a signal, and all should be evaluated before a decision to install a signal is made. However, failure to meet any of the warranting criteria indicates that a traffic signal should not be installed, as there should be a better way of addressing the problems or needs at that location.

The public has expressed concern about the inability of cities and TxDOT to install traffic signals when locations do not meet the required traffic signal warrants. Specific concerns include locations where pedestrians cross the street, especially elderly and disabled pedestrians. A proposed warrant suggested by a citizens group was considered during the 76th Legislative Session. The current minimum pedestrian volume warrant is very rarely used to justify the installation of a traffic signal. This infrequent use may be partly due to the fact that the number of pedestrians required is high and locations with that type of pedestrian traffic typically meet another of the warrants. It may also be partly due to the fact that the required data collection for

the minimum pedestrian volume warrant is very time consuming. There is a need to address the concerns of the general public and state lawmakers as well as a need to develop a more "user friendly" pedestrian signal warrant while still recognizing the disadvantages of installing an unwarranted traffic signal.

The focus of the project was on the following factors and criteria:

- pedestrian factors such as safety, mobility, and delay;
- vehicular factors such as speed, gap distributions, delay;
- ease of use; and
- reasonable data collection efforts.

In addition to a possible revision to the pedestrian signal warrant, the research team was also charged with the task of developing pedestrian crossing guidelines. More specifically, the guidelines are for intersections and mid-block crossings that do not satisfy the revised traffic signal warrant criteria but may be warranted for less restrictive remedies. The intent of the guidelines is to outline the numerous alternatives that are available to address pedestrian safety problems or public concerns at roadway crossings. It is not the intent of the guidelines to recommend a specific pedestrian crossing treatment exclusive of conditions, nor to recommend specific design dimensions. General criteria and design dimensions used elsewhere may be provided with some treatments, but engineering judgment should be used in applying these criteria and designs (*1*).

CURRENT TEXAS MUTCD PEDESTRIAN WARRANT

The current Texas Manual on Uniform Traffic Control Devices (MUTCD) pedestrian signal warrant is reproduced in Figure 1 (*2*). The warrant is slightly different from the current pedestrian signal warrant contained in the national MUTCD (*3*). The difference is the last paragraph (note the different style font used to signify the difference), which is not included in the national MUTCD.

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:

100 or more for each of any four hours; or
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 feet 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 feet 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 feet in advance of and 20 feet 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.

Signals may be installed at non-intersection locations (mid-block) provided the requirements of this warrant are met, and provided that the related crosswalk is not closer than 150 feet to another established crosswalk. Curbside parking should be prohibited for 100 feet in advance of and 20 feet 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.

Figure 1. Warrant 3 - Current Minimum Pedestrian Volume (4C-5).

BACKGROUND INFORMATION

A recently completed project sponsored by TxDOT investigated various warranting considerations for traffic signals (*4*). As part of the research, the research team surveyed TxDOT traffic engineers from each district as well as other city and state traffic engineers. Researchers designed the survey to resolve certain issues associated with the project and to address vague

issues concerning the warrants and the warranting procedure. Table 1 illustrates the primary warrant usage as estimated by the returned surveys.

Table 1. Primary Warrant Used for Signalization.

Warrant	Agency		
	TxDOT (19)	State (32)	City/County (50)
1 - Minimum Vehicular Volume	28	44	36
2 - Interruption of Continuous Traffic	16	27	21
3 - Minimum Pedestrian Volume	0	0	2
4 - School Crossings	2	2	2
5 - Progressive Movements	3	0	2
6 - Accident Experience	7	6	11
7 - Systems	4	1	1
8 - Combination of Warrants	4	5	5
9 - Four Hour Volumes	3	4	9
10 - Peak Hour Delay	2	2	1
11 - Peak Hour Volume	11	7	11
12 - Volumes for Actuated Signals	19	0	0
Other Warrants not in Texas MUTCD	0	1	3
NOTE: Values are shown as percentages			

It is obvious from the data shown in Table 1 that the pedestrian signal warrant is the least used warrant to justify a signal installation. The reason is because engineers have a hard time satisfying the minimum pedestrian volume requirements of the pedestrian signal warrant, not because they do not attempt to satisfy the pedestrian signal warrant.

Recent Pedestrian Warrant Considerations

The Traffic Engineering Council of Institute of Transportation Engineers (ITE) has recently completed a member survey of "potentially controversial issues" (5). Table 2 lists the pedestrian signal warrant issues addressed in the survey. Also provided are the ITE members' responses.

Table 2. ITE Traffic Engineering Council Survey Results.

Statement	Agree	Impartial	Disagree
The pedestrian warrant volumes are too high	24	31	32
New traffic signal warrants are needed	22	23	44
Installing an unwarranted signal to provide safe pedestrian crossing is sometimes acceptable	21	42	27
The assumed walking pedestrian walking speed of 3.5 feet/second is too fast	15	33	46
NOTE: Values are shown as percentages			

Other Recent Traffic Signal Warrant Activity

The same TTI survey discussed above considered other signal warrant issues related to the revision of the pedestrian signal warrant *(4)*. The survey asked one question concerning whether pedestrian delay was measured and if so, under what circumstances. Table 3 provides the responses.

Table 3. Modifications of Existing Warrants.

Agency	Respondents Measuring Delay (%)	Comments
TxDOT	29	At schools Depends on vehicle speeds and volumes
State DOT	17	Used to design ped crossing and signals for each leg of intersection For school X-ings, we do gap studies School locations School crossings at signalized locations
City/County	8	The need to interrupt vehicular traffic for ped crossing is the primary purpose of this warrant. Not based on pedestrian delay as much as providing protection. If request for signal is school related Gap analysis for school crossings Do gap studies near schools, retirement homes, etc. Schools

A related question was designed to determine the need to modify existing warrants. Agencies were asked if they thought any of the warrants should be modified and then to provide comments based on their responses. Table 4 provides summaries of this question as they are related to pedestrian issues.

Table 4. Modifications of Existing Warrants.

Agency	Modification Needed (%)	Related Comments
TxDOT	26	For signals near schools, school bus routes
State DOT	43	None
City/County	39	Modifications based on (1) severity of accidents; and (2) heavy pedestrian activity mid-block

Finally, agencies were asked if there was a need for a new warrant and if so, to identify the need. Most of the comments were oriented to improvements for the accident warrant, although a few pedestrian-related comments were received. Table 5 summarizes the responses from this question.

Table 5. Modifications of Existing Warrants

Agency	New Warrant Needed (%)	Related Comments
TxDOT	18	None
State DOT	17	None
City/County	29	Gaps are too hard and laborious to measure, so a substitute for a gap warrant An engineering judgment warrant that would factor in issues such as restricted access, land use decisions, or others not covered by existing warrants Possible special warrant for shopping centers or developments

BASIS FOR CURRENT PEDESTRIAN WARRANTING CRITERIA

One of the key questions often asked by practicing engineers is how the criteria for the pedestrian signal warrant were established. In an effort to determine the origins of the pedestrian signal warrant criteria, the primary author of this report, Mr. Carlson, traveled to Washington D.C. in January 2000 to attend the Annual Meeting of the National Committee on Uniform Traffic Control Devices (NCUTCD). At this meeting, Mr. Carlson made a presentation to the Signal Technical Committee (STC). During the presentation, he asked the members of the STC about the origins of the pedestrian signal warrant criteria. Apparently, there was not a formal documentation system when the warrant was last revised (in 1988). However, members of the STC who were around during the mid-1980s seem to recall a consensus agreement generally between the city and state representatives.

Since the presentation to the STC at the NCUTCD did reveal much in terms of the origins of the pedestrian signal warrant criteria, researchers performed a thorough and critical review of the literature. The goal of this literature review was to evaluate research recommendations related to pedestrian signal warrants, and determine or identify possible relationships between the literature and the current pedestrian signal warrant criteria.

The current pedestrian signal warrant contains two main criteria. The first is a minimum threshold pedestrian volume and the second is a gap criterion. Each of these criteria are discussed below. Their hypothesized development based on the literature and findings from the STC presentation is included. It should be noted that development of the current pedestrian signal warrant criteria presented below has not been confirmed or validated by an authority because for all practical purposes, none exist.

Another note of caution is that the criteria that make up any warrant are somewhat arbitrarily determined. The signal warranting process cannot be a cookbook process. Engineering judgment is needed, and warrants cannot provide an adequate substitute for engineering judgment. Any warrant should be considered a tool to help the traffic engineer determine signalization needs.

Minimum Threshold Pedestrian Volume

Zeeger conducted the most recognized pedestrian signal warrant research in the 1980s *(6-8)*. The Federal Highway Administration (FHWA) sponsored his research. The main thrust was that previous MUTCD pedestrian volumes were believed to be inappropriate in that an inordinately large pedestrian volume was required over an extended period (150 ped/hr for 8 hrs in 1978).

Zeeger's FHWA work shows that a safety break point exists at about 1,200 pedestrians per day. Of his analysis of 1,289 intersections, Zeeger shows that of the 609 intersections with pedestrian volumes less than 1,200, the mean pedestrian accidents (per location per year) was 0.178, compared to 0.533 for 680 locations above 1,200 pedestrians per day. A caveat to these numbers is that the intersections were all signalized. Although the breakpoint may not be the same exact volume, traffic signals are generally believed to improve pedestrian safety by adding artificial gaps. With this theory, the breakpoint for unsignalized intersections may be something less than 1,200. By using 1,200, a factor of safety is established.

Combining the 1,200 daily pedestrian volume with the pedestrian distribution numbers obtained from around the country, Zeeger was able to develop the minimum threshold pedestrian volumes.

Other recommendations related to the pedestrian volumes suggested 100 pedestrians per hour for four hours *(10, 11)*. Combining this four-hour threshold with Zeeger's findings, the values in the current MUTCD can be reproduced. A full explanation is discussed in the report.

Gap Criteria

The gap criterion has been included in the warrant as a surrogate for pedestrian delay. Gaps are easier to measure than delay and intuitively make sense. The gap criterion is useful in that it accounts for site-specific combinations of street width, pedestrian walking speed, vehicle speed, and traffic volume and arrival patterns. The actual number of 60 came from the school warrant which dates back to a 1962 ITE Recommended Practice for School Crossing Protection Warrant (*12*). The actual value of the criteria has been partially validated based on tolerable pedestrian delay (*9, 10, 11*). Although somewhat arbitrarily chosen, 60 seconds has been accepted as a tolerable pedestrian delay. This equates to the need for 60 adequate gaps per hour, which is the current pedestrian signal warrant criteria.

IDENTIFIED CONCERNS

The research team met with the project Advisory Panel on three occasions. The primary focus of the first meeting was to identify the issues and develop a framework to resolve the issues. During the second meeting, the research team and Advisory Panel reviewed the issues and work plan. The final meeting was held to go over final recommendations.

Issues identified during the first and second meetings included:

Overall

- avoid a major overhaul of the warrant,
- suggest tweaking where needed,
- maintain gap and pedestrian volume criteria,
- easy to understand and easy to use, and
- do not add or significantly increase data collection needs.

Possible Factors

Primary

- minimum pedestrian volume and
- gap criteria.

Secondary

- adjacent signal proximity,
- progression, and
- adjacent crosswalk proximity.

Reduction/Other Factors

- pedestrian delay,
- pedestrian safety,

- pedestrian walking speed,
- perception / reaction times,
- refuge island / median island,
- vehicle speed,
- environment / area type,
- latent demand,
- cyclists' need to cross streets,
- pedestrian and motorist compliance with traffic control devices,
- Americans with Disabilities Act (ADA) requirements,
- vehicle volume, and
- false sense of security provided by an unwarranted signal.

SITE ASSESSMENTS

In order to address these issues and determine if the pedestrian signal warrant should include criteria for any of the listed issues, a work plan was established. The work plan included the identification of pedestrian problem areas around the state where a possible solution may be a traffic signal. Next, the research team collected, analyzed, and reduced data at six of these sites. The Advisory Panel and other engineers throughout the state who had volunteered their services were then asked to make site assessment visits and determine, based on their professional judgment and limited data, whether a signal or some other form of traffic control should be used to address the pedestrian issues. Next, the engineers were asked to list which factors caused them to make their decisions.

The goal of this task was to include the possibility of any and all criteria as being part of the pedestrian signal warrant. It was meant to be a thought provoking task with no limits. However, most of the responses were focused on the current MUTCD pedestrian signal warrant criteria and few variations resulted.

RECOMMENDATIONS

After considering several options internally, the final recommendations were made based on information gathered from the STC of NCUTCD, comments and concerns voiced by practicing engineers following a project presentation during the summer 2000 Texas Chapter of the Institute of Transportation Engineers (TexITE) meeting, comments received through the site assessment visits, and the opportunity to address many of the identified issues without completely reformatting the warrants and/or the procedures associated with implementation of the warrants. Furthermore, with some small modifications, the project Advisory Panel agreed with the recommendations.

In short, the recommendations include providing pedestrians and cyclists with the same level of priority in terms of crossing the major street as passenger vehicles receive in the current warrants. This priority can be accomplished simply by replacing the "vehicles per hour" when referring to minor street approaches, with "vehicle, pedestrians, and cyclists per hour," which includes a 1:1 equivalency for vehicles, pedestrians, and cyclists – walking or riding.

The recommendations also include the retention of the pedestrian signal warrant with some subtle changes that allow the warrant to be applied only to mid-block crossings. Other changes include dropping the walking speed reduction option (walking speed should be accounted for when determining adequate gap size) and replacing it with other more sensitive reduction factors such as vehicle speed, area type, and proximity to pedestrian trip generators.

The current Texas MUTCD warrants have been modified to include these recommendations and can be found in Appendix A. Appendix B contains the national Millennium MUTCD warrants, modified to include the recommendations.

The remainder of this report fully documents the research activities, findings, and recommendations conducted as part of this project. The pedestrian crossing guidelines were published as a stand-alone document entitled, "Pedestrian Crossing Guidelines for Texas" *Report No. FHWA/TX-01/2136-P1*, Texas Transportation Institute, College Station, September 2000.

CHAPTER 2
LITERATURE REVIEW

INTRODUCTION

The objectives of the literature review are to demonstrate the science behind the criteria in the current pedestrian signal warrant and present other pedestrian-related signal warrants proposed in the literature and used abroad. In order to accomplish the first objective, two main activities were conducted. The first was a thorough and critical review of the literature pertinent to the pedestrian signal warrant. The second activity was a presentation and request for information from the STC of the NCUTCD.

BACKGROUND

The literature related to the development of the pedestrian signal warrant is limited. In fact, the topic has been the focus of a limited number of research projects. Each investigation into the pedestrian signal warrant has been thoroughly reviewed and summarized herein. However, before these studies are presented, it is important to understand the evolution of the pedestrian signal warrant.

The very first version of the MUTCD in 1935 contained a traffic signal warrant based on pedestrians. Since then, the pedestrian signal warrant has undergone many revisions. The evolution of the pedestrian signal warrant is summarized in Table 6.

Table 6. Evolution of the Pedestrian Signal Warrant.

MUTCD Year	Warranting Conditions
1935, 1939	The minimum pedestrian and vehicular volumes ... are as follows: ‣ Pedestrian volume crossing the major street must average at least 300 persons per hour for at least 6 hours per day, ‣ Vehicular traffic entering the intersection from the major street must average at least 750 vph for the same 6 hours, and ‣ Vehicular speeds during the 6 hours must frequently exceed 15 mph.
1942	The minimum pedestrian and vehicular volumes ... are as follows: ‣ Pedestrian volume crossing the major street must average at least 300 persons per hour for at least 6 hours per day and ‣ Vehicular traffic entering the intersection from the major street must average at least 750 vph for the same 6 hours.
1948, 1954	In urban areas: ‣ Pedestrian volume crossing the major street must average at least 250 persons per hour for any 8 hours of an average day; ‣ Vehicular traffic entering from the major street must average at least 600 vph for the same 8 hours; and ‣ The average vehicle speed must exceed 15 mph on the approaches to the intersection. In rural areas: ‣ Pedestrian volume crossing the major street must average at least 125 persons per hour for any 8 hours of an average day; ‣ Vehicular traffic entering from the major street must average at least 300 vph for the same 8 hours; and ‣ The average vehicle speed must exceed 30 mph on the approaches to the intersection.
1961, 1971, 1978	This warrant is satisfied when for each of any 8 hours of an average day, the following volumes exist: ‣ On the major street, 600 or more vph enter the intersection (total of both approaches); or 1,000 or more vph (total of both approaches) enter the intersection on the major street where there is a raised median island 4 feet or more in width; and ‣ During the same 8 hours as in paragraph 1, there are 150 or more pedestrians per hour on the highest volume crosswalk crossing the major street. When the 85th percentile of major street traffic exceeds 40 mph, or when the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the minimum pedestrian volume warrant is 70 percent of the requirements above, in recognition of the differences in the nature and operational characteristics of traffic in urban and rural environments and smaller municipalities.
1988, 2000	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: ‣ 100 or more for each of any 4 hours, or ‣ 190 or more during any 1 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 feet per second. In addition to the volumes 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.

The evolution of the pedestrian signal warrant does not follow a consistent path. Since the inception of the warrant in 1935, the criteria were becoming more difficult to satisfy up until the introduction of the 1961 criteria. The 1961 criteria were the most difficult to satisfy and remained unchanged until the 1988 criteria were established. It is probably no coincidence that the literature review conducted for this paper shows that the majority of the research related to the pedestrian signal warrant was conducted during this time (i.e., 1961 - 1987). In 1988, probably as a result of many complaints and the related research, the pedestrian signal warrant criteria were reduced. Although the 2000 version of the MUTCD has not been released (FHWA expects to have it ready by early 2001), the proposed language for the pedestrian signal warrant has been approved by the NCUTCD and it shows no substantial change from the current language in the 1988 MUTCD.

LITERATURE

The review of the literature is presented in a chronological order so that its relation with the various versions of pedestrian signal warrant can be traced. There are four major efforts related to the investigation of pedestrian-based criteria for the warrants.

NJUTCD–ITE Study

In 1966, the Signals Technical Committee of the National Joint Committee on Uniform Traffic Control Devices (NJUTCD), now referred to as the NCUTCD, recognized a need for review of the existing warrants. Since publication of the 1961 MUTCD, widespread research and individual study had gone into traffic elements which potentially affect warrant values. Furthermore, dissatisfaction over some warranting criteria had become apparent. The Signals Technical Committee received a grant from the ITE to research these studies. Box et al. conducted the research which had four objectives (*13, 14*):

1. Search for and collect all pertinent material.
2. Prepare a bibliography of the information collected.
3. Group, consolidate, and coordinate the information.
4. Prepare suggested factors and considerations to be included in warrants for traffic control signals, and suggest numerical values thereof.

The areas of information were divided into six categories, one of which included pedestrians. The researchers proposed a warrant for pedestrians that was based on delay due to gap availability versus group size and roadway width. This warrant was similar to the one devised by the ITE committee for school crossings and adopted by ITE in 1962 as recommended practice.

The researchers thoroughly reviewed approximately 30 reports and studies related to the pedestrian signal warrant and gap analysis. Several different warrants from other countries were

reviewed as well as the domestically developed pertinent material. They looked at proposed Australian warrants for pedestrian crossings and the actual Canadian and New Zealand warrants.

The proposed Australian warrant did not take into account the variability of the gap distribution, which Box et al. considered a fatal flaw. Because of this factor, the ITE recommended practice for school crossings accounts for pedestrian delay related to the actual site measurement of gap distribution.

An additional factor omitted by most other authors is an initial reaction time, usually 1 to 3 seconds. Box et al. preferred the ITE recommended practice for school crossings, which includes a 3-second reaction time.

The Canadian Traffic Signal Installation Warrant of 1966 required a minimum of 60 pedestrians per hour. This condition had to exist for any four hours of a normal day. In addition to the volume of pedestrians required, they had to wait an average time in excess of 60 seconds before being able to cross the main street safely. The delay value was then 1.0 hours. In using the delay concept, vehicular volume and gap distribution and gap acceptance criteria were included.

The New Zealand Traffic Signal Warrant implemented an approach unique of all other references reviewed by Box et al. pedestrian volumes up to 600 per hour were considered equivalent to one-third of a vehicle. Those in excess of 600 were considered equivalent to one-sixth of a vehicle. The units were then treated as vehicles in terms of volume, delay, and crashes as a consideration for applying the warrant.

Other approaches looked at hazard ratings and attempted to quantify pedestrian-crossing crashes in a way that could be used to justify traffic control. While most of these studies showed a decrease in pedestrian-vehicle crashes, others showed the opposite–an actual increase in crashes and cases of misuse after pedestrian signal or full vehicular signals were installed.

