Probabilistic Approach to Implementing Traffic Signal Warrants

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(Reviewed by the Urban Transportation Division)

Abstract: Traffic signal warrants documented in the *Manual on Uniform Traffic Control Devices* neglects the effect of daily and hourly volume variations in traffic. Furthermore, current practice cannot be used to prioritize signal installations among multiple intersections that meet the warrants. Finally, there is no guidance in the *Manual on Uniform Traffic Control Devices* on how the warrants can be applied to projected traffic conditions when hourly counts are not available. This paper describes a probabilistic approach to implementing traffic signal warrants. The proposed approach used Monte Carlo simulation to generate, on the basis of variable hourly traffic counts, the probability that any particular signal warrant will be met at an intersection. The simulation approach was extended to develop planning level guidelines for signal installation using predefined synthetic traffic flow profiles and the average daily traffic estimates for the intersecting streets. The proposed guidelines were compared with current planning guidelines used in Texas and California. The comparison results indicate that the Texas guidelines tend to underestimate the need for traffic signal installation, whereas the California guidelines tend to overestimate the need.

INTRODUCTION AND BACKGROUND

A traffic signal can be an efficient control device at an intersection when traffic volumes exceed those that can be handled by less restrictive devices such as yield or stop signs. The *Manual on Uniform Traffic Control Devices* (MUTCD) is the principal document providing standards and warrants for the design and application of traffic control devices. The earliest national manuals on traffic control devices published in 1927 and 1930 were combined to create the first MUTCD in 1935. Up to 1999, seven editions of the MUTCD have been published.

Historically, minimum vehicular volumes were generally used in warranting traffic signal installation (Saka 1993). Prior to 1985, most of traffic signal installations were justified on the basis of Warrants 1 and 2 (the 8-h volume warrants), which apparently did not have solid data supporting their development (McShane et al. 1998). Three additional warrants were incorporated in 1985. Warrants 9–11 were based on 4-h volumes, peak hour delay, and peak hour volume, respectively, from an extensive research and development effort (Henry et al. 1982). Currently, there are 11 traffic signal warrants in the MUTCD related to vehicular volume, pedestrian volume, school crossing, accident experience, and delay (MUTCD 1988). Among those, five warrants are directly related to traffic volume (Warrants 1, 2, 9, and 11 mentioned earlier and Warrant 8 on systems warrant). However, none of the existing warrants takes into account the normal daily or hourly traffic volume variations in determining the need for traffic signal installation. McShane et al. (1998) pointed out that traffic volumes can vary significantly from day-to-day for a given hour of the day. If an agency bases its signal installation decision on a traffic count from just 1 day, it may choose not to install a signal where one is needed or to install a signal where one is not needed. Therefore, a probabilistic approach, in contrast to the present ''yes'' or ''no'' approach might be helpful in assessing the likelihood that a traffic signal installation is needed.

Traffic signals are expensive to install and maintain. Typical capital costs per intersection range from $35,000–$45,000 with wood poles and spanwire to $55,000–$70,000 with metal poles and mast arms. Furthermore, the current MUTCD traffic signal warrants require considerable time and personnel to gather the necessary data to apply. Thus, there is a need for a method that can improve upon the decision-making process for current and future signal installations by (1) incorporating the effect of variability of traffic counts; (2) prioritizing among intersections that meet at least one warrant when there are insufficient funds to install signals at all intersections; and (3) providing guidelines for projected traffic conditions at an intersection using planning-level average daily traffic (ADT) data.

Early research efforts utilized computer simulations of intersection traffic flow to evaluate the need for a traffic signal, including those by Kell (1963), Lewis and Michael (1963), and Bleyl (1964). Kell used a simulation program to compare total intersection delay between two-way stop control and pretimed signalized control, whereas Lewis and Michael simulated intersections under minor street stop control and semiactuated traffic signal control. Bleyl employed a simulation program to compare the delay resulting from pretimed signal control and flashing operation. Interestingly, however, none of these simulation-based studies used a probabilistic approach to implementing and evaluating traffic signal warrants.

At existing or newly designed intersections, traffic signal installation decisions must sometimes be made on the basis of volume projections. The draft section for the MUTCD 2000 emphasizes the importance of estimating hourly volumes for signal warrants studies (MUTCD 1999):

> At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants.

Under these conditions, traffic volume estimates are typically made in terms of ADT. Because the hourly distribution of ADT

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is not normally available, minimum requirements of current planning practice are based on the assumption that traffic volumes in the 8 highest hours will each exceed a certain percentage of the ADT. For example, California and Texas use volume thresholds equivalent to 6.25 and 5.6% of the ADT for the average hour of the 8 h of interest, respectively (Kell and Fullerton 1991). These values were synthesized from Warrants 1, 2, and 8 to provide minimum ADT requirements that can justify the signal installation. Thus, the California and Texas approaches do not consider Warrants 9 and 11, which apply to the highest 4-h and peak hour volumes, respectively.

This paper is organized as follows. The methodology used in this study is discussed in the second section, followed by the third section on model application (and a numerical example). The fourth section provides a numerical evaluation of current MUTCD warrants. Proposed planning level guidelines are presented in the fifth section. Finally, conclusions and recommendations are given in the last section.

METHODOLOGY

Monte Carlo Simulation

Monte Carlo simulation is one of the most widely used simulation techniques (Fishman 1996). Monte Carlo methods are based on the use of random numbers and probability distributions to examine complex problems. The primary components of a Monte Carlo simulation method include a probability distribution function, a random number generator, and a sampling rule.