In summary, the ITE-recommended school crossing practice using a surrogate for delay accounts for all variables of vehicular volume and headway distribution. Box et al. proposed that the same principle could be used for adult pedestrians. The then present adult warrant of 150 pedestrians per hour on the highest volume crosswalk, sustained for an 8 hour period, was thought to be unrealistically high although quantification of the unreasonableness was not provided. In their review, Box et al. showed that pedestrian volume alone does not provide a meaningful description of pedestrian arrival and delay, particularly where large groups of pedestrians are crossing at one time. They suggested that the Canadian warrant of a minimum of 60 pedestrians delayed an average of more than one minute for four hours is a realistic approach.

The proposed pedestrian signal warrant by Box et al. reads:

> Pedestrian signal control is warranted when the peak 30-minute pedestrian delay, for at least two periods of an average weekday, or eight hours of a Saturday or Sunday, equals or exceeds 0.5 hours each, and when the peak-hour pedestrian crossing volume is at least 60 persons, including one of the 30-minute periods.

According to the authors, the time element of this proposed warrant is 30 minutes for the delay value, but the 1 hour for volume gives greater flexibility. If all 60 pedestrians attempted to cross during the peak 30 minutes, and waited an average of 30 seconds each, then the delay criterion would be satisfied. The P85 (85^{th} percentile) value for waiting time would be about 52 seconds. If, on the other hand, the pedestrian arrivals were more evenly spread across the peak hour, then average waiting time would increase to about 60 seconds, or a P85 of about 110 seconds. Therefore, the proposed warrant requires a smaller number of pedestrians arriving during the peak 30 minutes to wait longer times. Consequently, the proposed warrant favors higher rates of pedestrian flow.

Furthermore, under this proposed pedestrian signal warrant, drivers are penalized by longer waiting times in their delay warrant. Several justifications can be provided and include:

- Drivers are protected from the weather, and therefore, longer waiting times are less vexing.
- Drivers can better judge gaps.
- Vehicle passengers are less likely to be injured if an inadequate gap is accepted.

Box et al. also offer advice for controller type. In general, they advocate use of fully or semi-actuated control. An ideal controller would account for not only vehicle measures but also pedestrian-related measures such as arrivals and delay. This capability would be particularly beneficial in areas that frequently operate during absolute peak hour (such as industrial plants, shopping centers, and persons going to and from transit terminals or parking lots).

NCHRP 3-20 – Traffic Signal Warrants

In 1976, National Cooperative Highway Research Program (NCHRP) sponsored a project to evaluate the adequacy of the traffic signal warrants of the 1971 MUTCD and the need for revised or additional warrants (*11*). KLD Associates performed and reported on the work. One of the three authors of the NCHRP report, King, went on to publish the work related to the revised pedestrian signal warrant in another source (*10*). These two works are based on the same queuing model and, consequently, are very similar in concept. The review below summarizes the concepts and presents King's proposed warrant, which is somewhat different but much more simplified than the NCHRP-proposed warrant.

The NCHRP report (which investigated all warrants) recommendations included replacing three, revising three, retaining two, and adding two new signal warrants. The pedestrian signal warrant was one of the three recommended for revision.

The development of the proposed pedestrian signal warrant was based on a queue-theoretical model that had been developed and documented in the literature (*15*). Using a queuing theory based model eliminates the need for a gap criterion in the warrant and therefore has the potential to increase the ease of use of the warrant. The research team collected data and calibrated the model. The recommended criteria were based on a consensus reflected in the MUTCD and by others.

The revised warrant is based on a queue-theoretical model and presented in graphical form. The procedure includes consideration of such factors as the total major street volume, pedestrian volume, vehicle approach speed, pedestrian walking speed, and street width.

Queuing Model

The main rationale underlying the pedestrian signal warrant is to determine those traffic flow conditions that are characterized by inadequate gaps in the traffic stream for safe passage by pedestrians. This rationale implies a concomitant reasonable threshold of delay for pedestrians. Should this threshold be violated, traffic control devices should be introduced to create a sufficient number of adequate gaps artificially.

Tanner developed theoretical analysis of pedestrian delay in 1951 (*15*). On the assumption of exponential gap distribution, justified for an isolated location, he derived the following formula for the delay to a randomly arriving pedestrian:

$$P(T) = \sum_{s=0}^{r+1} \frac{(-1)^s e^{-sNI} N^s (T - sI + I)^s}{s!} + \sum_{s=1}^{r+1} \frac{(-1)^s e^{-sNI} N^s (T - sI + I)^{s-1}}{(s-1)!}$$

where: P(T) = probability [Delay > T]
I = required gap
N = number of vehicles arriving per unit time
r = largest integer ≤ T/I

The mean of this distribution was determined, as a function of volume, for various values of I. The results have been calculated (and shown below) and validated at the 95th percent confidence level, except for extremely small values of T. This exception has been attributed to pedestrians' disinclination to accept otherwise satisfactory lags. The mean can be calculated from:

$$E(D) = \frac{e^{NI} - NI - 1}{N}$$

The pedestrian signal warrant developed here is based on the following considerations:

- an acceptable level of average pedestrian delay;
- a tolerable level of maximum pedestrian delay (i.e., 95th percentile level); and
- an equitable allocation of total delay between the pedestrian and vehicular components.

King also considered the validity of adopting the condition of equalizing delay between pedestrians and vehicle passengers (*10*). This analysis led to the conclusion that such a criteria would always produce excessive pedestrian delays. Furthermore, the criteria is suspect itself. Since pedestrians are exposed to the elements, it may be unreasonable to subject them to the same levels of delay as experienced by passengers comfortably ensconced in vehicles. Consequently, this criterion was eliminated from further consideration.

Analysis of 1971 Pedestrian Signal Warrant

King felt that a rational pedestrian signal warrant should be based on the following assumptions:

- an acceptable level of average pedestrian delay;
- a tolerable level of maximum, i.e., 95th percentile, pedestrian delay; and
- an equitable allocation of total delay between the pedestrian and vehicle components of the traffic stream.

Using these criteria, King analyzed the 1971 pedestrian signal warrant with the following hypothetical conditions:

- vehicle volume = 600 vehicles per hour;
- pedestrian walking speed = 3.5 feet per second; and
- street width = 40 feet.

For an isolated and uncontrolled location that is under the assumption of exponential arrivals, the mean delay for each pedestrian is 22.9 seconds. For a pedestrian volume of 150 per hour as required in the 1971 pedestrian signal warrant, a total pedestrian delay of 57.2 person-minute per hour can be calculated. Using a random pedestrian arrival rate and the mean pedestrian delay of 22.0 seconds, more than five pedestrians will accumulate only 0.1 percent of the time. Since five pedestrians can cross a street in an abreast formation, no additional gap is needed. Heavier pedestrian volume, nonrandom arrival rates, or group arrivals may change this situation.

Long delays will accrue as follows:

- 23 pedestrians will be delayed > 45 seconds;
- 13 pedestrians will be delayed > 60 seconds; and
- 6 pedestrians will be delayed > 80 seconds.

The 95th percentile delay was found to be 75 seconds. If a signal were installed, the delay would become a function of cycle length and split time. For a 60 second cycle with 5 second walking intervals, the average pedestrian delay would be approximately 25 seconds, and the 95th percentile would be about 52 seconds.

As mentioned, King investigated the concept of equalizing pedestrian and vehicular delay. For all vehicle rates below saturation level, King found that the average pedestrian delay without signals was always higher than the average delay for vehicles with signals. Furthermore, the criterion itself is suspect. Pedestrians are exposed to the elements while drivers are in the comfort of their vehicle. Consequently, this criterion was dismissed.

Development of a Proposed Warrant

For the proposed warrant, King selected 30 seconds as an acceptable level of average pedestrian delay and 60 seconds as a tolerable level of maximum delay (i.e., the 95th percentile). The use of 95th percentile rather than 85th percentile was based on stochastic behavior, exposure to elements, and the pedestrians' exposure to accidents of increased severity. Furthermore, the values selected also reflect those in the literature (*13*).

Using these delay criteria and the queuing theory, King developed combinations of common roadway configurations and the corresponding vehicular volumes that would satisfy the criteria. These values are presented in Table 7.

Table 7. Estimated Vehicle Volumes.

Number of Lanes	Median Presence	Total Vehicle Flow	
		Avg. Delay (30 s)	95th Percentile Delay (60 s)
2	No	1440	1160
3	No	800	625
4	No	525	390
4	Yes	2080	1860
6	Yes	1100	960

Assuming random pedestrian arrival, then pedestrian volume is independent of the relationship summarized in Table 7. However, it is not realistic to warrant a signal for one or several pedestrians. Consequently, a minimum pedestrian threshold is needed to complete the warrant. The 1971 pedestrian signal warrant of the MUTCD used 150 pedestrians per hour. However, Box et al. (*13*) and the Canadian pedestrian signal warrant of 1961 suggest 60 pedestrians per hour as the minimum threshold for warranting a traffic signal, as long as the pedestrians accrue a total delay of least 1.0 hour. Other pedestrian-based warranting criteria from Ireland showed a minimum threshold of 90 pedestrians per hour. Furthermore, the 1971 Interruption of Continuous Traffic Warrant says that delay to 100 or more traffic units per hour (vehicles and/or pedestrians) may justify signals. Based on these criteria, King proposed two minimum thresholds for the candidate warrant:

- an aggregate pedestrian delay of 1 hour per hour, and
- a minimum pedestrian volume of 100 per hour.

Recommended Warrant

The warrant is presented below. The curves in Figure 2 were constructed by superimposing the 95th percentile delay curve that applies for hourly pedestrian volumes exceeding 200 and the 1 hour aggregate delay curves for lower pedestrian volumes. Another set of curves were developed for divided highways using the assumption of approximately equal directional traffic volume split. The curves do not apply for the case in which the split is markedly unbalanced. A divided highway was defined as one with a center median (curbed or painted) that is wide enough to accommodate the 95th percentile pedestrian platoon.

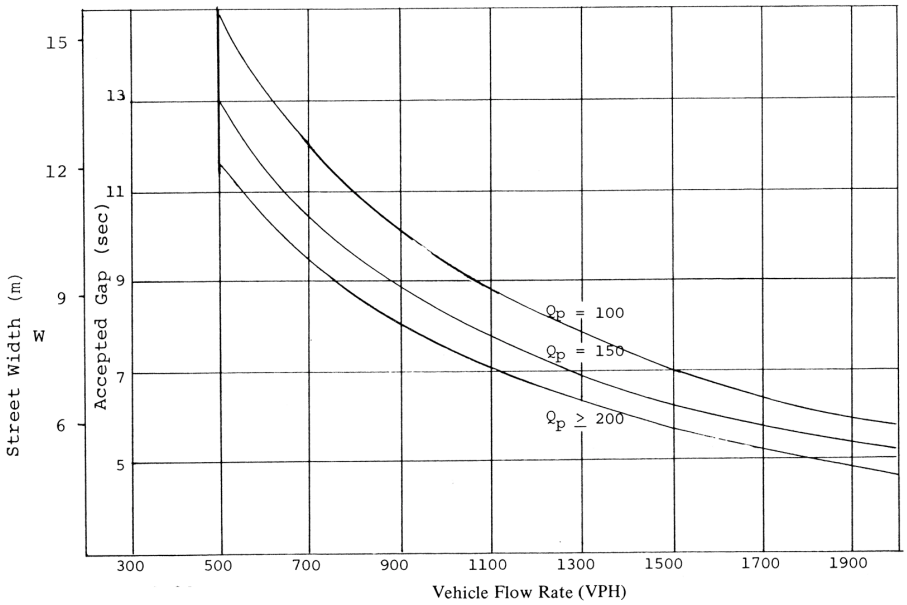

Figure 2. Proposed Warrant Curves.

Figure 2 shows the measured value of traffic flow and the required value for an accepted gap. When approach speeds are 40 mph or greater, the required gap should be increased by 1.0 second to reflect the increased difficulty in identifying an appropriate gap. The accepted gap is the time needed to cross the roadways at the prevailing walking speed.

The minimum pedestrian volume that warrants a signal is read, and, if the actual pedestrian volume exceeds this value, a signal is warranted. The W-scale can be used if walking speed is assumed to be 2.5 ft/s.

Before signals are installed, these warrants should be met for 4 hours of an average weekday. Alternatively, the warrant could be satisfied for 10 hours on any weekend if at least 3 hours are satisfied on a day with lighter volumes. This alternative is based on King's earlier work (*11*) and reflects the typical peaking characteristics associated with urban traffic.

Zeeger's Work

Zeeger's work related to the pedestrian signal warrant was published in the mid 1980s. It includes three different publications under three different sources (*6-8*). All three publications were reviewed and found to be the same work. According to the literature review, these three documents represent the last time the pedestrian signal warrant has been under scrutiny.

Zeeger's work related to the pedestrian signal warrant had two main objectives:

- Conduct an in-depth analysis of the 1978 MUTCD pedestrian signal warrant and other recommended warrants reported in the literature and from other countries.
- Develop a revised pedestrian signal warrant that might lend itself to better practical application.

The 1978 pedestrian signal warrant (which was the same as the 1961 and 1971 warrants, see Table 6) has a minimum pedestrian criterion of 600 vehicles per hour entering the intersection of each of any 8 hours of an average day. The warrant also has a criterion for at least 150 pedestrians per hour during the same period and on the highest volume crosswalk. Traffic engineers and researchers have argued that the 1978 pedestrian signal warrant was inappropriate. Pedestrian volume requirements were considered too high by most traffic experts. In order to provide signalization for pedestrians, most traffic engineers had to rely on their engineering judgment. This process created inconsistency between regions of the country and even within regions, particularly from state to city areas.

The researchers reviewed many different practices, including those described herein. They also performed a critical review of the 1978 pedestrian signal warrant. This review focused on the following five criteria:

1. appropriateness and reasonableness of the warrant;
2. complexity of the warrant;
3. data requirements;
4. flexibility of the warrant; and
5. acceptability of the warrant by practicing traffic engineers in the US.

Under the first criterion, the researchers conducted interviews with more than 50 practicing traffic engineers throughout the US. An overwhelming proportion of these interviews indicated that the pedestrian signal warrant was unrealistically set too high. The research team also collected 12-hour pedestrian count data at 388 locations around the country. They developed distributions of the pedestrian volumes from the 1st highest hour to the 12th highest hour. The average of the highest hour was 16.5 percent of the 12-hour total. By using another data set that included 24-hour counts, the research team identified the peak 12-hour period from 7:00 am to 7:00 pm and found that this period included about 8 percent of the total pedestrian volume. The data were adjusted for locations and are reproduced as Table 8.

Table 8. Distribution of Pedestrian Volume by the 12 Highest Hourly Volumes.

Hour	CBD locations (n=43)		OBD and fringe locations (n=77)		Residential locations (n=268)		All locations (n=388)	
	12 h	24 h	12 h	24 h	12 h	24 h	12 h	24 h
Highest	18.6	16.0	16.0	13.8	16.4	14.1	16.5	14.2
2nd	14.7	12.6	13.1	11.2	13.2	11.4	13.3	11.4
3rd	11.9	10.2	11.2	9.6	11.2	9.6	11.3	9.7
4th	9.7	8.3	9.8	8.4	9.9	8.5	9.8	8.4
5th	8.8	7.6	8.9	7.7	8.9	7.7	8.9	7.7
6th	7.9	6.8	8.2	7.1	7.9	6.8	8.6	7.4
7th	6.8	5.8	7.3	6.3	7.2	6.2	7.2	6.2
8th	6.0	5.2	6.6	5.7	6.4	5.5	6.4	5.5
9th	5.2	4.5	5.9	5.1	5.8	5.0	5.7	4.9
10th	4.5	3.9	5.3	4.5	5.1	4.4	5.0	4.3
11th	3.6	3.1	4.3	3.7	4.4	3.8	4.3	3.7
12th	2.3	2.0	3.4	2.9	3.6	3.0	3.0	2.6
Total	100.0	86*	100.0	86*	100.0	86*	100.0	86*

Notes: CBD = Central Business District, OBD = Outlying Business District
* The remaining 14 percent occur during the nighttime (between 7:00 PM and 7:00 AM)

It can be seen that, for an average intersection, the eighth highest hourly pedestrian volume would represent about 5.5 percent of the 24-hour pedestrian volume. Also, the cumulative 8-hour pedestrian volume equals about 70 percent of the total 24-hour volume. The researchers go on to show, based on these numbers, that a typical four-legged intersection needs about 7,600 daily pedestrians in order to satisfy the 1978 pedestrian signal warrant thresholds. Obviously, volumes of this level are unrealistic and cannot be met in most areas.

The complexity level of the 1978 pedestrian signal warrant was deemed "good" based on the need for vehicle and pedestrian volumes. Additional consideration is given based on the speed which is also an easy factor to obtain.

The data requirements of the 1978 warrant were reviewed and determined to be "poor." Most cities did not perform 8-hour counts and the thought of needing to do so at a significant number of intersections was deemed unrealistic.

The fourth criterion deals with the flexibility of the warrant to be able to incorporate a large range of highway and traffic conditions. The 1978 warrant allowed for a 70 percent reduction in the minimum criteria for high-speed locations or small towns. It also considered the presence of a median for pedestrian refuge. However, the warrant was not adequately sensitive to gaps in the traffic stream or to the following related traffic and highway variables:

- traffic speed (i.e., 25 versus 35 mph);
- street width (i.e., undivided streets of 20 versus 50 ft);
- vehicle volumes (i.e., volumes of 700 versus 2,000 per hour);
- vehicle arrival rates (i.e., random versus platoons); and
- pedestrian walking speeds.

The final criterion was the acceptability of the warrant to traffic engineers. Based on interviews with over 50 traffic engineers, the researchers showed that the 1978 warrant did not fare well with traffic engineers.

Development of a Revised Warrant

After reviewing the proposed warrants, the researchers felt that a warrant based on a minimum volume of pedestrians for a specified period, that conforms to either a minimum delay per pedestrian or a maximum number of adequate gaps per time (1-hour, 4-hour, etc.) provides the best approach for a revised warrant. Therefore, the research team focused on the following four criteria for their revised pedestrian signal warrant:

1. duration of time required;
2. number of legs for warrant;
3. minimum pedestrian requirement; and
4. criteria for gaps or pedestrian delay.

The duration was decided to be between 1 and 4 hours. The lower threshold was chosen because values less than 1 hour may tend to give erroneous results. The upper threshold of 4 hours was chosen as a reasonable length of time for cities to be required to collect pedestrian data.

The 1978 MUTCD warrant contains a requirement that the pedestrian volume be on the highest volume approach. This requirement can cause significant problems which Zeeger documents thoroughly. Therefore, researchers developed the revised warrant so the pedestrian volume would be in terms of pedestrians crossing the highest-volume street (or crossing a mid-block location).

The researchers investigated three levels of minimum pedestrian volumes (based on their data collection efforts at 388 locations). They applied minimum levels of 60, 100, and 150 pedestrians per hour to their data. The percent of locations (of the 388) meeting the minimum volume criteria are shown in Figure 3.

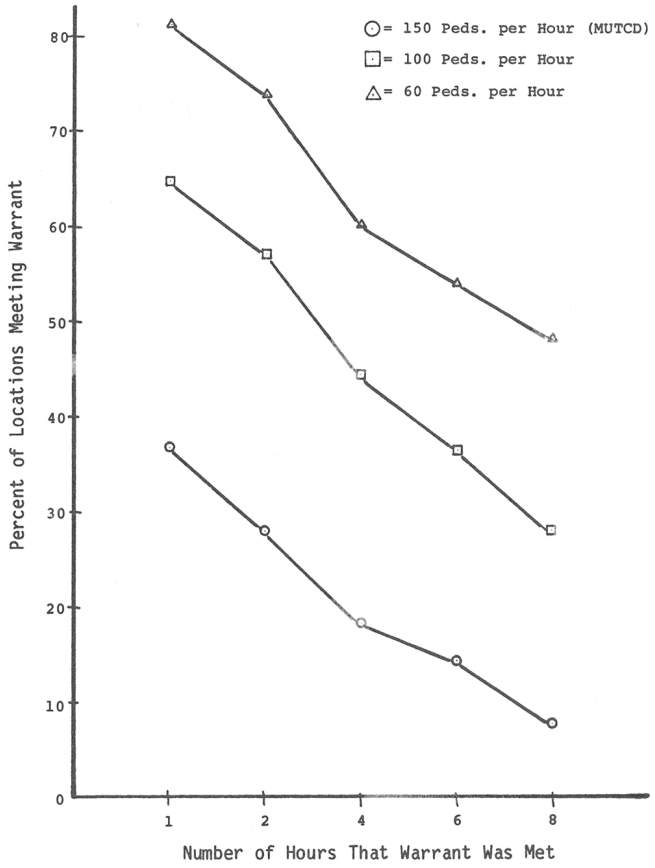

Figure 3. Minimum Pedestrian Volume Threshold Sensitivity.

A significant concern with Figure 3 is that the percentages shown are for locations with moderate to high volumes of traffic and pedestrians with existing traffic signals. Therefore, the percentages meeting the warrant would be much lower for a random sample of unsignalized locations.

An additional analysis of 1,289 intersections was conducted to determine what traffic and roadway variables explain the most variation in pedestrian crash experience. It was also hoped that this analysis would provide additional detail in regard to traffic and geometric factors that are important in pedestrian crash experience. One significant finding was that a breakpoint occurs at about 1,200 pedestrians per day. In other words, at intersections with 1,200 or more pedestrians per day, the crash rate is significantly higher than at intersections with daily pedestrian volumes less than 1,200 (0.376 versus 0.178). Once again, these intersections were signalized, so the results could be different at non-signalized intersections. However, a pedestrian volume of 1,200 per day corresponds to 750 pedestrians crossing the major street. Based on hourly pedestrian distributions, this would convert to the following volumes for the first, second, and fourth highest hourly volume as shown in Table 9.

Table 9. Recommended Pedestrian Minimum Volumes.

Volume Period	Equivalent Pedestrian ADT
1st highest hour	110
2nd highest hour	90
4th highest hour	60

The corresponding minimum pedestrian volume for the fourth highest hour corresponds to the Canadian pedestrian criterion of 60 pedestrians per hour for four hours. It also falls in the middle ground when compared to the less restrictive recommendations by Box and Alroth (*13*) and the more restrictive recommendations proposed by the NCHRP (*11*) work and King's (*10*) work. A review of other countries' pedestrian-based warrants showed significant variability in the minimum threshold pedestrian volume criterion. A review of the policies in Great Britain, Ireland, Australia, and New Zealand showed ranges from 90 to 600 pedestrians per hour.

A critical component of the warrant is the gap requirement. The number of gaps is directly related to the traffic speed, traffic volume, and traffic arrival distribution. Additionally, the number and length of gaps related to safe pedestrian crossing are related to the street width, pedestrian walking speed, and pedestrian volume. A gap-based criterion also accounts for site specific factors and interactions of those factors. The school warrant was the first warrant to include a gap criterion. This criterion is 60 adequate gaps per hour and is the same criterion that Zeeger et al. recommended for the pedestrian signal warrant.

In summary, the proposed pedestrian signal warrant includes the following language. A traffic signal is warranted if:

1. The minimum pedestrian volume crossing the major street equals or exceeds
   a. 60 per hour for each of any four hours;
   b. 90 per hour for each of any two hours; or
   c. 110 per hour during the peak hour.
2. The number of adequate gaps in the traffic stream on the major street is less than 60 per hour during the same period when the pedestrian volume criterion is satisfied.
3. When a traffic signal is warranted based on criteria 1 and 2 above, pedestrian indications should be used; the warrant is for either mid-block locations or for intersections.

Zeeger et al. also examined warranting criteria for special provisions such as abnormally high percentages of elderly and/or handicapped pedestrians. They reviewed the work of ITE's Committee 4A-6, which only had a draft of their recommendations available at the time but were reported to include warrants sensitive to the needs of elderly and/or handicapped pedestrians.

They also reviewed a set of related warrants from the city of Seattle. They ultimately recommended a warrant for elderly and handicapped pedestrians that includes a minimum volume of pedestrians and the number of acceptable gaps per hour. The following special warrant was recommended to be included in the minimum pedestrian volume warrant.

> A special traffic signal is warranted to accommodate elderly and/or handicapped pedestrians at locations with the following conditions:
>
> 1. The number of elderly (60 years of age or older) and/or handicapped pedestrians is at least:
>   a. 60 pedestrians per hour during the peak hour;
>   b. 45 pedestrians per hour in any two hours; or
>   c. 30 pedestrians per hour in any four hours.
> 2. During the hour that pedestrian volume is the highest, there must be less than 60 adequate gaps. The determination of adequate gaps should be made according to the ITE procedure. Walking speeds of about 3.5 ft/sec should be used when computing adequate gap time.
> 3. At a crossing where traffic signals are installed based on this warrant, pedestrian actuation should be provided with pedestrian indications. Also, advance signing and/or flashing beacons may be provided to alert motorists to use added caution.

FHWA Gap-Based Warrants

In 1982, Neudorff reported on signal warrants applicable to gap criteria (9). One of the proposed warrants includes a pedestrian signal warrant. The proposed warrant is based on the concept of a minimum frequency of adequate gaps occurring in the major street traffic flow. The research was reviewed and it was concluded that 60 seconds of pedestrian delay is an acceptable threshold. Thus, the number of adequate gaps is 60 per hour (i.e., one adequate gap per 60 seconds).

Neudorff used recommendations from Zeeger's work (7) for the minimum volume criteria. The proposed warrant reads the same as Zeeger's proposed warrant.

To demonstrate the validity and credibility of the proposed warrants, they were tested at 18 intersections in five different states. The gap warrants turned out to be more restrictive than the then current 1978 MUTCD warrants (7 satisfied gap warrants and 11 satisfied MUTCD warrants). The results of the gap-based and MUTCD warrants were also compared to the local traffic engineer's judgment. The gap-based warrants better matched the traffic engineers' judgment, especially for the pedestrian-related cases (3 of the 18 intersections were studied because of pedestrian concerns).

STC - NCUTCD Presentation

In January 2000, Paul Carlson attended the NCUTCD Annual Meeting in Washington, D.C. At the STC meeting, Mr. Carlson presented the project and inquired about the current pedestrian signal warrant and thoughts of a revised warrant.

The STC comments verified much of the undocumented but generally believed background associated with the pedestrian signal warrant. Specifically, the last time the warrant was modified (in 1988), it was done to alleviate concern that the criteria were too difficult to satisfy and that a need for signalization occurred before the thresholds were met. There is no specific documentation concerning the 1988 revised criteria. The STC members who were involved with STC in 1988 recalled a consensus among the local traffic engineers and the state Department of Transportation (DOT) traffic engineers.

The MUTCD is currently undergoing a complete overhaul and expected to be completed and released by March 2001. Mr. Carlson asked members of the STC if they considered revisions to the pedestrian signal warrant for the new MUTCD. They had not.

After presenting a series of tables and numbers indicating general trends in the warranting process and traffic engineers' opinions of the current pedestrian signal warrant, Mr. Carlson asked the members of the STC if they thought it was time for another revision to the pedestrian signal warrant. The results were mixed. After subsequent discussions, the committee agreed that

the pedestrian volume thresholds were perhaps too high. However, the gap criterion is an essential part of the warrant and the committee feels strongly that it should be maintained at some degree.

Finally, Mr. Carlson asked the committee members if they would be receptive to a revised pedestrian signal warrant with lower pedestrian volume thresholds combined with gap criteria. They responded favorably, as long as the research provides validation of the proposed numbers.

BASIS FOR CURRENT CRITERIA

The current pedestrian signal warrant contains two main criteria. The first is a minimum threshold pedestrian volume and the second is a gap criterion. Each of these criteria is discussed below. Their hypothesized development based on the literature and findings from the STC presentation is included. It should be noted that development of the current pedestrian signal warrant criteria presented below has not been confirmed or validated by an authority because, for all practical purposes, none exist.

Another note of caution is that the criteria that make up any warrant are somewhat arbitrarily determined. The signal warranting process cannot be a cookbook process. Engineering judgment is needed, and warrants cannot provide an adequate substitute for engineering judgment. Any warrant should be considered a tool to help the traffic engineer determine signalization needs.

Minimum Threshold Pedestrian Volume

Zeeger's FHWA work shows that a safety break point exists at about 1,200 pedestrians per day. In his analysis of 1,289 intersections, Zeeger shows that of the 609 intersections with pedestrian volumes less than 1,200, the mean pedestrian accidents (per location per year) was 0.178, compared to 0.533 for 680 locations above 1,200 pedestrians per day. A caveat to these numbers is that the intersections were all signalized. Although the breakpoint may not be the same exact volume, traffic signals are generally believed to improve pedestrian safety by adding artificial gaps. With this theory, the breakpoint for unsignalized intersections may be something less than 1,200. Using 1,200 establish a factor of safety.

Combining the 1,200 daily pedestrian volume with the distribution numbers presented in Table 8, Zeeger was able to develop the following minimum threshold pedestrian volumes for his proposed warrant. His recommendation is shown in Table 10 along with the current MUTCD criteria.

Table 10. Comparison of Minimum Pedestrian Volumes.

Volume Period	Zeeger's Recommendation	Current MUTCD Criteria
1st highest hour	110	190
2nd highest hour	90	n/a
4th highest hour	60	100

Interestingly, if one were to apply NCHRP's (*11*) and King's (*10*) recommendations of 100 pedestrians per hour for the fourth highest hour and back-calculate the peak hour using the data and Central Business District (CBD) trends supplied through Zeeger's work (*7*), the resulting minimum pedestrian hourly volume is 190, rounding to the nearest integer. The result is 100 pedestrians per hour for the four-hour period and 190 pedestrians for the peak hour. These are the same values in the current pedestrian signal warrant.

While this process may not be the way the current pedestrian volume threshold values were determined, it certainly provides at least one explanation of the rather odd number of "190" for the peak-hour threshold. It also makes sense in that research findings from multiple efforts were combined to strengthen the basis for the warrant. Researchers hypothesize that this is how the current MUTCD criteria for minimum pedestrian volumes were established.

Gap Criteria

The gap criterion has been included in the warrant as a surrogate for pedestrian delay. It is easier to measure than delay and intuitively makes sense. The actual value of the criterion is derived from what has been determined to be tolerable pedestrian delay. Although somewhat arbitrarily determined, 60 seconds has been accepted as a tolerable pedestrian delay. This time equates to the need for 60 adequate gaps per hour, which is the current pedestrian signal warrant criterion.

ADDITIONAL WARRANTS FROM ABROAD*

Australian Signal Warrant Guidelines – Current *(16)*

Mid-Block

Pedestrian-activated traffic signals may be provided where:

1. The pedestrian volume exceeds 350 persons per hour for each of 3 hours on an average day, and during each of the same 3 hours the traffic volume exceeds 600 vehicles per hour (total of both directions), or 1,000 vehicles per hour (total of both directions) where there is a central pedestrian refuge.
2. For each of 8 hours of an average day:
   a. the traffic volume on the road exceeds 600 vehicles per hour (total of both directions), or 1,000 vehicles per hour (total of both directions) where there is a central pedestrian refuge; and
   b. during the same 8 hours, the pedestrian volume is 175 or more pedestrians per hour; and
   c. there is no other pedestrian crossing, footbridge, or subway within reasonable distance.
3. The guidelines for a pedestrian crossing (zebra) are met and the site is either:
   a. adjacent to a railway level crossing,
   b. close to a signalized intersection on an arterial road, or
   c. in or adjacent to a coordinated traffic signal system, and the pedestrian-actuated traffic signals can be operated as part of the coordinated system.

   If it is necessary to install mid-block signals in such close proximity to an intersection or railway level crossing that queuing is likely to occur across the intersection or railway level crossing, the signal controls at the two points should be coordinated to obviate such queuing. The need to keep pedestrian delays to a minimum should also be considered.
4. A pedestrian crossing exists and two or more reported casualty accidents of a type susceptible to correction have occurred on or near the crossing within the past three years.

Intersections

To assist the safe and efficient movement of pedestrians, intersection signals may be considered where, for each of 4 hours of an average day, 600 or more vehicles enter the intersection from the

* This section includes metric units as published in the foreign references.

major road and 150 or more pedestrians cross this movement, provided that there is no alternative and reasonably accessible pedestrian-crossing facility.

Where there is a raised median island 1.2 m or more in width, higher vehicular volumes are acceptable, and 1,000 vehicles per hour should be attained rather than 600 vehicles per hour.

Where the 85th percentile speed on the major road exceeds 70 km/h, the above vehicular volume requirements can be reduced to 450 vehicles per hour and 750 vehicles per hour, respectively.

Australian Signal Warrant Guidelines – Proposed

The following general guidelines can be used to determine whether installation of traffic signals is warranted at an intersection subject to the following considerations:

1. Where alternative or additional criteria exist in local guidelines, they should be applied.
2. All other relevant factors should be taken into account and proper engineering judgment should be exercised.
3. The warrants alone should not be used to justify an installation. If a site satisfies warrants, this does not necessarily mean that signals are the best solution. Alternative treatments such as the use of a roundabout should be considered to determine the optimum solution in terms of traffic performance measures, levels of service, and benefit-cost ratios.

Signalized Intersections

The terms *major road* and *minor road* are used below to indicate roads carrying the larger and smaller traffic demand volumes.

As a guide, installation of signals may be considered at an intersection if one of the following warrants is met.

1. ***Traffic demand volumes***: For each of four one-hour periods of an average day, the major road flow exceeds 600 veh/h in both directions, and the highest volume approach on the minor road exceeds 200 veh/h. OR
2. ***Continuous traffic***: For each of four one-hour periods of an average day, the major road flow exceeds 1,000 veh/h in both directions, and the highest volume approach on the minor road exceeds 100 veh/h, and the speed of traffic on the major road or limited sight distance from the minor road causes undue delay or hazard to the minor road vehicles, and there is no other nearby installation easily accessible to the minor road vehicles. OR
3. ***Pedestrian safety***: For each of four one-hour periods of an average day, the major road flow exceeds 600 veh/h in both directions (or where there is a central pedestrian refuge

at least 1.2 m wide, the major road flow exceeds 1,000 veh/h in both directions), and the pedestrian flow crossing the major road exceeds 150 ped/h. For high-speed major road conditions where the 85th percentile speed on the major road exceeds 75 km/h, the above major road traffic flow criteria are reduced to 450 veh/h without refuge and 750 with refuge. OR

4. ***Crashes***: The intersection has been the site of an average of three or more reported tow-away or casualty crashes per year over a three-year period where the crashes could have been prevented by traffic signals, and the traffic flows are at least 80 percent of the volume warrants given in (a) and (b). Signals should only be installed if simpler devices will not effectively reduce the accident rate. OR
5. ***Combined factors***: In exceptional cases, signals occasionally may be justified where no single guideline is satisfied but where two or more of the warrants given in (a), (b) and (c) are satisfied to the extent of 80 percent or more of the stated criteria.

Signalized Mid-block Pedestrian Crossings

The need for a signalized mid-block pedestrian crossing depends on the probability of pedestrians being able to find suitable gaps in vehicular traffic stream. This probability is decreased with the increased speed, and increased volume and density of vehicles. Other factors to consider include platooning of vehicle flows from upstream signals, number of traffic lanes to cross, pedestrian desire lines, impact of future development, as well as the proportion of children, elderly, or handicapped pedestrians.

Justification for the provision of a signalized mid-block pedestrian crossing should be based on the potential pedestrian flows rather than the existing flows, considering that this facility may attract additional pedestrians to the site.

Provision of a signalized mid-block pedestrian crossing should be avoided within 130 m of a signalized intersection.

The warrants for *Pelican* crossings are the same as those for conventional signalized mid-block crossings, except that they should *not* be installed at very wide roads with six-lane approaches or very wide medians, two-stage crossings, sites used predominantly by children, elderly or handicapped pedestrians, and sites with audio-tactile push buttons.

As a guide, a signalized mid-block pedestrian crossing may be considered if one of the following warrants is met.

1. For each of four one-hour periods of an average day, the pedestrian flow crossing the road exceeds 250 ped/h, and the vehicular flow exceeds 600 veh/h in both directions, or where there is a central pedestrian refuge at least 1.2 m wide, the major road flow exceeds 1000 veh/h in both directions. OR

2. For each of eight one-hour periods of an average day, the pedestrian flow crossing the road exceeds 175 ped/h, and the vehicular flow exceeds 600 veh/h in both directions, or where there is a central pedestrian refuge at least 1.2 m wide, the major road flow exceeds 1,000 veh/h in both directions, and there is no other pedestrian crossing within a reasonable distance. OR
3. Where the crossing is used predominantly by *children*, and for each of two one-hour periods of an average day, the pedestrian flow exceeds 50 ped/h, and the vehicular flow exceeds 600 veh/h in both directions. OR
4. Where at least 50 percent of pedestrians using the crossing are elderly or handicapped persons, and for each of two one-hour periods of an average day, the pedestrian flow exceeds 50 ped/h, and the vehicular flow exceeds 600 veh/h in both directions. OR
5. A signalized mid-block pedestrian crossing may also be considered in special situations if one of the following warrants is met:
    a. The location has been the site of two or more pedestrian casualties over a three-year period where these could have been prevented by a signalized mid-block pedestrian crossing. OR
    b. There is a large seasonal variation in the vehicular traffic flow (such as at a holiday resort) and it can be shown to meet the general criteria during the busy season, even if during the rest of the year, the general criteria are not met. OR
    c. The flow warrant for a zebra crossing is realized (see AUSTROADS GTEP Part 13, Appendix B), but its provision could cause a hazard to pedestrians because of the width of the carriageway, insufficient sight distance to the crossing, or the speed or number of vehicles. OR
    d. The site meets the warrants for a zebra crossing, but a signalized crossing would improve traffic flow by enabling it to be coordinated with another site or sites.

Signalized Pedestrian Crossings at Signalized Intersections

As a guide, a signalized pedestrian crossing may be considered at a signalized intersection if one of the following warrants is met.

1. Where the pedestrian movement crosses the major road, for each of two one-hour periods of an average day, the pedestrian flow exceeds 30 ped/h. OR
2. Where the pedestrian movement crosses the minor road, for each of two one-hour periods of an average day, the pedestrian flow exceeds 60 ped/h. OR
3. A signalized mid-block pedestrian crossing is warranted within 130 m. OR
4. Where the pedestrian flow criterion is not met but one or more of the following conditions apply:
    a. A number of young children will use the crossing; OR
    b. Elderly or handicapped pedestrians will use the crossing; OR

c. There will be a hazard to pedestrians due to the width of the carriageway (greater than six lanes or 25 m); OR
d. There will be a hazard to pedestrians due to the high speed or number of vehicles.

LITERATURE SUMMARY

The evolution of the MUTCD pedestrian signal warrant has been traced from its beginning to the proposed MUTCD tentatively scheduled to be ready in early 2001. A critical review of the literature related to the pedestrian signal warrant has also been reported. A possible explanation of the current warranting criteria has been proposed. Warrants from other countries have also been described. Finally, a summary of the warranting criteria has been developed and presented on the following page (see Table 11).

DESIRABLE ATTRIBUTES OF A REVISED PEDESTRIAN SIGNAL WARRANT

After completing this review and presenting it to the project Advisory Panel, discussions were held in order to develop a list of the desirable attributes for a pedestrian signal warrant. The following list summarizes the desirable attributes as identified by the project Advisory Panel.

Overall

- avoid a major overhaul of the warrant,
- suggest tweaking where needed,
- maintain gap and pedestrian volume criteria,
- easy to understand and easy to use, and
- do not add or significantly increase data collection needs.

Possible Factors

Primary

- minimum pedestrian volume and
- gap criteria.

Secondary

- adjacent signal proximity,
- progression, and
- adjacent crosswalk proximity.

Reduction/Other Factors

- pedestrian delay (accounted for with gap criteria),
- pedestrian safety (somewhat addressed),
- pedestrian walking speed (should be a part of the adequate gap size calculation),
- perception / reaction times,

- refuge island / median island (impacts how gap criteria is applied),
- vehicle speed,
- environment / area type,
- latent demand,
- cyclists' need to cross streets,
- pedestrian and motorist compliance with traffic control devices,
- ADA requirements,
- vehicle volume (accounted for with gap criteria), and
- false sense of security provided by an unwarranted signal.

Table 11. Warranting Criteria.

Warrant		Criteria		Reduction Factors
Source	**Year**	**Primary**	**Secondary**	
MUTCD	1935, 1939	minimum pedestrian volume, minimum vehicle volume, minimum vehicle speed		
MUTCD	1942	minimum pedestrian volume, minimum vehicle volume		
MUTCD	1948, 1954	minimum pedestrian volume, minimum vehicle volume, minimum vehicle speed		urban / rural
MUTCD	1961, 1971, 1978	minimum pedestrian volume, minimum vehicle volume		85th percentile speed, urban / rural
Box et al.	1967	minimum pedestrian volume, minimum pedestrian delay		
NCHRP	1976	minimum pedestrian volume, minimum vehicle volume, gap criteria		vehicle speed
Neudorff	1983	minimum pedestrian volume, gap criteria		
Zeeger	1985	minimum pedestrian volume, gap criteria		elderly / disabled pedestrians
MUTCD	1988, 2000	minimum pedestrian volume, gap criteria	adjacent signal proximity, progression, adjacent crosswalk proximity (for mid-block crossings only)	pedestrian walking speed
Australian	current and proposed	minimum pedestrian volume, minimum vehicle volume		vehicle speed

CHAPTER 3
SITE ASSESSMENT VISITS

In order to address the list of desirable attributes and determine if the pedestrian signal warrant should include criteria for any of the identified desirable issues, a work plan was developed with help from the project Advisory Panel. The work plan included the identification of pedestrian problem areas around the state where a possible solution may be a traffic signal. Next, the research team collected, analyzed, and reduced data at six of these sites. The Advisory Panel, and other engineers throughout the state who had volunteered their services, were then asked to make site assessment visits and determine, based on their engineering judgment and a limited amount of supplied data, whether a signal or some other form of traffic control should be used to address the pedestrian issues. Next, the engineers were asked to list which factors caused them to make the decisions they had made. This chapter includes a detailed description of these activities. Chapter 4 provides the findings and recommendations. Appendix C contains the site assessment worksheet that was provided to those who performed the site assessment visits.

SITE SELECTION

With help from personnel from the city of Austin, city of College Station, and Trans Texas Alliance, 12 potential sites were identified for the site assessment visits. These sites were selected based on previous public requests for a traffic signal (based on pedestrians) or higher-than-average pedestrian-vehicle crashes. All sites were non-signalized. There was also a mix between mid-block crossing needs and intersection needs.

Site visits were made to each of the 12 sites. The purpose of the visits was to evaluate the problem first hand, collect some preliminary data such as existence of crosswalks and other traffic control devices, and determine the key issues at each site.

With recommendations from the project Advisory Panel, five sites were selected for site assessment visits. The following list summarizes the selected sites:

- 5th Street in Austin, Texas;
- 45th Street in Austin, Texas;
- South Lamer Blvd. in Austin, Texas;
- Oltorf Ave. in Austin, Texas; and
- University Drive in College Station, Texas.

DATA COLLECTION AND REDUCTION

Data were collected using the equipment and procedure described below. Vehicle speed, vehicle volume, vehicle gaps, pedestrian and cyclist volumes, and site specific geometrics were all collected at each site to provide insight into the operational performance of the various sites.

Data Collection Equipment

The data collection effort used the following equipment:

- one mobile recording video system with a high-mast camera support. The mobile recording video system includes:
  - outdoor Cohu surveillance camera with a 10 - 105 mm auto-focus lens;
  - 380-mm color monitor;
  - 24-hour time-lapse video cassette recorder; and
  - gas-powered generator; and
- two sets of battery powered traffic counter/classifiers (TCC).

The mobile video recording system allows for continuous video recording without requiring access to the camera. The system consists of an enclosed trailer (providing protection and storage for the recording equipment) and a 30 ft. telescoping pole with a camera in an environmental housing unit. An internal view of the trailer is shown in Figure 4. Figure 5 shows how the trailer can be hidden when roadside development is present. The video was used to make pedestrian counts and verify the accuracy of the TCC data. The video also provides a way to reevaluate certain issues that may not have been previously evaluated.

Figure 4. Internal View of Video System Trailer.

Figure 5. Video System.

To collect the vehicle speed, volume, and gap data, conventional road tubes were used in conjunction with TCCs. One pair of tubes were set up along each direction of flow. Where one-way streets were involved, one pair of tubes were stretched across the road.

All of the data were collected during the summer of 2000. Data collection was performed for approximately 12 hours (7:00 AM - 7:00 PM) on dry, clear weekdays.

Data Reduction

The vehicle data from the TCCs were downloaded and entered into spreadsheets. The 85th percentile speeds of the major street were then calculated. Vehicle volumes were binned into 15 minute intervals. The adequate-sized gap was then calculated based on an assumed walking speed of 3.5 ft/sec. Using the 15-minute binned data, the number of adequately sized gaps was then determined.

The video data was reviewed in the office and used to determine the pedestrian and cyclist volume. To match the vehicle data, the pedestrian and cyclist data were binned into 15-minute sections.

Using the reduced data, each of the sites was evaluated based on the current pedestrian signal warrant. The only site to satisfy the current pedestrian signal warrant was University Drive in College Station.

SITE ASSESSMENTS

Using the reduced data, a site assessment worksheet was developed for those individuals who would be conducting the site assessment visits. The site assessment worksheet is shown in Appendix C. The goal of this task was to include the possibility of any and all criteria as being part of the pedestrian signal warrant. It was meant to be a thought provoking task without limits.

Participants

The six-member project Advisory Panel was initially chosen to participate in the site assessment visits. However, recognizing that four of the members were TxDOT representatives and TxDOT has fewer pedestrian issues than cities, a goal was established to get more local traffic engineers involved. Fortunately, shortly before the site assessment task was initiated, the Texas section of the Institute of Transportation Engineers held its annual summer meeting. This project was added to the agenda and during the presentation audience members were asked to participate with the site assessment visits. About 12 people volunteered and were sent the site assessment worksheet along with the Advisory Panel members. In addition, other TxDOT and city of Austin engineers were recruited to participate in the site assessment task.

Anticipated Results

It was anticipated that this task would result in similar features between those sites where the engineering judgment recommended a traffic signal and those where a traffic signal was not needed. These features would then be evaluated for inclusion into the warranting process. If feasible, a revised pedestrian signal warrant would be developed that would include the identified features or surrogates for the features.

Responses

A total of 14 responses were received from the site assessment visits. The breakdown of those who responded is shown in Table 12.

Table 12. Site Assessment Responses.

Agency	Number of Responses
TxDOT	6
City	7
Consultant	1

Findings

The findings from the site assessment task are summarized below. Each site is addressed sequentially with a summary of the overall findings presented last. All of the comments received are also listed. The total number of responses for each question varies depending on which sites the participants were able to visit.

Site 1 – Fifth Street (Austin, Texas)

Should a traffic signal be installed here?

Yes - 7
- Gaps less than 60 but pedestrian volumes greater than 60 per hour
- Land use and street design not compatible

No - 5
- Did not appear to be heavy enough pedestrian concentrations. Although speeds were well over the posted speed limit and three lanes of traffic make it difficult to cross, people seemed to be willing to wait and take their chances.
- Sufficient gaps in traffic
- High speed vehicles on Fifth Street
- Roadway geometrics limit sight distance
- Pedestrian bridge 500 ft of intersection
- Even though there is high pedestrian volume, a pedestrian bridge is nearby. It is a private bridge and something should be worked out so all peds have access.
- High vehicle speeds but pedestrian bridge 200 yards away
- Poor sight distance
- Pedestrian bridge available
- Crosswalk available but not used
- Signal would provide pedestrians a false sense of security because of restrictive sight distance
- Average pedestrian age appears to be mid 20s with no difficulties in judging gaps and crossing

Should less restrictive traffic control be implemented here?

Yes - 1
- Better speed enforcement would help
- If a definite concentrated crossing area could be established, then an overhead beacon should be enough

No - 4
- Existing pedestrian signs and markings
- Could have a flashing beacon turned on with push button; however, not all pedestrians cross at the intersection
- Signs and markings already exist

This location does not meet the current pedestrian warrant. Do you agree with this assessment?

Yes - 5
No - 1
- High speed and incompatible land use and street design ... a series of coordinated signals would be a better design

Site 2 – West 45th Street (Austin, Texas)

Should a traffic signal be installed here?

Yes - 2
No - 10
- Not enough pedestrians!
- Not enough pedestrians or bikes and plenty of opportunities to cross
- No sight distance problem
- Adequate gaps and time for pedestrians, bikes, and vehicles to cross
- Not enough pedestrian traffic, however if study was in fall or spring when school was in, there could be different results
- Low pedestrian volumes
- Adequate gaps
- Small crossing distance
- This was probably not a typical observation at this location because most pedestrians at this crossing are students and observation was not made during the school year
- Close signalized intersection
- Relatively low volumes
- High nighttime activity may be a concern

Should less restrictive traffic control be implemented here?

Yes - 1
- Pedestrian activated signal with flashing or lighted crosswalk

No - 5
- Not enough pedestrians. Residential area. Plenty of good gaps.
- People crossing along the entire area. Good sight distance. Close to adjacent signal.
- There are pedestrian crossing signs and markings ... anything else would not be helpful
- Signs and markings already exist

This location does not meet the current pedestrian warrant. Do you agree with this assessment?

Yes - 6
- A signal at this location would disrupt traffic more than help pedestrians cross the street

No - 0

Site 3 – South Lamar (Austin, Texas)

Should a traffic signal be installed here?

Yes - 0

No - 12
- Not enough people seemed to want to cross.
- Two-Way-Left-Turn-Lane (TWLTL) was being used as a pedestrian refuge area.
- Bikers were not having a hard time crossing using the TWLTL.
- Accident history should be considered
- Age of pedestrians should be considered
- Not enough pedestrian or bike traffic
- Width of street could justify a signal
- Pedestrian volume is minimal
- Lack of pedestrian traffic
- Pedestrian volumes were low
- Pedestrian crossings are not localized and did not appear to be easily concentrated to one crossing
- Close signal (1/4 mile)

Should less restrictive traffic control be implemented here?

Yes - 4
- Pedestrian crossing signs would be helpful
- Pedestrian refuge in the TWLTL would be helpful

- Pedestrian warning signs should be added and pavement markings for crosswalk
- Pedestrian volumes consisted of relatively large portion of disabled pedestrians
- Pedestrians had no problem making to TWLTL and waiting for another adequate gap
- Conflicts between pedestrians and vehicles seemed to occur most often in TWLTL when vehicles accelerated
- It may be possible to use jiggle bars in TWLTL to facilitate the use of TWLTL as pedestrian refuge by making its use of an acceleration lane unattractive to motorists
- Lighted or flashing crosswalk

No - 2

- Aside from perceived danger, crossing seemed reasonable.
- This could be borderline because of the lack of adequate gaps even though pedestrians for the most part were light.

This location does not meet the current pedestrian warrant. Do you agree with this assessment?

Yes - 6

- What about transit stops and induced pedestrian and vehicle traffic if signal installed

No - 0

Site 4 – Oltorf Ave. (Austin, Texas)

Should a traffic signal be installed here?

Yes - 0

No - 12

- Businesses and homes, neighborhood, good gaps with few people wanting to cross
- Good sight distance
- Mid-block location with two shopping centers
- Vertical curve restricts sight distance
- Sufficient gaps in traffic for pedestrians
- The problem with this site is geometrics ... sight distance is poor
- Enough gaps in traffic, however sight distance is restrictive
- Poor sight distance
- Pedestrian crossings were not localized and there is not an easy way to concentrate them
- Signal nearby
- Adding a signal to this location would be cost prohibitive
- Less than 1/4 mile to adjacent signal

Should less restrictive traffic control be implemented here?

Yes - 3

- Flatten vertical curve
- Install pedestrian crossing signs
- Install crosswalks
- Lighted or flashing crosswalk

No - 3

- The main problem here is sight distance
- It is not cost effective to correct geometrics
- It is a matter of pedestrians choosing to cross at a poor location rather than walking a relatively short distance to a signalized intersection

This location does not meet the current pedestrian warrant. Do you agree with this assessment?

Yes - 6
No - 0

Site 5 – University Drive (College Station, Texas)

Should a traffic signal be installed here?

Yes - 1

- Spacing compatible with other signals
- Compatible land use

No - 2

- The proximity of the adjacent ramps
- Limited sight distance
- Already congested operations in that area
- Another signal might compound these problems

Should less restrictive traffic control be implemented here?

Yes - 1

- Pedestrian traffic could be routed to the adjacent signal where pedestrian facilities are already available

No - 1

This location does meet the current pedestrian warrant. Do you agree with this assessment?

Yes - 1
No - 1

- No real refuge area
- There have been pedestrian injuries at this crossing

Final Site Assessment Response Area

Are the correct criteria used in the MUTCD warrant?

Yes - 6
No - 1
- Walk times need to be adjusted
- What is ADA population using area
- Pedestrian volumes too high for too long

Are the correct threshold values used in the MUTCD warrant?

Yes - 6
No - 1
- Need flexibility, however a signal one block in either direction may not be appropriate
- Cross street traffic should be considered ... convert pedestrians to autos?

Is the current reduction criteria (walking speed) appropriate?

Yes - 4
- The walking speed and reduction factor are fine, however, how do you estimate walking speed? Should 40 percent of the pedestrians have a walking speed of less than 3.5 ft/sec?
- Vehicle speed greater than 40 mph

No - 3
- You might be able to increase the number of crossings that would satisfy the warrant by using the 85th percentile walking speed to give a reduced speed to use when deciding if the volume should be reduced or if gaps are of adequate size. The MUTCD leaves this option open to interpretation by using "predominant" walking speed. It may be possible to develop a curve that provides a percentage reduction based on average walking speed.
- I think there should only be one speed used ... otherwise we will have to do a ped speed study to calculate the average or 85th percentile speed just to do a signal warrant.
- How does one measure ADA population and walking speed?

What other factors should be considered?
- Driver expectancy should be considered
- Roadway geometrics affect both the vehicles and pedestrians. Some examples of a horizontal curve into a vertical curve, a raised median versus a TWLTL, and two lanes versus six lanes.
- Signal spacing

- Percent pedestrians in evening hours
- Need some flexibility for engineers to allow closely spaced signals in very urban areas with 60 ped/hr for four hours
- There should be some guidance for pedestrian-activated crosswalks, flashing in-ground lights, or pedestrian signals
- Warrants 1, 2, and 3 should be used together with a pedestrian conversion factor into vehicles. This would account for a mix of pedestrian and vehicle volumes and allow the 40 mph reduction factor to be implemented.
- It seems that the existing pedestrian volume warrant is appropriate for mid-block locations where the "cross street movement" is exclusively pedestrians. For other locations (intersections and driveways), the combination of pedestrians and vehicles appears to me to be the appropriate factor to consider. (This would include bikes as one or the other depending on whether they are being ridden or pushed.)

SITE ASSESSMENT SUMMARY

The goal of this task was to include the possibility of any and all criteria as being part of the pedestrian signal warrant. It was meant to be a thought provoking task with no limits. The site assessment worksheet (Appendix C) was designed to reduce the amount of influence from the current pedestrian signal warrant. The data were provided so that participants of this task would have a feel for vehicle and pedestrian movements without having to spend considerable time observing vehicle and pedestrian operations at the sites.

Despite these efforts, most of the responses were focused on the current MUTCD pedestrian signal warrant criteria and few variations resulted. This could be considered an indication that the current pedestrian signal warrant may be appropriate. However, the researchers disagree with this conclusion. Rather, the research team feels that the current methodology has been so ingrained in the profession's signal warrant analysis activities that it becomes difficult to provide engineering judgment without relying on the existing criteria. Furthermore, the majority of the site assessment participants were not heavily involved in the research project and therefore were not as likely to be as intimate with the issues at hand as the project Advisory Panel and research team.

While the majority of the comments focused on existing warranting criteria, the need for clarification, or the need for additional guidelines for crossing treatments, there was one set of comments in particular that were interesting. The comments focused on combinations of vehicle and pedestrians volumes, counting a pedestrian or cyclist or vehicle equally. The same set of comments also suggested that the current pedestrian signal warrant appears to be more appropriate for mid-block crossings where the "cross street movement" is exclusively pedestrians. For other intersection locations, pedestrians and cyclists would be considered together. These comments are similar to those expressed by practicing engineers at the project presentation at the summer 2000 TexITE meeting. It appears that many engineers feel that a

combination of the vehicle and pedestrian criteria would be an appropriate consideration for a warrant. In fact, a review of previous pedestrian signal warrants included in Table 11 from Chapter 2 illustrates that a combination of vehicle and pedestrian criteria were being used until the latest modification in 1988.

Other notable and/or multiple comments that support possible modifications to the pedestrian signal warrant are listed below:

- land use and street design not compatible,
- pedestrian volumes too high for too long,
- need flexibility,
- cross street traffic should be considered, and
- vehicle speed should be considered.

CHAPTER 4
CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

The conclusions from the research activities are presented and discussed in this chapter with recommendations following. The recommendations are based on the conclusions and are designed to address the significant issues while retaining the general format of the current warrants. In addition, the recommendations were designed to be easy to use and require reasonable data collection efforts. The recommendations provide engineers with additional flexibility in terms of satisfying signal warrants based on pedestrian and cyclist issues while maintaining the ability to refuse a signal request based on site-specific issues.

Using the five study sites used for the site assessment task, the recommended warrants were implemented to determine the impact of the recommended changes. The results show that the recommended changes result in findings more consistent with the engineers' professional judgment than the current warrants allow.

CONCLUSIONS

The following conclusions are based on the research activities presented in this research report. They are organized in a manner consistent with topic presentation throughout the report.

Literature Review

Researchers conducted a literature review to develop an understanding of the science behind the current pedestrian signal warrant criteria. In order to facilitate this effort, a project presentation was made to the STC of the NCUTCD. This presentation included a review of the project objectives, solicitation for information about current activities involving warrant considerations, and solicitation concerning the origins of the current criteria. The conclusions from these activities are summarized below.

- The current pedestrian signal warrant is the least used warrant to justify signal installations. This is not because of lack of effort. Rather, the current pedestrian volume thresholds are difficult to satisfy.
- A summary of the pedestrian signal warrant evolution shows that a combination of vehicle and pedestrian volumes was a major element of the warrants until the most recent revision of the pedestrian signal warrant in 1988. In 1988, the major warranting criteria were revised to include pedestrian volumes and frequency of adequately sized vehicular gaps on the major street.
- The current pedestrian signal warrant minimum pedestrian volume criteria appear to be developed from a combination of the most significant pedestrian signal warrant-related research efforts.

- The current pedestrian signal warrant gap criterion was adopted from an ITE school crossing recommended practice. It has been accepted and validated as a surrogate for reasonable pedestrian delay of 60 seconds.
- Overall desirable attributes of a revised pedestrian signal warrant as developed by the project Advisory Panel and research team include:
  - avoid a major overhaul of the warrants;
  - suggest tweaking where needed;
  - maintain gap and pedestrian volume criteria;
  - warrant(s) must be easy to understand and use; and
  - avoid significant increases to data collection needs.

TexITE Presentation

Approximately two-thirds of the way through this project, the ITE Texas Section held its annual summer meeting in College Station. At this meeting, researchers presented the project objectives and work plan. Comments were solicited and subsequent discussions were held with many of the practicing engineers (both local and consultants) regarding the pedestrian signal warrant. The conclusions from this activity are summarized below.

- The current pedestrian signal warrant is difficult to apply to intersection locations. The determination of adequately sized vehicular gaps on the major street is difficult to determine because of entering and exiting vehicles from the minor street(s).
- A combination of vehicle and pedestrian volumes should be included for intersection locations. For mid-block locations, only pedestrian volumes are needed. There may be a need for two separate warrants: one for intersections and one for mid-block crossings.
- The current pedestrian signal warrant gap criterion is useful in that it indirectly accounts for vehicle volumes, street width, and pedestrian walking speeds. Essentially, the gap criterion allows for site-specific conditions to be considered in the warrant analysis.

Site Assessment Visits

Researchers implemented a site assessment task to identify and assess which factors should be included in a revised pedestrian signal warrant. Engineers visited five “pedestrian problem” sites and were asked to make an evaluation of traffic control needs based on their professional judgment, supplemented with a limited amount of data. Additional questions were also asked in reference to factors that led to their decisions. The results of analyses using the current pedestrian signal warrant were also presented. The conclusions of this task are summarized below.

- For all but one site, the professional judgment provided by the engineers resulted in the same conclusions as the signal warrant analysis performed with the current pedestrian signal warrant.
- The comments received were mostly based on the current pedestrian signal warrant criteria.
- Innovative comments included:
  - Combining warrants 1, 2, and 3 using combinations of pedestrian and vehicular volumes on the minor approach.
  - Using the current pedestrian signal warrant as a mid-block only warrant.
- Other notable and/or multiple comments that support possible modifications to the pedestrian signal warrant include:
  - land use and street design not compatible;
  - pedestrian volumes too high for too long;
  - need flexibility;
  - cross street traffic should be considered; and
  - vehicle speed should be considered.

RECOMMENDATIONS

The recommendations were made based on information gathered from the literature review and presentation to the STC of NCUTCD, comments and concerns voiced by practicing engineers during and following a project presentation during the summer 2000 TexITE meeting, comments received through the site assessment visits, and the opportunity to address many of the identified issues without completely reformatting the warrants and/or the procedures associated with implementation of the warrants. The warrants that are affected are shown for each recommendation.

- Include pedestrians and cyclists in the minor-street approach volumes for all warrants that currently consider only vehicle minor-street approach volumes (Warrants 1, 2, 9, 10, 11, and 12).
- Include a reduction factor in warrants based upon the presence of certain types of pedestrian trip generators (Warrants 1, 2, 3, 9, 11, and 12).
- Change the existing pedestrian signal warrant to a mid-block only pedestrian crossing warrant, remove language about pedestrian crossing speeds, and add a reduction factor for high-speed roadways or built-up areas (Warrant 3).

These recommendations have been integrated into the current Texas MUTCD warrants and are included in Appendix A. Additionally, the recommendations have been integrated into the national Millennium MUTCD warrants were published in the December 2000 revision of the MUTCD and are shown in Appendix B.

The first two recommendations enhance the warranting process in that pedestrian and cyclist sensitivity is increased. In other words, implementation of the recommendation brings equality to the warranting process in that pedestrians, cyclists, and vehicles are treated equally. Furthermore, the warranting process is not significantly changed, and data collection needs are not unduly increased. The recommended warrants are easy to understand and use.

The suggestion to remove the walking speed reduction option is primarily based on the fact that walking speed should be accounted for when the calculation of an adequate-sized gap is performed. Furthermore, replacement of a reduction option that includes vehicle speed is based on the increased difficulty in judging gaps when traffic on a major street is moving faster and because of the increased pedestrian risk involved when crossing a street with high speeds. Also, the use of the same reduction option as used in vehicle volume warrants maintains consistency throughout the warrants.

IMPLICATIONS

In order to assess the impacts of the research recommendations, the data from the study sites used for the site assessment task were applied to the modified warrants to determine if the results match that of the engineers' professional judgment better than the results of the current MUTCD pedestrian signal warrant. Table 13 provides a summary of the results.

Table 13. Implications of Recommendations.

Site No.	Site Characteristics	Traffic Signal Needed?		
		Current Warrants	Modified Warrants	Engineers' Professional Judgment ①
1	One-way road at T-intersection	No	Yes	Yes
2	Typical 4-way intersection next to city park	No	No	No
3	T-intersection	No	No	No
4	Mid-block crossing	No	No	No
5	T-Intersection near college campus	Yes	Yes	Mixed

① Decided by majority of responses

There was only one site (site 1) where there was a difference between the results of the current warrant and the modified warrant. The engineers' professional judgment regarding a signal at this location favored the installation of a signal 7 to 5. The modified warrants would be satisfied at this location, providing the traffic engineer with additional flexibility to apply engineering judgment in borderline cases.

Site 5 was located in College Station, which is about a 2-hour drive from Austin, where sites 1 through 4 were located. Furthermore, most of the participants of the site assessment task lived and worked in Austin, making visits to the Austin sites more convenient than the College Station site. Consequently, only three responses were returned regarding site 5. The responses were split. Regardless, both the current pedestrian signal warrant and the modified warrants are satisfied at this location.

The mixed professional judgment responses for sites 1 and 5 demonstrate that the warrant process cannot be boiled down to a cookbook process. Engineering judgment is needed, and site specific conditions must be considered for each site. By implementing the modified warrants, the profession would be enhancing its recognition of pedestrians and cyclists and the rights these users have regarding use of the roadway network. In addition, the practicing engineer is afforded additional flexibility in satisfying a signal based on the needs of vehicles, pedestrians, and cyclists.

FUTURE RESEARCH

The recommendations currently include equality among pedestrians, cyclists, and vehicles. However, it is quite possible that different equivalency factors may be needed. There are many factors to consider and a number of different ways they can be implemented. For instance, recently published data indicate that 5 percent of the pedestrians struck by a vehicle traveling 20 mph will die. The fatality rate jumps to 40 percent for vehicles traveling 30 mph, 80 percent for vehicles going 40 mph, and 100 percent for vehicles going 50 mph or faster (*17*). Consequently, it may make sense to increase the pedestrian equivalency rate as vehicle speed increases. Additional research is needed to determine the most appropriate equivalency factors between pedestrians and vehicles and cyclists and vehicles.

It would also be beneficial to conduct additional case studies regarding the recommended warrants. Five locations were used herein and the results are promising. A more comprehensive analysis of the implications of adapting recommended warrants may be needed before they are accepted.

CHAPTER 5
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APPENDIX A

MODIFIED TEXAS MUTCD WARRANTS

CURRENT TRAFFIC SIGNAL WARRANTS

This Appendix provides the modified language of the Texas MUTCD sections addressing the 12 traffic signal warrants. The modifications include the recommendations of this research project.

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. The additional language from the Texas MUTCD that is not contained within the national MUTCD is distinguished using a different font.

RESEARCH RECOMMENDATIONS

For ease of reference, the recommendations of the research are summarized below. The warrants that are affected are shown for each recommendation.

- Include pedestrians and cyclists in the minor-street approach volumes for all warrants that currently consider only vehicles for the minor-street approach volumes (Warrants 1, 2, 9, 10, 11, and 12).
- Include a 30 percent volume reduction factor in the above warrants based upon the presence of certain types of pedestrian trip generators such as medical facilities, pedestrian transportation facilities, and activity centers serving pedestrians (Warrants 1, 2, 3, 9, 11, and 12).
- Change the existing pedestrian warrant to a mid-block only pedestrian crossing warrant, remove language about pedestrian crossing speeds, and add a reduction factor for high-speed roadways or built-up areas (Warrant 3).

MODIFIED TRAFFIC SIGNAL WARRANTS

Warrant 1, Minimum ~~Vehicular~~ Volume (4C-3)

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 Table A-1 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 A-1. 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, pedestrians, and cyclists 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.

The minor-street approach volumes (shown in Table A-1) may be reduced to 70 percent of the stated requirements when an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

Warrant 2, Interruption of Continuous Traffic (4C-4)

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 A-2. 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, pedestrians, and cyclists 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.

The minor-street approach volumes (shown in Table A-2) may be reduced to 70 percent of the stated requirements when an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.

- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

Warrant 3, Minimum Pedestrian Volume (4C-5)

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

100 or more for each of any four hours; or
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 feet per second.~~

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 Pedestrian Volume warrant is 70 percent of the requirements above.

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 feet 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 feet in advance of and 20 feet 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.

Signals may be installed at non-intersection locations (mid-block) provided the requirements of this warrant are met, and provided that the related crosswalk is not closer than 150 feet to another established crosswalk. Curbside parking should be prohibited for 100 feet in advance of and 20 feet 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.

The minimum pedestrian volumes (shown above) may be reduced to 70 percent of the stated requirements when an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

Warrant 4, School Crossing (4C-6)

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:

- Pedestrian indications shall be provided at least for each crosswalk established as a school crossing.
- 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.

- At non-intersection crossings, the signal should be pedestrian actuated, parking and other obstructions to view should be prohibited for at least 100 feet in advance of and 20 feet 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.

Warrant 5, Progressive Movement (4C-7)

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 feet.

Warrant 6, Accident Experience (4C-8)

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.

Warrant 7, Systems Warrant (4C-9)

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 five 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.

Warrant 8, Combination of Warrants (4C-10)

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.

Warrant 9, Four Hour Volume (4C-10.1)

The Four Hour Volume Warrant is satisfied when each of any four 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, pedestrians, and cyclists per hour on the higher volume minor street approach (one direction only) all fall above the curve in Figure A-1 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 four hour volume requirement is satisfied when the plotted points referred to fall above the curve in Figure A-2 for the existing combination of approach lanes.

When an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location, the four hour volume requirement is satisfied when the plotted points referred to fall above the curve in Figure A-2 for the existing combination of approach lanes:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

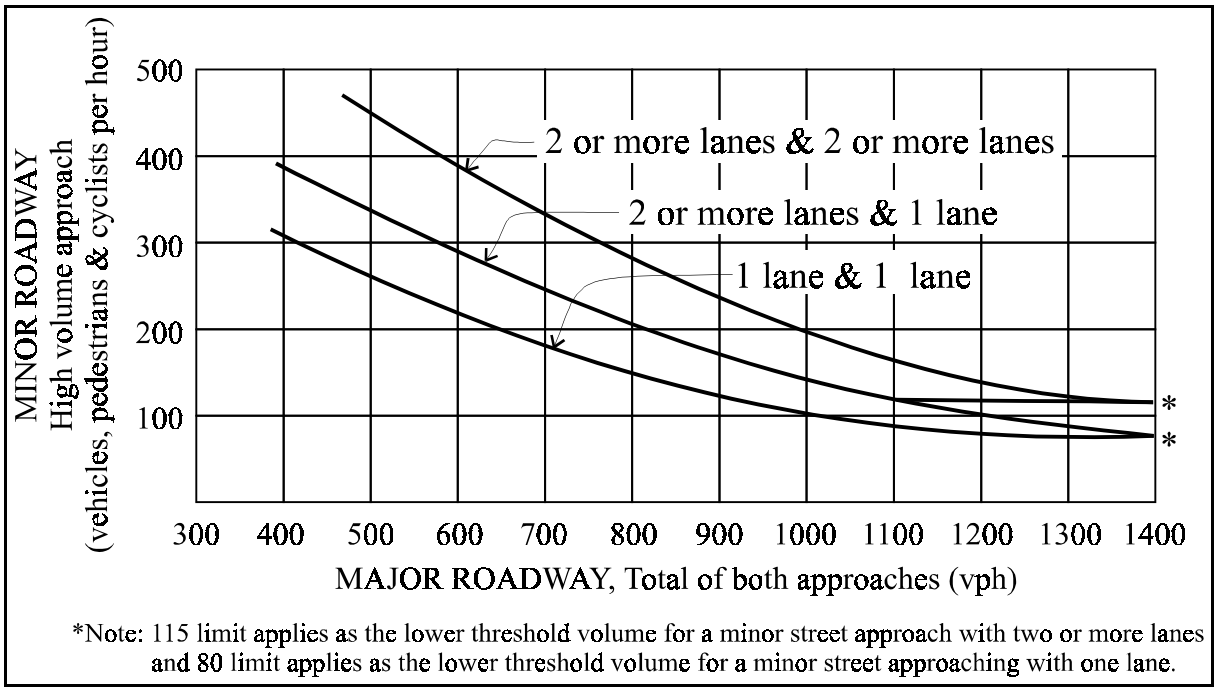


Figure A-1. Four Hour Volume Warrant.

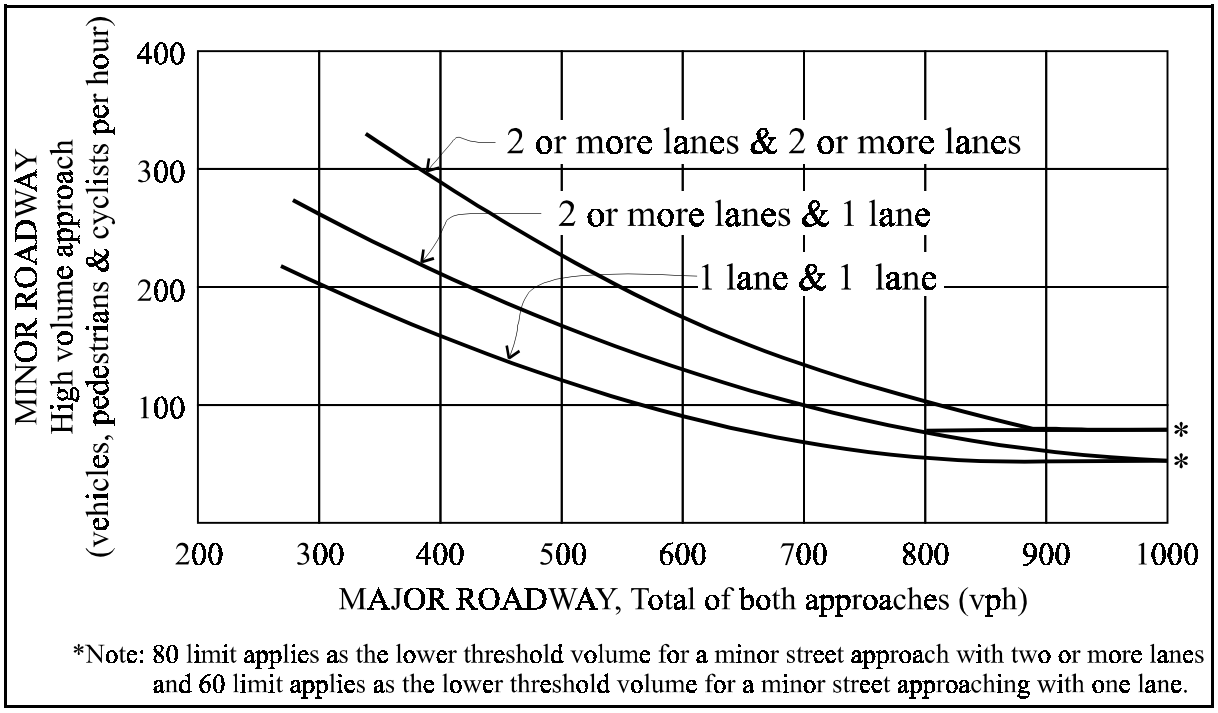


Figure A-2. Reduced Four Hour Volume Warrant.

Warrant 10, Peak Hour Delay (4C-10.2)

The Peak Hour Delay Warrant is intended for application where traffic conditions are such that for one 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 one 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 four vehicle-hours for a one-lane approach and five vehicle hours for a two-lane approach, and
2. The volume on the same minor street approach (one direction only) equals or exceeds 100 ~~vph~~ vehicles, pedestrians, and cyclists per hour for one moving lane of traffic or 150 ~~vph~~ vehicles, pedestrians, and cyclists per hour for two moving lanes, and
3. The total entering volume serviced during the hour equals or exceeds 800 ~~vph~~ vehicles, pedestrians, and cyclists per hour for intersections with four (or more) approaches or 650 ~~vph~~ vehicles, pedestrians, and cyclists per hour for intersections with three approaches.

Warrant 11, Peak Hour Volume (**4C-10.3)**

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 vehicles, pedestrians, and cyclists per hour of the higher volume minor street approach (one direction only) for one hour (any four consecutive 15-minute periods) of an average day falls above the curve in Figure A-3 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 requirement is satisfied when the plotted point referred to above falls above the curve in Figure A-4 for the existing combination of approach lanes.

When an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location, the peak hour volume requirement is satisfied when the plotted points referred to fall above the curve in Figure A-4 for the existing combination of approach lanes:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

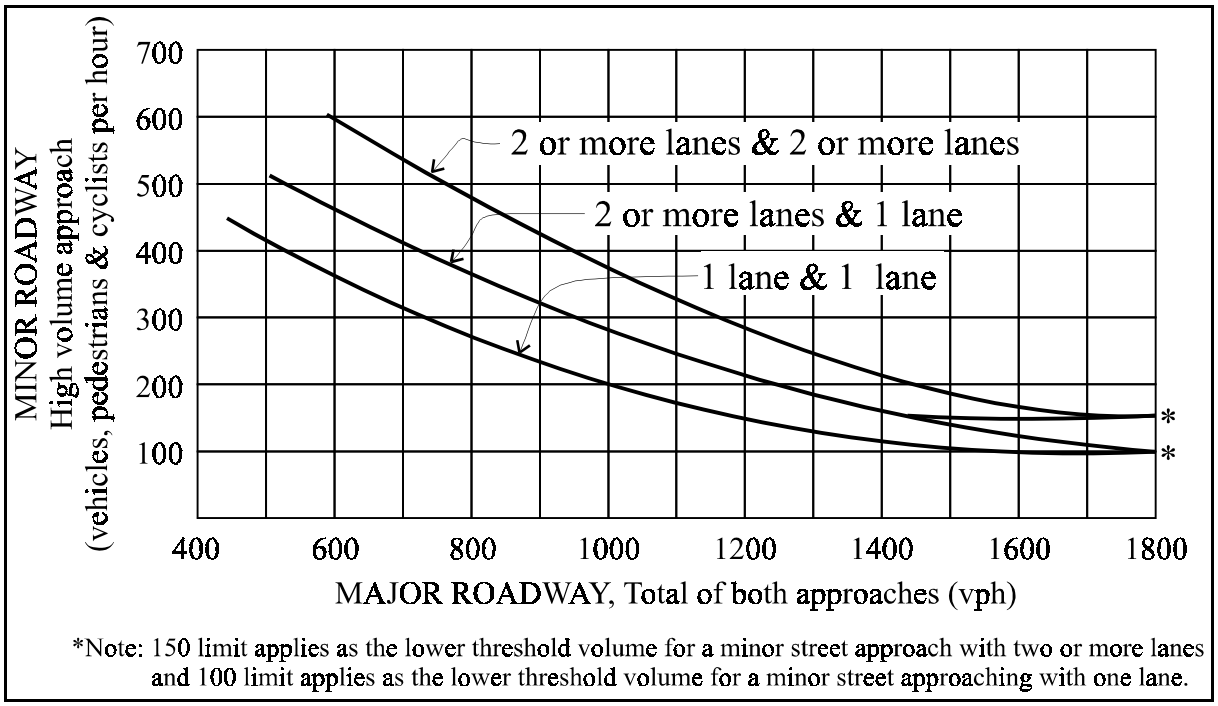


Figure A-3. Peak-Hour Volume Warrant.

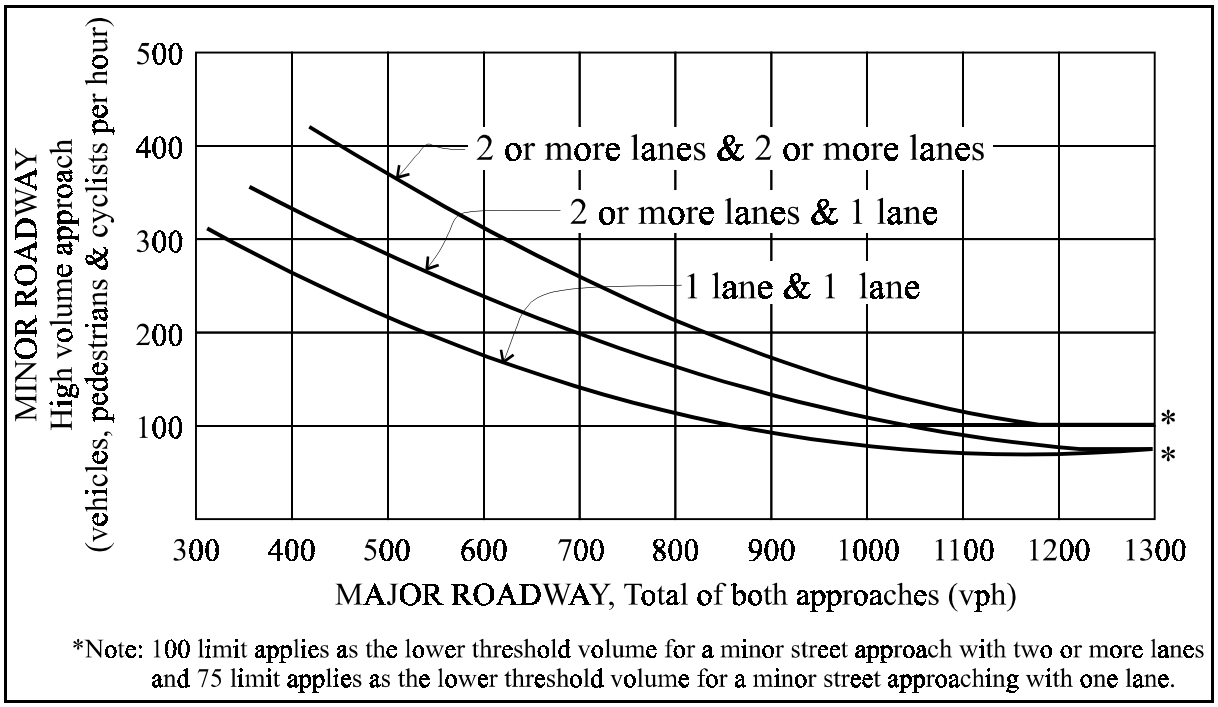


Figure A-4. Reduced Peak Hour Volume Warrant.

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

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 eight 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, pedestrians, and cyclists per hour on the higher volume minor street (one direction only), all lie above the applicable curve in Figures A-5 and A-6. The major street and minor street volumes are for the same eight hours.
2. For each of any two 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, pedestrians, and cyclists per hour on the higher volume minor street (one direction only), all lie above the applicable curve in Figures A-7 and A-8. The major street and minor street volumes are for the same two 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.

When an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location, the rural warrant curves should be utilized:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.

- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

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.

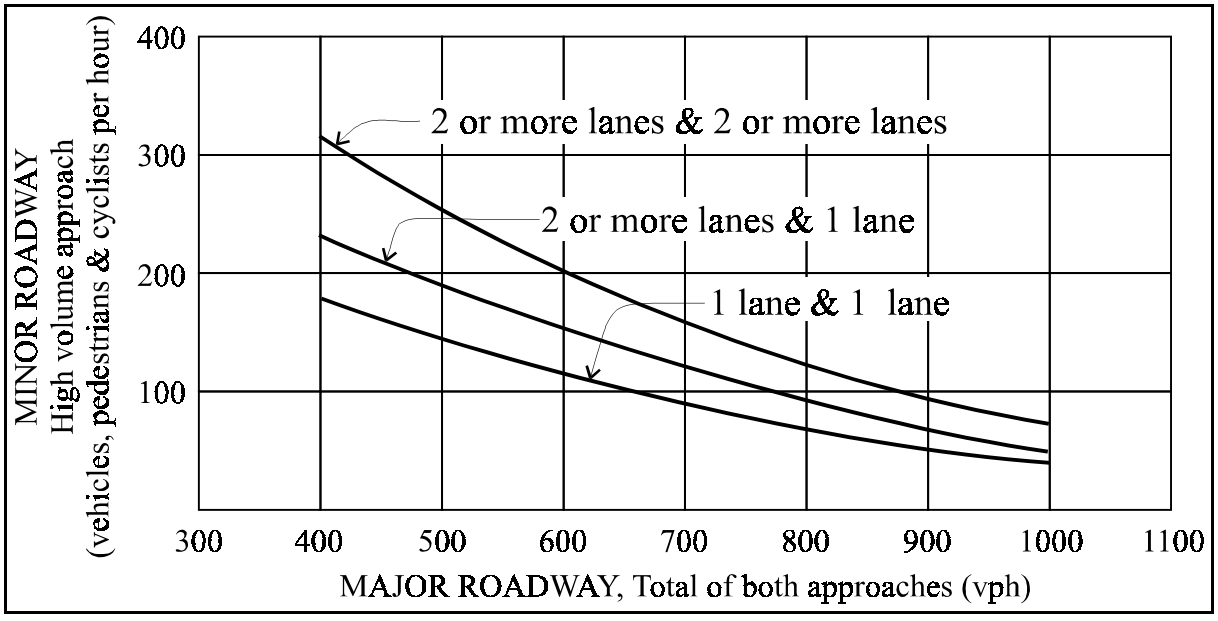


Figure A-5. Urban, Eight-Hour Traffic Actuated Warrant.

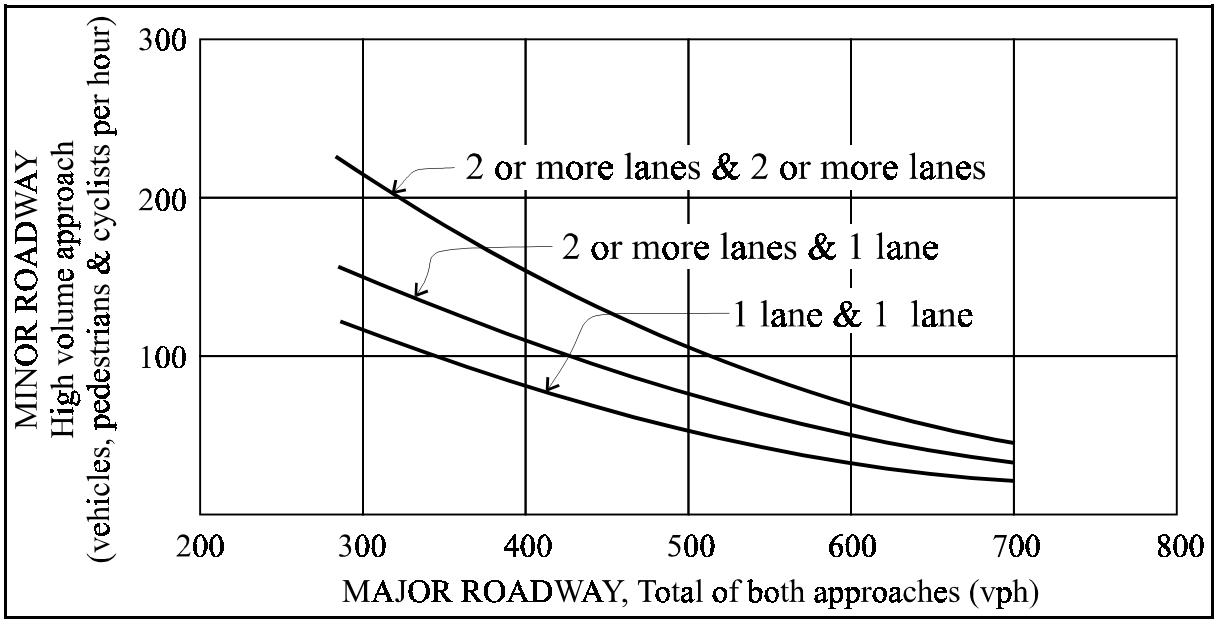


Figure A-6. Rural, Eight-Hour Traffic Actuated Warrant.

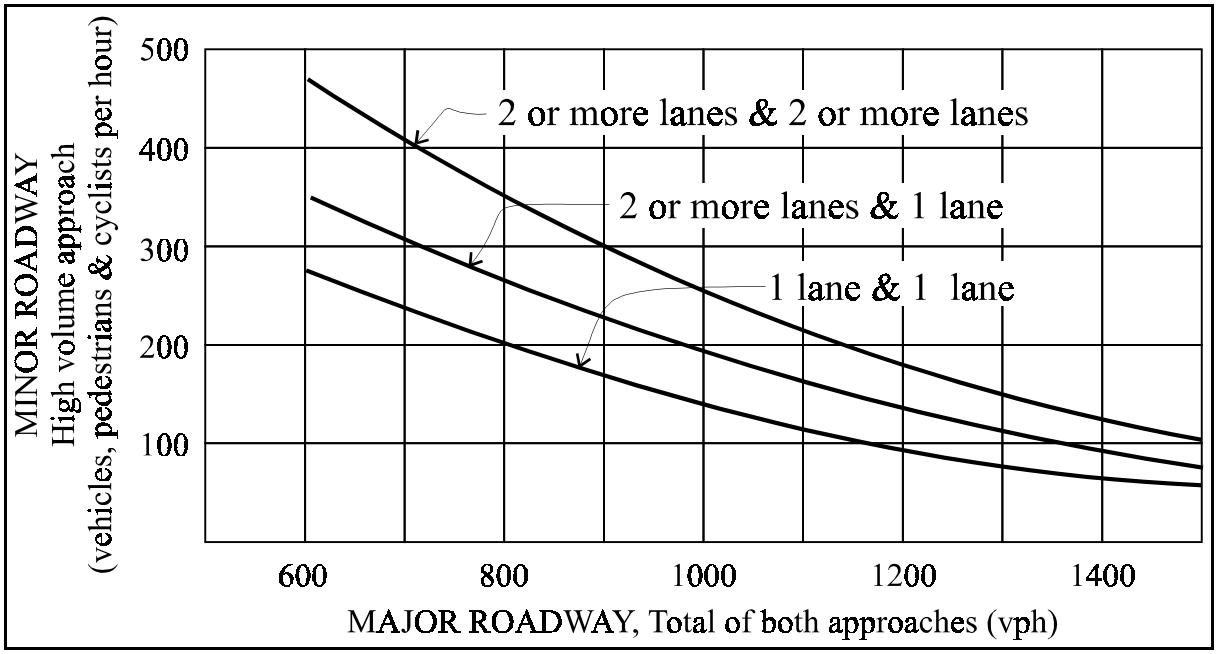


Figure A-7. Urban, Two-Hour Traffic Actuated Warrant.

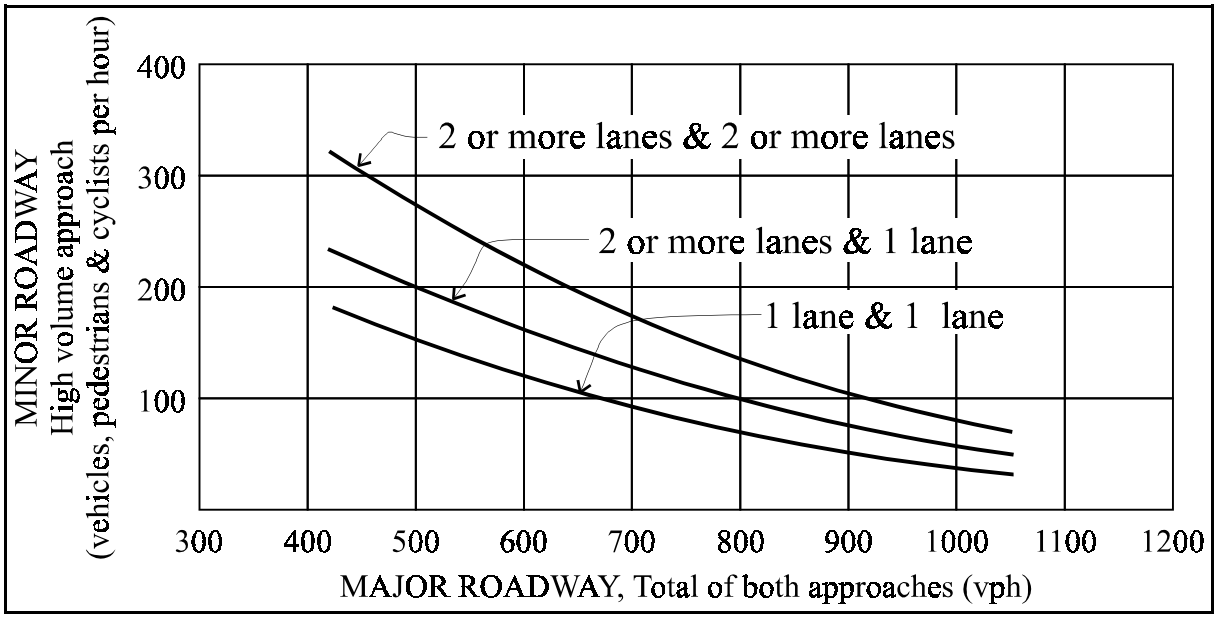


Figure A-8. Rural, Two-Hour Traffic Actuated Warrant.

APPENDIX B

MODIFIED NATIONAL WARRANTS

TRAFFIC SIGNAL WARRANTS

Continuing advances in technology have and will continue to produce changes in the highway, the vehicle, and in driver proficiency. Accordingly, portions of the system of control devices in the MUTCD will require updating. The National Committee on Uniform Traffic Control Devices (NCUTCD) and the Federal Highway Administration (FHWA) have recently completed the massive task of rewriting the MUTCD to meet the demands that have developed since the last edition was published in 1988. The Millennium MUTCD was published in December 2000.

Section 4C of the Millennium MUTCD lists eight warrants for determining the threshold condition for installation of a highway traffic control signal. The number of national warrants was reduced from eleven warrants to eight warrants. This is in response to FHWA receiving a number of complaints concerning the number and complexity of the current warrants. The following is a brief summary of how the warrants were reduced:

1. The Interruption of Continuous Traffic Warrant will be combined with the new warrant number 1 entitled, “Eight-Hour Vehicular Volume Warrant.”
2. Warrant 8 will be incorporated into warrant 1.
3. The Peak-Hour Delay Warrant will be included in warrant 3.

The results of these efforts are the eight warrants listed below. This Appendix includes a reproduction of these warrants, modified to include the recommendations of this research.

- Warrant 1 - Eight-Hour Vehicular Volume
- Warrant 2 - Four-Hour Vehicular Volume
- Warrant 3 - Peak-Hour Volume
- Warrant 4 - Pedestrian Volume
- Warrant 5 - School Crossing
- Warrant 6 - Coordinated Signal System
- Warrant 7 - Crash Experience
- Warrant 8 - Roadway Network

In addition to reducing the number and complexity of the warrants, the Millennium MUTCD also contains other significant changes. Among them is the formatting. NCUTCD has eliminated inconsistent and ambiguous language, such as “it is desirable that,” “shall preferably be,” “may be required,” “may be justified,” “shall be permitted,” “it is necessary that,” “normally should,” and “is intended for use.” The reformatting of the MUTCD language is summarized in Table B-1.

Table B-1. Reformatting Guidelines for the Proposed MUTCD

Heading	Description	Typical Phrases
Standard:	Mandatory actions, which are required without exceptions or with exceptions so noted, under this heading.	Shall, shall mean, shall be satisfied, shall consist
Guidance:	Advisory usage, recommended but not mandatory with deviations allowed where engineering judgment indicates the deviation to be appropriate.	Should, should be used, should be considered, should be given
Option**:**	Includes those procedures and devices which are allowed but carry no recommendation or mandate. The user is free to use or refrain from their use.	May, may be used, may be considered
Support:	Includes all introductory or explanatory language. It may occur before, within, or after any heading, but shall be clearly marked as "Support."	Is, are, warrants, considered, required [1]
Notes: [1] Support words may be used provided there is no intention of mandating, recommending, or authorizing any procedure or device under this heading.		

Warrant 1, Eight-Hour ~~Vehicular~~ Volume (4C-02)

Support:

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

The Interruption of Continuous Traffic, Condition B, is intended for application where the traffic volume on a major roadway is so heavy that traffic on a minor intersecting roadway suffers excessive delay or hazard in entering or crossing the major roadway.

Standard:

The need for a traffic control signal shall be considered if one of the following conditions exist for each of any 8 hours of an average day.

A. The ~~vehicles per hour~~ volumes given in both of the 100 percent columns of condition A in Table B-2 exist on the major roadway and on the higher volume minor roadway approaches, respectively, to the intersection, or

B. The ~~vehicles per hour~~ volumes per hour given in both of the 100 percent columns of condition B in Table B-2 exist on the major roadway and on the higher volume minor roadway approaches, respectively, to the intersection.

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

Table B-2. Warrant 1. Eight-Hour ~~Vehicular~~ Volume

	Number of lanes for moving traffic on each approach		Vehicles per hour on major roadway (total of both approaches)			Vehicles, pedestrians, and cyclists per hour on higher-volume minor-roadway approach (one direction only)		
Condition A Minimum ~~Vehicular~~ Volume	Major roadway	Minor roadway	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
	1	1	500	400	350	150	120	105
	2 or more	1	600	480	420	150	120	105
	2 or more	2 or more	600	480	420	200	160	140
	1	2 or more	500	400	350	200	160	140
Condition B Interruption of Continuous Traffic	Major roadway	Minor roadway	100%[a]	80%[b]	70%[c]	100%[a]	80%[b]	70%[c]
	1	1	750	600	525	75	60	53
	2 or more	1	900	720	630	75	60	53
	2 or more	2 or more	900	720	630	100	80	70
	1	2 or more	750	600	525	100	80	70

Notes:
[a] Basic minimum hourly volume.
[b] Used for combination of conditions A and B after adequate trial of other remedial measures.
[c] May be used when the major roadway speed exceeds 65 km/h (40 mph) or in an isolated community with a population of less than 10,000 or when the proposed crossing location is located within 300 feet of the identified pedestrian trip generators.

Option**:**

If the posted or statutory speed limit or the 85th-percentile speed on the major roadway exceeds 70 km/h (40 mph), or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table B-2 may be used in place of the 100 percent columns.

The minor-street approach volumes (shown in Table B-2) may be reduced to 70 percent of the stated requirements when an entrance to one or more of the following pedestrian trip generators is located within 300 feet of the proposed crossing location:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

Standard:

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

A. The ~~vehicles per hour~~ volumes given in the 80 percent columns of Condition A in Table B-2 exist on the major roadway and on the higher volume minor roadway approaches, respectively, to the intersection, and

B. The ~~vehicles per hour~~ volumes given in the 80 percent columns of Condition B in Table B-2 exist on the major roadway and on the higher volume minor roadway approaches, respectively, to the intersection.

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

Guidance:

The combination of Conditions A and B should be applied only after adequate trial of other less restrictive alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.

Warrant 2, Four-Hour ~~Vehicular~~ Volume (4C-03)

Support:

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

Standard:

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

Option**:**

If the posted or statutory speed limit or the 85th-percentile speed on the major roadway exceeds 70 km/h, or the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure B-2 may be used in place of Figure B-1.

If the proposed crossing location is located within 300 feet of the following pedestrian trip generators, Figure B-2 may be used in place of Figure B-1:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

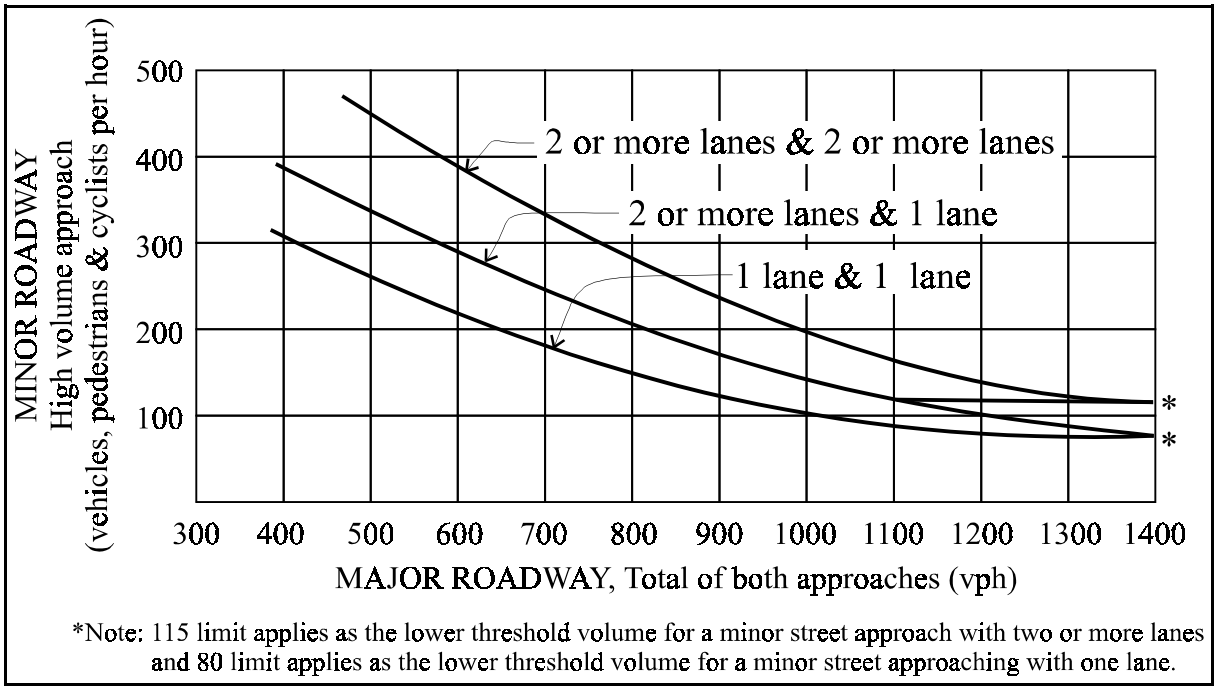


Figure B-1. Four-Hour Volume Warrant

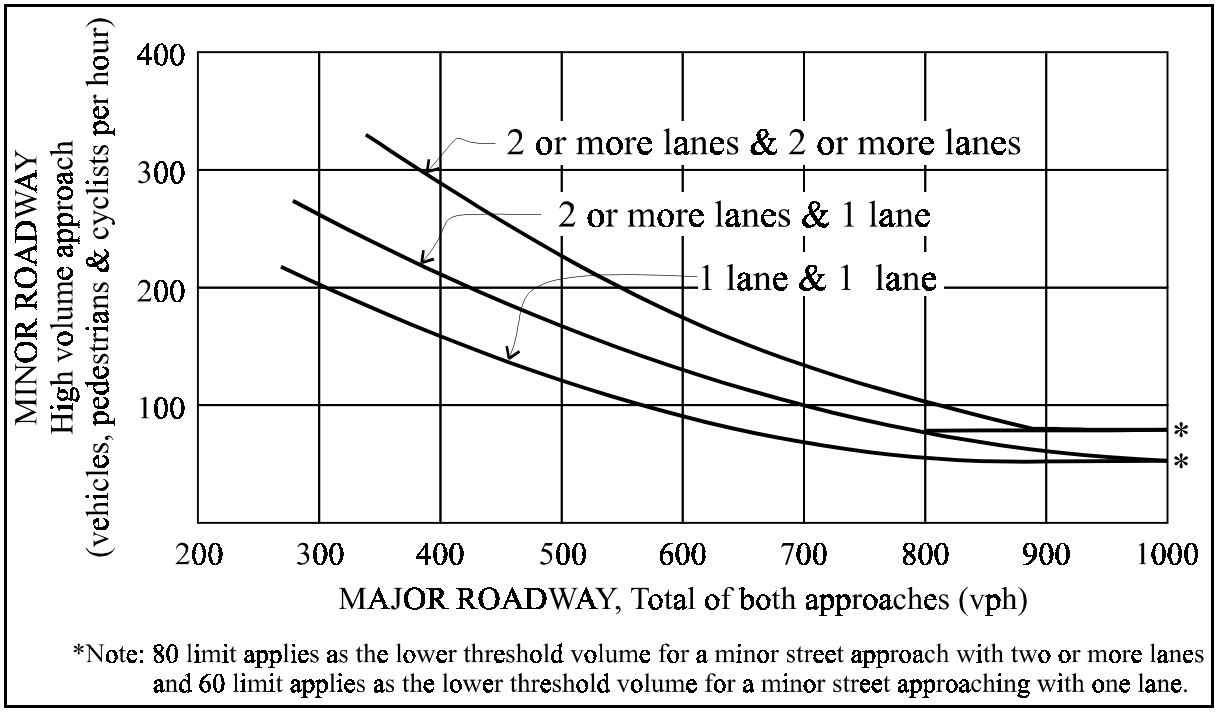


Figure B-2. Reduced Four-Hour Volume Warrant

Warrant 3, Peak Hour (4C-04)

Support:

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

Standard:

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

The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:

- **A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15- minute periods) of an average day:**
  1. **The total delay experienced by the traffic on one minor-roadway approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach; or 5 vehicle-hours for a two-lane approach, and**
  2. **The volume on the same minor-roadway approach (one direction only) equals or exceeds 100 ~~vph~~ vehicles, pedestrians, and cyclists per hour for one moving lane of traffic or 150 ~~vph~~ vehicles, pedestrians, and cyclists per hour for two moving lanes.**
  3. **The total entering volume serviced during the hour equals or exceeds 650 ~~vph~~ vehicles, pedestrians, and cyclists per hour for intersections with three approaches or 800 ~~vph~~ vehicles, pedestrians, and cyclists per hour for intersections with four or more approaches.**
- **B. The plotted point representing the vehicles per hour on the major roadway (total of both approaches) and the corresponding vehicles, pedestrians, and cyclists per hour on the higher-volume minor-roadway approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure B-3 for the existing combination of approach lanes.**

Option**:**

If the posted or statutory speed limit or the 85th-percentile speed on the major roadway exceeds 70 km/h, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure B-4 may be used in place of Figure B-3 to satisfy the criteria in the second category of the standard.

If the proposed crossing location is located within 300 feet of the following pedestrian trip generators, Figure B-4 may be used in place of Figure B-3:

- medical facilities – includes hospitals and medical clinics.
- housing for pedestrian or transit-dependent populations – includes retirement homes, senior housing, student housing, high-density low-income housing, and hospice centers.
- service centers for pedestrian or transit-dependent populations – includes senior service centers, disabled service centers, and child and adult protective service centers.
- pedestrian transportation facilities – includes staircases or trails connecting grade-separated transportation facilities; shared use trail crossings; neighborhood plan-designated key pedestrian linkages; transit transfer points, stations, and stops; and bridges where at least one side of the bridge is restricted to pedestrians.
- activity centers serving pedestrians – includes parks, libraries, and community centers.

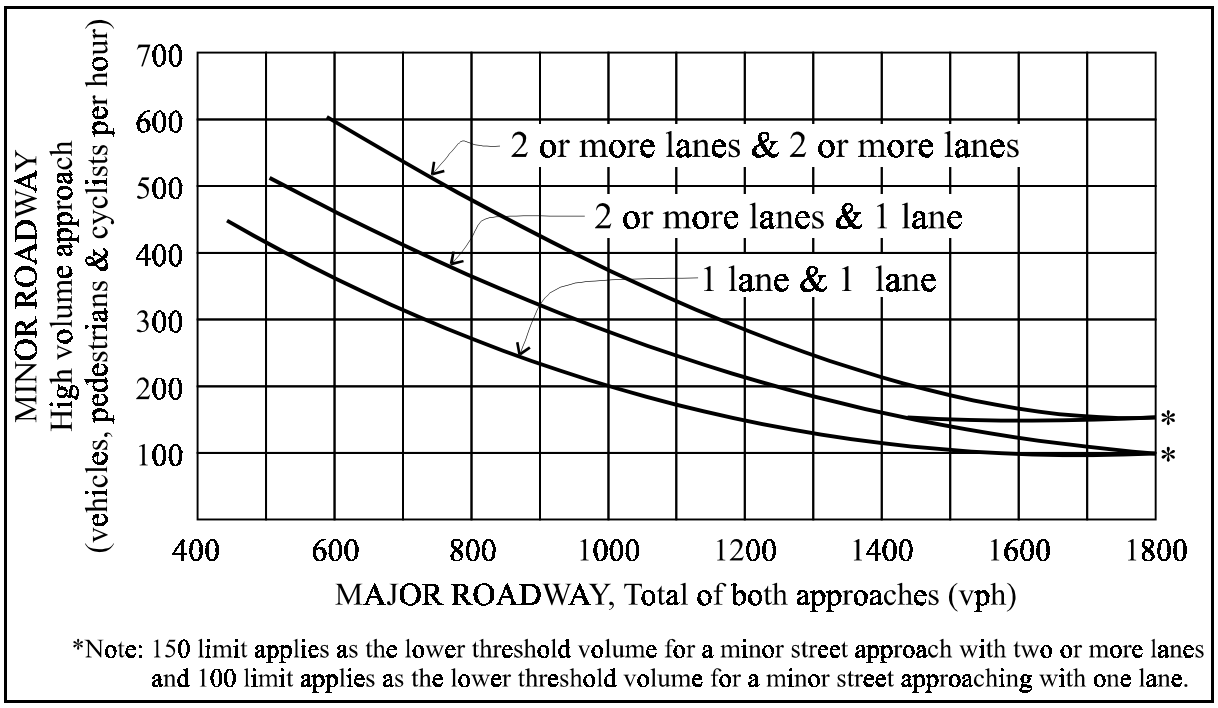


Figure B-3. Peak-Hour Volume Warrant

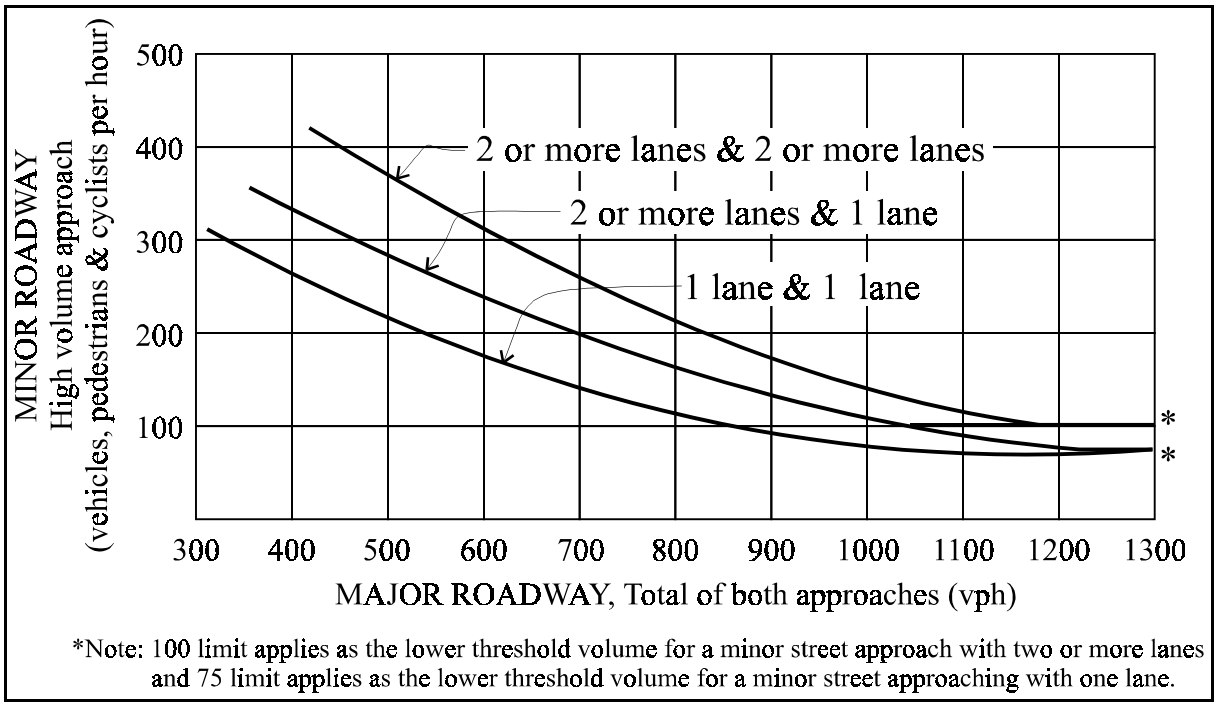


Figure B-4. Reduced Peak-Hour Volume Warrant

Warrant 4, Mid-Block Pedestrian Volume (4C-05)

Support:

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

Standard:

The need for a traffic control signal ~~at intersections or~~ mid-block crossings shall be considered if an engineering study finds that both of the following criteria are met:

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

The Pedestrian Volume Warrant shall not be applied at locations where the distance to the nearest traffic control signal installation along the major roadway is less than 90 meters, unless the new traffic control signal will not restrict the progressive movement of traffic.

A traffic control signal installation justified by both this warrant and a traffic engineering study shall be equipped with pedestrian signal heads conforming to requirements set forth in Chapter 4E.

Guidance:

If a traffic control signal installation is justified by both this warrant and a traffic engineering study:

A. If installed within a signal system, the traffic control signal installation should be coordinated.
B. At an intersection, the traffic control signal installation should be traffic-actuated and should include pedestrian detectors. As a minimum, it should have semi-actuated operation, but full actuation operation with detectors on all approaches might also be appropriate.
C. At non-intersection crossings, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and at least 6 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.

Option**:**

~~The criterion for pedestrian volume crossing the major roadway may be reduced as much as 50 percent if the average crossing speed of pedestrians is less than 1.2 m/sec (4ft/sec).~~

~~A traffic control signal installation may not be needed at the study location if adjacent coordinated traffic control signal installations consistently provide gaps of adequate length for pedestrians to cross the roadway, even if the rate of gap occurrence is less than one per minute.~~

If the posted or statutory speed limit or the 85th-percentile speed on major-street traffic exceeds 65 km/h, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the Mid-Block Pedestrian Volume warrant is 70 percent of the requirements above.

Warrant 5, School Crossing (4C-06)

Support:

The School Crossing sign warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal.

Standard:

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

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

The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 90 m (300 ft), unless the proposed traffic control signal will not restrict the progressive movement of traffic.

Guidance:

If a traffic control signal is justified by both this signal warrant and an engineering study:

A. If installed within a signal system, the traffic control signal should be coordinated.
B. At an intersection, the traffic control signal should be traffic-actuated and should include pedestrian detectors. As a minimum, it should have semi-actuated operation, but full-actuated operation with detectors on all approaches might also be appropriate.
C. At non-intersection crossings, the traffic control signal should be pedestrian-actuated, parking and other sight obstructions should be prohibited for at least 30 m (100 ft) in advance of and as least 6.1 m (20 ft) beyond the crosswalk, and the installation should include suitable standard signs and pavement markings.

Warrant 6, Coordinated Signal System (**4C-07**)

Support:

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

Standard:

The need for a traffic control signal shall be considered if one of the following criteria is met:

A. On a one-way roadway or a roadway that has traffic predominantly in one direction, the adjacent traffic control signal installations are so far apart that they do not provide the necessary degree of vehicle platooning.
B. On a two-way roadway, adjacent traffic control signal installations do not provide the necessary degree of platooning, and the proposed and adjacent traffic control signal installations will collectively provide a progressive operation.

Guidance:

The Coordinated Signal System Warrant should not be applied where the resultant spacing of traffic signal installations would be less than 300 m (1,000 ft).

Warrant 7, Crash Experience (**4C-08**)

Support:

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

Standard:

The need for a traffic control signal shall be considered is an engineering study finds that all of the following criteria are met:

A. Adequate trial of less restrictive alternatives with satisfactory observance and enforcement has failed to reduce the accident frequency.
B. Five or more reported accidents, of types susceptible to correction by traffic control signal have occurred within a 12-month period, each accident involving personal injury or property damage apparently exceeding the applicable requirements for a reportable accident.
C. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 14 (see Section 4C.02), or in both of the 80 percent columns of Condition B in Table 14 exist on the major roadway and on the higher-volume minor-roadway approach, respectively, to the intersection, or the vph in both of the 80 percent columns of Condition B in Table 14 exist on the major roadway and on the higher-volume minor-roadway approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the pedestrian volume warrant. These major-roadway and minor-roadway volumes shall be for the same 8 hours. On the minor roadway, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Warrant 8, Roadway Network (4C-09)

Support:

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

Standard:

The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two of more major routes meets one or both of the following criteria:

- **A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vph during the peak hour of a typical weekday and has 5 year projected traffic volumes, based on an engineering study, that meet one or more of warrants 1, 2, and 3 during an average weekday, or**
- **B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vph for each of any 5 hours of a non-normal business day (Saturday or Sunday).**

A major route, as used in this warrant, shall have one or more of the following characteristics:

- **A. It is part of the roadway or highway system that serves as the principal network for through traffic flow.**
- **B. It includes rural or suburban highways outside, entering, or traversing a city.**
- **C. It appears as a major route on an official plan, such as a major roadway plan in an urban area traffic and transportation study.**

APPENDIX C

SITE ASSESSMENT WORKSHEET

Revising the Pedestrian Traffic Signal Warrant
Project Advisory Committee & Volunteers

Dear friends:

Project advisory committee members and volunteers, the time has come for your input into current TxDOT-sponsored research aimed at investigating potential revisions to the Pedestrian Traffic Signal Warrant. This packet of information includes maps, summarized data for five areas where pedestrian issues are of concern, and worksheets. Four of these areas are in Austin and one in College Station.

The summarized data may or may not include all the pertinent factors that may be needed to fully understand the issues at each site. However, the data should provide a relatively reasonable representation of the vehicular and pedestrian operations at the site. The data has been provided for you to make a site visit any time during the week and have a better understanding of operations at times other than your visit. Operations at each site were recorded for approximately 14-hours during a typical weekday. Specific dates and other pertinent notes are included hereafter.

What we need from you is to make a site visit to preferably all five sites. With the data in hand, using your engineering judgement or expert opinion, please make an assessment of the need for a traffic signal based on pedestrian factors. If you feel that something less restrictive than a traffic signal is needed, please indicate so. Group site visits and discussions are encouraged but individual responses are requested. The more the better.

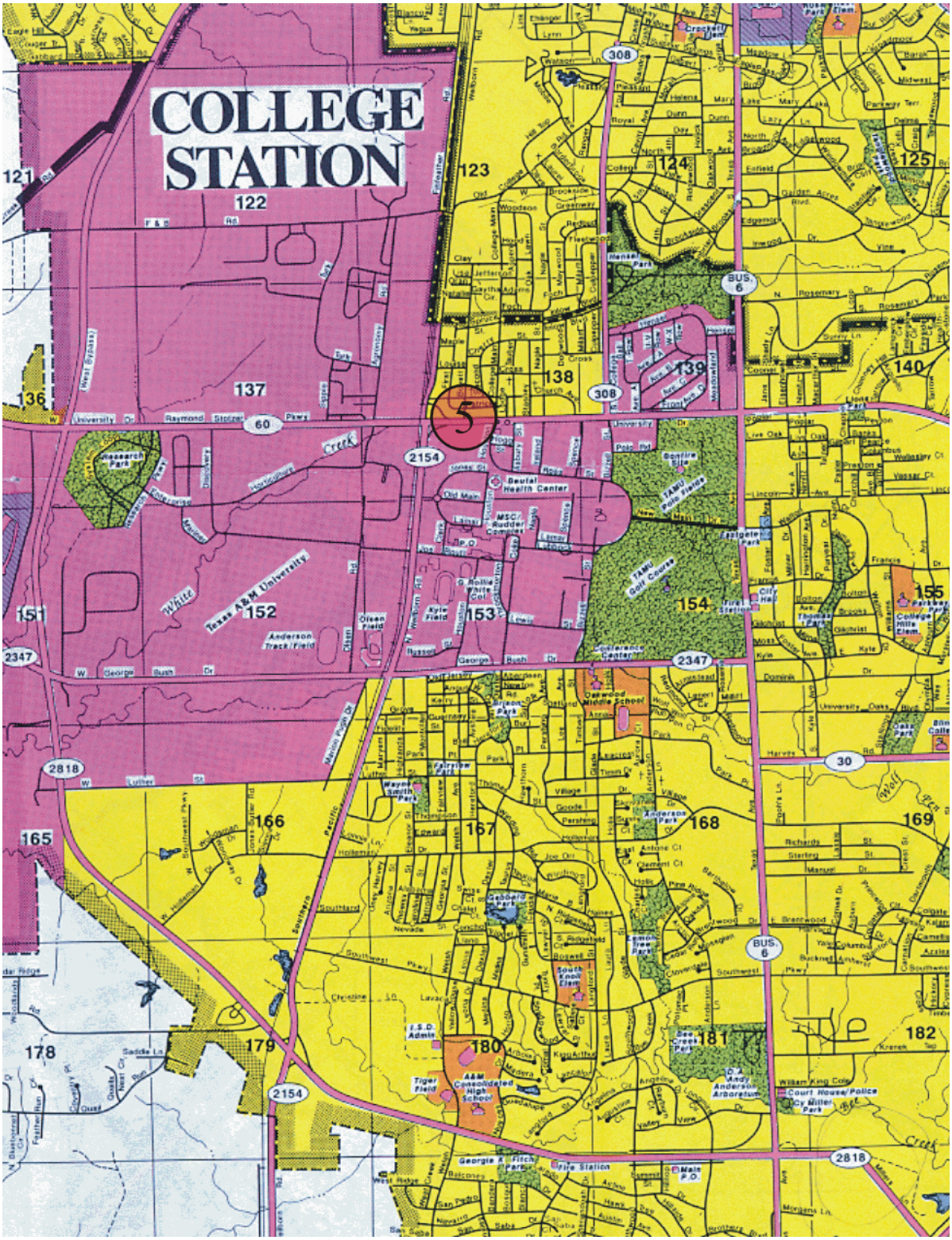
I know that this task is dependent on your travel schedules and we all are busier than ever. We would truly appreciate it if you could respond by August 9. If you have any questions, please call me or Shawn Turner. Thank you for your cooperation.

Sincerely,

Paul J. Carlson

MAP OF AUSTIN WITH FIRST FOUR SITES

MAP OF COLLEGE STATION WITH FIFTH SITE



SITE 1 – Fifth Street (between MOPAC and Powell)

Eastbound View

5th Street

DATA FOR SITE 1

TIME (hourly)	Peds	Vehs total	Good Gaps (>10.3 sec)
7:00 - 8:00	3	1241	42
7:15 - 8:15	6	1255	47
7:30 - 8:30	8	1300	45
7:45 - 8:45	8	1337	38
8:00 - 9:00	9	1342	34
8:15 - 9:15	7	1339	36
8:30 - 9:30	8	1297	32
8:45 - 9:45	9	1242	32
9:00 - 10:00	7	1200	28
9:15 - 10:15	9	1161	26
9:30 - 10:30	16	1137	27
9:45 - 10:45	23	1094	29
10:00 - 11:00	23	1073	28
10:15 - 11:15	20	1074	26
10:30 - 11:30	14	1101	25
10:45 - 11:45	30	1109	35
11:00 - 12:00	59	1118	39
11:15 - 12:15	78	1113	38
11:30 - 12:30	90	1087	44
11:45 - 12:45	81	1122	39
12:00 - 13:00	76	1108	43
12:15 - 13:15	76	1117	54
12:30 - 13:30	80	1128	55
12:45 - 13:45	72	1138	49
13:00 - 14:00	52	1158	42
13:15 - 14:15	38	1145	41
13:30 - 14:30	23	1117	37
13:45 - 14:45	23	1078	37
14:00 - 15:00	21	1074	38
14:15 - 15:15	22	1035	32
14:30 - 15:30	19	1047	30
14:45 - 15:45	19	1066	30
15:00 - 16:00	21	1058	29
15:15 - 16:15	16	1060	28
15:30 - 16:30	17	1024	37
15:45 - 16:45	12	1001	41
16:00 - 17:00	19	985	41
16:15 - 17:15	25	1017	35
16:30 - 17:30	29	1051	29
16:45 - 17:45	48	1044	25
17:00 - 18:00	58	1061	23
17:15 - 18:15	94	1057	29
17:30 - 18:30	120	1082	27
17:45 - 18:45	128	1120	24
18:00 - 19:00	146	1102	32
18:15 - 19:15	120	1071	48
18:30 - 19:30	98	991	69
18:45 - 19:45	73	903	97

Dist to nearest signal

WB	0.6 mile
EB	0.3 mile

85th % Speeds (mph)

EB	41

Data Collection Date:

April 20, 2000

Notes:

ONE-WAY

RESPONSE AREA FOR SITE 1

Using the data provided, observations made during your site visit, and your expert opinion, do you think a traffic signal should be installed here (please disregard the warrant analysis results when making this decision)?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

Is a form of less restrictive traffic control needed here?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

According to the current MUTCD Pedestrian Traffic Signal warrant, this site does not meet the non-reduced criteria. Do you agree with this finding?

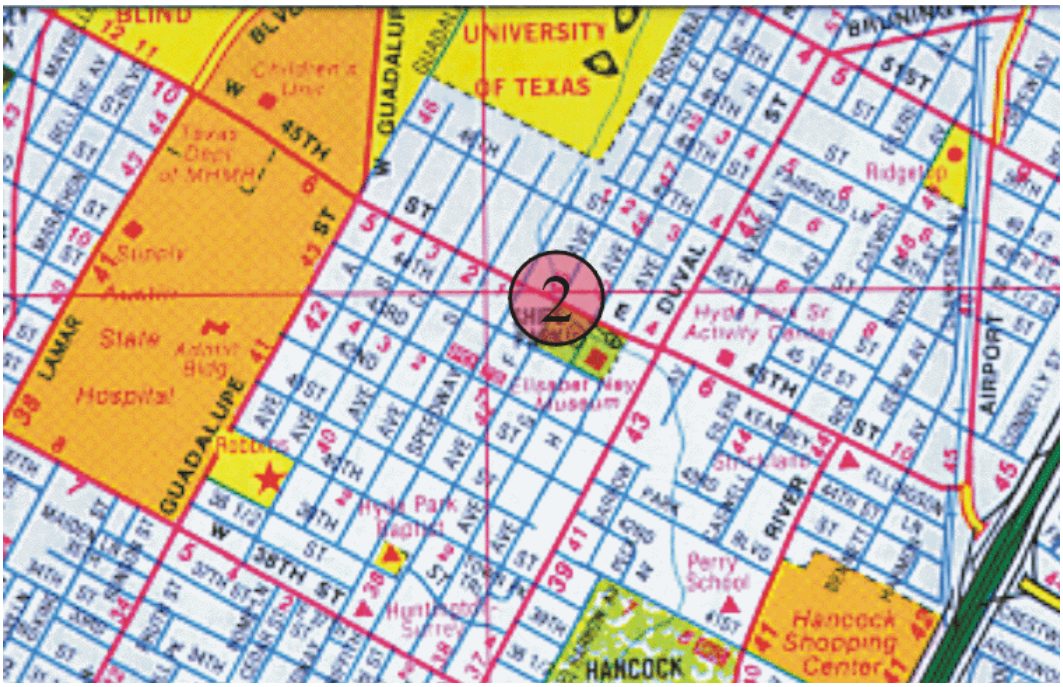
❒Yes ❒No

If no, please explain why. In other words, what factors led you to make you decision that are not part of the current warrant? Should other factors be considered in this case?

Date & Time of site visit: _____

SITE 2 – 45th Street (between Speedway and Duval)

Eastbound View



45th Street

DATA FOR SITE 2

TIME (hourly)	Peds Only	Peds & Bikes	Vehs total	Good Gaps (>11.4 sec)
7:00 - 8:00	17	26	713	100
7:15 - 8:15	14	20	972	109
7:30 - 8:30	18	25	1020	105
7:45 - 8:45	19	26	1025	107
8:00 - 9:00	20	32	961	116
8:15 - 9:15	26	41	899	106
8:30 - 9:30	25	43	848	109
8:45 - 9:45	27	46	803	109
9:00 - 10:00	30	45	800	105
9:15 - 10:15	32	46	806	112
9:30 - 10:30	32	42	795	117
9:45 - 10:45	30	38	808	105
10:00 - 11:00	26	33	778	113
10:15 - 11:15	27	37	768	119
10:30 - 11:30	27	39	818	114
10:45 - 11:45	25	38	851	114
11:00 - 12:00	29	46	900	120
11:15 - 12:15	22	36	997	110
11:30 - 12:30	22	35	1043	104
11:45 - 12:45	18	29	1111	104
12:00 - 13:00	22	34	1173	100
12:15 - 13:15	28	40	1151	98
12:30 - 13:30	24	39	1172	95
12:45 - 13:45	25	39	1136	98
13:00 - 14:00	16	25	1111	100
13:15 - 14:15	11	17	1101	103
13:30 - 14:30	11	15	1051	103
13:45 - 14:45	13	17	1040	95
14:00 - 15:00	16	21	1041	100
14:15 - 15:15	14	20	1061	105
14:30 - 15:30	12	17	1082	111
14:45 - 15:45	16	21	1067	117
15:00 - 16:00	14	23	1058	118
15:15 - 16:15	17	29	1060	117
15:30 - 16:30	21	34	1066	114
15:45 - 16:45	17	36	1123	116
16:00 - 17:00	21	39	1192	110
16:15 - 17:15	22	42	1246	99
16:30 - 17:30	22	47	1277	96
16:45 - 17:45	23	49	1270	90
17:00 - 18:00	24	53	1210	89
17:15 - 18:15	27	54	1146	98
17:30 - 18:30	26	51	1113	98
17:45 - 18:45	29	55	1074	101
18:00 - 19:00	33	60	1031	100
18:15 - 19:15	30	58	969	98
18:30 - 19:30	34	64	880	99
18:45 - 19:45	31	56	792	102

Dist to nearest signal

WB	0.1 mile
EB	0.2 mile

85th % Speeds (mph)

WB	39
EB	38

Data Collection Date:

May 24, 2000

Notes:

Neighborhood Park

RESPONSE AREA FOR SITE 2

Using the data provided, observations made during your site visit, and your expert opinion, do you think a traffic signal should be installed here (please disregard the warrant analysis results when making this decision)?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

Is a form of less restrictive traffic control needed here?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

According to the current MUTCD Pedestrian Traffic Signal warrant, this site does not meet the non-reduced criteria. Do you agree with this finding?

❒Yes ❒No

If no, please explain why. In other words, what factors led you to make you decision that are not part of the current warrant? Should other factors be considered in this case?

Date & Time of site visit: _____

SITE 3 – South Lamar (between Oltorf and Barton Springs)

Northbound View

South Lamar

DATA FOR SITE 3

TIME (hourly)	Peds Only	Peds & Bikes	Vehs total	Good Gaps NB	Good Gaps SB	Good Gaps (>15.7 sec)
7:00 - 8:00	7	14	1487	81	96	34
7:15 - 8:15	10	20	1601	86	126	32
7:30 - 8:30	10	20	1572	91	126	38
7:45 - 8:45	14	28	1555	92	128	39
8:00 - 9:00	12	26	1545	99	126	42
8:15 - 9:15	11	24	1527	109	132	46
8:30 - 9:30	10	24	1526	113	134	48
8:45 - 9:45	6	17	1476	124	132	50
9:00 - 10:00	5	14	1482	127	132	52
9:15 - 10:15	11	29	1432	130	132	52
9:30 - 10:30	13	32	1421	132	131	53
9:45 - 10:45	15	36	1456	129	142	54
10:00 - 11:00	15	35	1415	130	144	54
10:15 - 11:15	9	20	1486	127	139	52
10:30 - 11:30	12	25	1552	129	138	53
10:45 - 11:45	25	52	1619	131	124	45
11:00 - 12:00	31	64	1718	126	120	43
11:15 - 12:15	32	66	1782	127	112	40
11:30 - 12:30	30	62	1910	116	98	31
11:45 - 12:45	22	44	1944	112	102	32
12:00 - 13:00	18	36	2040	108	89	26
12:15 - 13:15	18	36	2052	100	98	27
12:30 - 13:30	18	36	1996	105	105	33
12:45 - 13:45	16	33	1988	107	105	33
13:00 - 14:00	18	37	1881	116	110	35
13:15 - 14:15	22	46	1871	122	110	36
13:30 - 14:30	23	49	1831	132	114	38
13:45 - 14:45	23	49	1793	140	110	41
14:00 - 15:00	22	48	1812	140	113	37
14:15 - 15:15	18	39	1781	135	115	41
14:30 - 15:30	18	40	1806	125	118	35
14:45 - 15:45	18	39	1883	108	115	34
15:00 - 16:00	17	38	1906	99	113	33
15:15 - 16:15	15	34	1910	94	105	31
15:30 - 16:30	17	36	1911	87	90	28
15:45 - 16:45	17	36	1949	87	90	28
16:00 - 17:00	18	36	1952	87	80	25
16:15 - 17:15	18	36	2078	84	71	20
16:30 - 17:30	19	38	2090	86	80	22
16:45 - 17:45	25	51	2032	86	75	20
17:00 - 18:00	30	62	2071	83	81	22
17:15 - 18:15	39	80	1965	83	90	26
17:30 - 18:30	39	81	1935	81	84	25
17:45 - 18:45	35	75	1941	83	91	27
18:00 - 19:00	33	72	1823	85	93	28
18:15 - 19:15	26	58	1897	88	93	29
18:30 - 19:30	20	45	1915	93	95	30
18:45 - 19:45	15	31	1840	100	103	32

Dist to nearest signal

NB 0.4 mile

SB 0.2 mile

85th % Speeds (mph)

NB 43

SB 40

Data Collection Date:

June 14, 2000

Notes:

RESPONSE AREA FOR SITE 3

Using the data provided, observations made during your site visit, and your expert opinion, do you think a traffic signal should be installed here (please disregard the warrant analysis results when making this decision)?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

Is a form of less restrictive traffic control needed here?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

According to the current MUTCD Pedestrian Traffic Signal warrant, this site does not meet the non-reduced criteria. Do you agree with this finding?

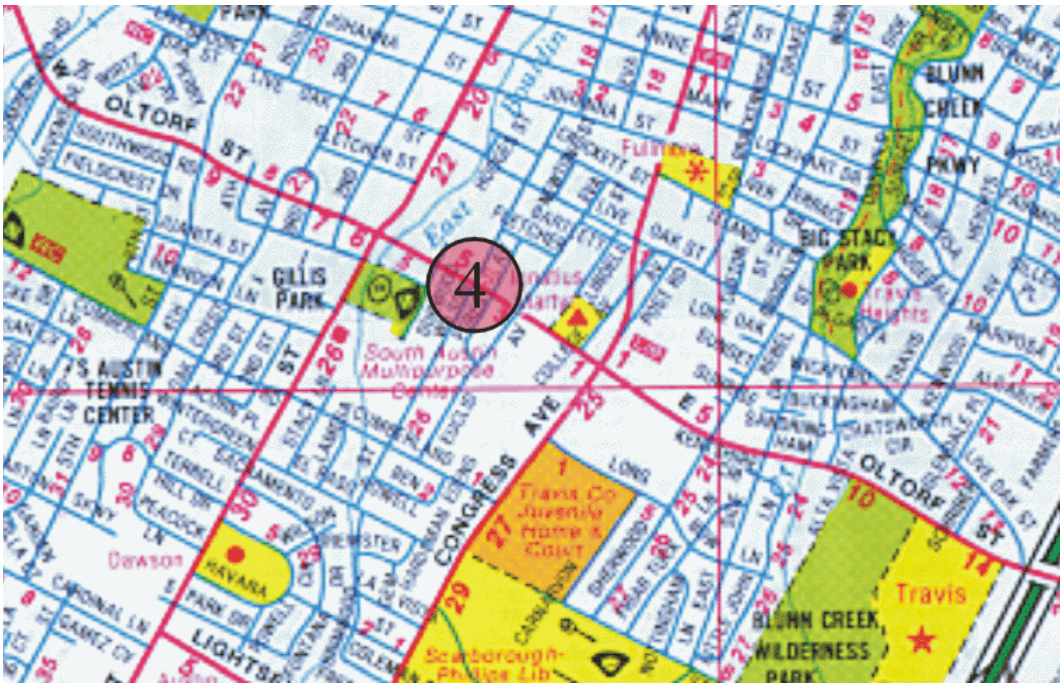
❒Yes ❒No

If no, please explain why. In other words, what factors led you to make you decision that are not part of the current warrant? Should other factors be considered in this case?

Date & Time of site visit: _____

SITE 4 – Oltorf (between 1st Street and Congress)

Westbound View



Oltorf

DATA FOR SITE 4

TIME (hourly)	Peds Only	Peds & Bikes	Vehs total	Good Gaps (>13.7 sec)
7:00 - 8:00	13	17	846	74
7:15 - 8:15	11	11	1128	64
7:30 - 8:30	13	13	1191	69
7:45 - 8:45	16	16	1164	74
8:00 - 9:00	9	11	1151	78
8:15 - 9:15	9	11	1152	79
8:30 - 9:30	10	13	1143	80
8:45 - 9:45	10	15	1152	81
9:00 - 10:00	14	17	1111	81
9:15 - 10:15	19	22	1083	83
9:30 - 10:30	20	22	1062	81
9:45 - 10:45	20	22	1026	81
10:00 - 11:00	24	28	1046	78
10:15 - 11:15	23	27	1102	79
10:30 - 11:30	22	27	1156	77
10:45 - 11:45	24	30	1258	66
11:00 - 12:00	19	23	1322	67
11:15 - 12:15	16	20	1386	65
11:30 - 12:30	21	28	1436	62
11:45 - 12:45	22	28	1455	63
12:00 - 13:00	22	28	1456	61
12:15 - 13:15	22	30	1447	62
12:30 - 13:30	21	27	1441	62
12:45 - 13:45	24	30	1359	69
13:00 - 14:00	29	35	1332	71
13:15 - 14:15	41	47	1290	71
13:30 - 14:30	43	49	1258	66
13:45 - 14:45	51	57	1295	66
14:00 - 15:00	49	58	1333	65
14:15 - 15:15	43	50	1348	66
14:30 - 15:30	36	41	1368	68
14:45 - 15:45	28	31	1417	59
15:00 - 16:00	31	31	1426	58
15:15 - 16:15	40	40	1423	58
15:30 - 16:30	45	46	1433	57
15:45 - 16:45	46	47	1431	59
16:00 - 17:00	37	38	1435	58
16:15 - 17:15	30	31	1504	58
16:30 - 17:30	35	37	1525	55
16:45 - 17:45	33	35	1547	56
17:00 - 18:00	41	43	1527	53
17:15 - 18:15	40	42	1486	52
17:30 - 18:30	33	33	1433	55
17:45 - 18:45	39	40	1363	60
18:00 - 19:00	40	44	1313	61
18:15 - 19:15	41	45	1226	58
18:30 - 19:30	44	56	1157	58
18:45 - 19:45	35	49	1085	57

Dist to nearest signal (ft)

WB	0.2 mile
EB	0.2 mile

85th % Speeds (mph)

WB	35
EB	35

Data Collection Date:

June 29, 2000

Notes:

RESPONSE AREA FOR SITE 4

Using the data provided, observations made during your site visit, and your expert opinion, do you think a traffic signal should be installed here (please disregard the warrant analysis results when making this decision)?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

Is a form of less restrictive traffic control needed here?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

According to the current MUTCD Pedestrian Traffic Signal warrant, this site does not meet the non-reduced criteria. Do you agree with this finding?

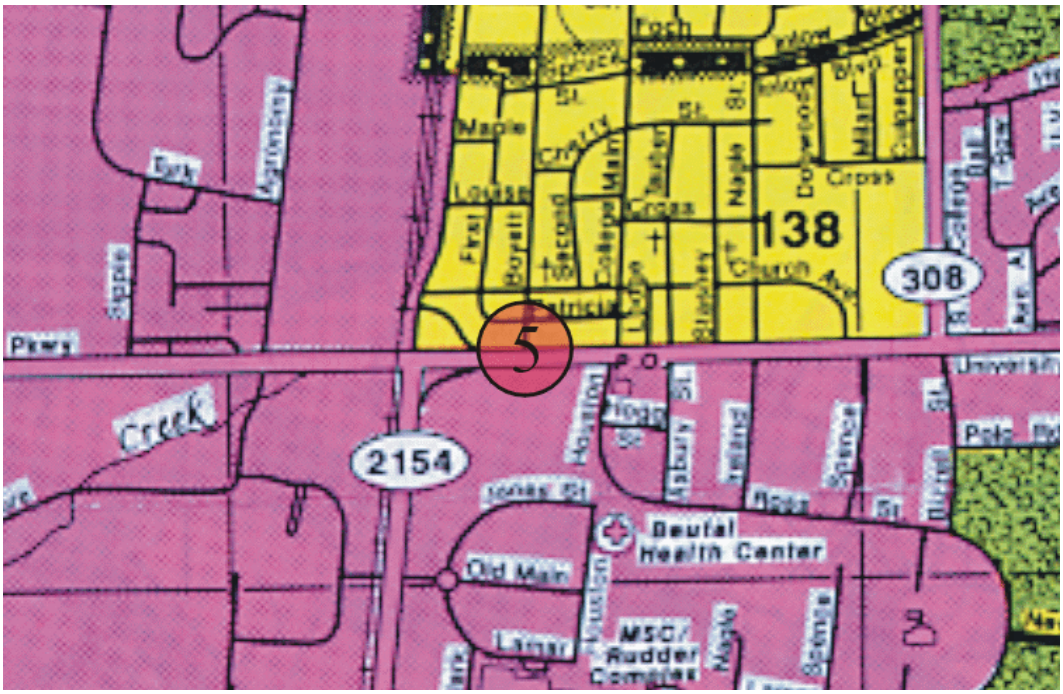
❒Yes ❒No

If no, please explain why. In other words, what factors led you to make you decision that are not part of the current warrant? Should other factors be considered in this case?

Date & Time of site visit: _____

SITE 5 – University Drive (between Wellborn and Houston)

Eastbound View



University Drive

DATA FOR SITE 5

TIME (hourly)	Peds	Vehs total	Good Gaps WB	Good Gaps EB	Good Gaps (>18.3 sec)
7:00 - 8:00	33				
7:15 - 8:15	36	889	78	83	54
7:30 - 8:30	39	1029	62	87	44
7:45 - 8:45	29	1186	56	87	38
8:00 - 9:00	26	1352	81	79	35
8:15 - 9:15	31	1422	79	73	27
8:30 - 9:30	38	1445	79	71	21
8:45 - 9:45	51	1405	87	66	21
9:00 - 10:00	54	1334	80	73	22
9:15 - 10:15	46	1261	83	74	27
9:30 - 10:30	40	1229	82	72	27
9:45 - 10:45	30	1243	82	73	27
10:00 - 11:00	55	1287	87	68	27
10:15 - 11:15	72	1282	85	68	26
10:30 - 11:30	73	1282	90	63	26
10:45 - 11:45	94	1310	86	57	24
11:00 - 12:00	89	1331	86	50	22
11:15 - 12:15	105	1419	87	49	19
11:30 - 12:30	119	1479	84	50	16
11:45 - 12:45	141	1458	95	51	16
12:00 - 13:00	144	1451	93	53	17
12:15 - 13:15	129	1397	89	54	17
12:30 - 13:30	130	1362	90	60	21
12:45 - 13:45	106	1421	89	63	23
13:00 - 14:00	106	1473	93	59	21
13:15 - 14:15	112	1501	101	71	19
13:30 - 14:30	111	1555	101	64	23
13:45 - 14:45	102	1533	96	60	20
14:00 - 15:00	88	1507	87	69	19
14:15 - 15:15	73	1496	85	62	22
14:30 - 15:30	67	1473	86	60	20
14:45 - 15:45	79	1502	85	60	20
15:00 - 16:00	80	1496	89	58	20
15:15 - 16:15	79	1463	81	53	19
15:30 - 16:30	81	1466	77	51	17
15:45 - 16:45	69	1488	74	55	17
16:00 - 17:00	81	1508	79	54	18
16:15 - 17:15	101	1538	81	64	18
16:30 - 17:30	105	1519	76	85	18
16:45 - 17:45	115	1475	79	77	20
17:00 - 18:00	108	1466	76	76	17
17:15 - 18:15	90	1468	77	68	17
17:30 - 18:30	83	1494	88	53	17
17:45 - 18:45	77	1485	88	56	17
18:00 - 19:00	71	1452	87	74	18
18:15 - 19:15	67	1429	88	70	21
18:30 - 19:30	63	1394	82	74	20
18:45 - 19:45	63	1349	83	82	25

Dist to nearest signal (ft)

WB	0.4 mile
EB	0.14 mile

85th % Speeds (mph)

WB	39
EB	36

Data Collection Date:

March 7, 2000

Notes:

TAMU classes were in session

RESPONSE AREA FOR SITE 5

Using the data provided, observations made during your site visit, and your expert opinion, do you think a traffic signal should be installed here (please disregard the warrant analysis results when making this decision)?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

Is a form of less restrictive traffic control needed here?

❒Yes ❒No

Please provide the reasons and/or factors that led to your decision.

According to the current MUTCD Pedestrian Traffic Signal warrant, this site does meet the criteria. Do you agree with this finding?

❒Yes ❒No

If no, please explain why. In other words, what factors led you to make you decision that are not part of the current warrant? Should other factors be considered in this case?

Date & Time of site visit: _____

FINAL RESPONSE AREA

Do you feel that the correct criteria are used in the current warrant?

❒Yes
❒No. If no, please identify other factors that should be considered.

Do you feel that the correct threshold values are associated with the current criteria?

❒Yes
❒No. If no, please identify other factors that should be considered.

Do you feel that the current reduction criteria (based on pedestrian walking speed is appropriate?

❒Yes
❒No. How should the walking speed reduction be changed?

Are there other reduction factors that should be included?

Please use this space to provide additional comments as necessary.

Name: _____ Telephone: _____

Employer: _____ Email: _____