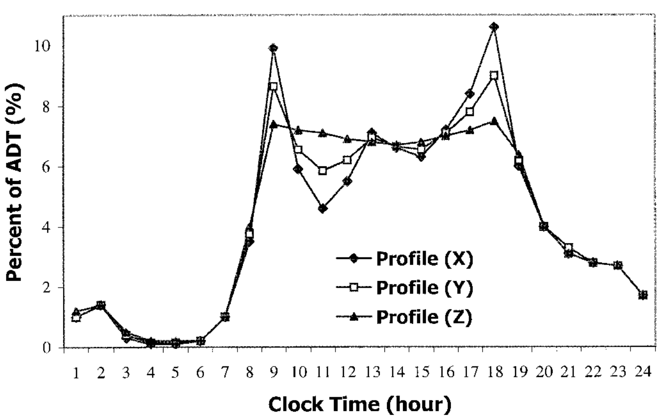


FIG. 1. Representative Hourly Traffic Flow

Proposed Simulation Approach

Given ADT estimates for the intersecting streets, we were interested in finding the probability of each combination of hourly volume on each street. For example, given a street with 10,000 ADT intersecting a street with 5,000 ADT, how often could one expect an hourly volume of 1,000 to meet an hourly volume of 400? Finding those probabilities was the key to better estimates of when signals are warranted.

We began by assuming an ''hourly profile'' for the intersection—that is, a percentage of a day's traffic within each of the 24 h. Then, we applied Monte Carlo simulation techniques to mimic the variation of traffic volume from day-to-day for a particular hour. After we provided the simulation model with a distribution of that day-to-day variation, it drew a random number to generate a traffic volume for a particular case. We looked at a large number of cases to formulate planning level guidelines.

In the development of planning level guidelines discussed below, default hourly profiles and a default error distribution were used. Users of the guidelines should select, from among the three representative hourly traffic flow profiles provided, the profile that best fits their intersection of interest. Profile X has higher a.m. and p.m. peaks, each at about 10% of ADT, than Profiles Y and Z. Profile Y has lower a.m. and p.m. peaks (8.5% of ADT), and slightly higher volumes between the peaks, than Profile X. Profile Z has virtually constant volumes between the peaks, at about 7% of ADT. Profile X is meant to simulate traffic patterns that will more quickly meet the peak hour and peak 4-h warrants, whereas Profile Z represents patterns that will more quickly meet the minimum volume Warrants 1, 2 and 8. Profile Y is an intermediate pattern between Profiles X and Z. Users of the guidelines should examine 24-h count data from stations near the intersection of interest, or stations on the same types of streets as at the intersection of interest, to help in selecting an appropriate profile. The three default profiles are illustrated in Fig. 1.

Functional Approximation of Warrants 9 and 11

Warrants 9 and 11 are represented in the MUTCD as continuous curves relating the two-way count on the major street to the highest count on the minor street. For each of these two warrants, the MUTCD provides a family of six curves based on intersection geometry and area characteristics (urban versus rural). For the purpose of including the warrants in the simulation, a polynomial approximation was used to express these curves.

TABLE 1. Polynomial Approximations for Minor Street Volume (Warrants 9 and 11)

Warrant (1)	Area (2)	Polynomial i (3)	Lane geometry (major and minor) (4)	Polynomial function (5)	R^2 (6)
9	Urban[a]	1	1 and 1	$3.14X_i^2 - 59.37X_i + 367.50$	0.998
		2	2 and 1	$2.65X_i^2 - 62.83X_i + 425.00$	0.999
		3	2+ and 2+	$2.97X_i^2 - 77.83X_i + 593.08$	0.999
	Rural[b]	4	1 and 1	$4.46X_i^2 - 61.37X_i + 267.32$	0.998
		5	2 and 1	$3.87X_i^2 - 63.99X_i + 323.04$	0.999
		6	2+ and 2+	$5.21X_i^2 - 86.58X_i + 434.91$	0.999
11	Urban[c]	7	1 and 1	$2.35X_i^2 - 64.70X_i + 542.22$	0.999
		8	2 and 1	$1.90X_i^2 - 65.35X_i + 650.20$	0.999
		9	2+ and 2+	$2.55X_i^2 - 84.43X_i + 836.04$	0.999
	Rural[d]	10	1 and 1	$3.50X_i^2 - 59.75X_i + 325.75$	0.998
		11	2 and 1	$2.95X_i^2 - 61.14X_i + 389.00$	0.999
		12	2+ and 2+	$3.49X_i^2 - 75.67X_i + 503.00$	0.999

[a] $V_{min} = 400$, $V_{max} = 1{,}300$, $V_{max} = 10$.
[b] $V_{min} = 300$, $V_{max} = 1{,}000$, $V_{max} = 8$.
[c] $V_{min} = 400$, $V_{max} = 1{,}800$, $V_{max} = 15$.
[d] $V_{min} = 400$, $V_{max} = 1{,}300$, $V_{max} = 10$.

The polynomial approximations used to calculate the minor street volume at which a signal would be warranted given a major street volume, for different geometry and locations, are summarized in Table 1. The explanatory variable X_i in these equations is a normalized value of the two-way major street count. For each polynomial i (i = 1–12), the X_i value is computed as follows:

$$X_i = 1 + (V_i - V_{\min}) \times (X_{\max} - 1) \div (V_{\max} - V_{\min})$$

where V_i = input two-way count on major street using polynomial i; $V_{\min}$ = minimum two-way count associated with polynomial i; $V_{\max}$ = maximum two-way count associated with polynomial i; and $X_{\max} = 1 + (V_{\max} - V_{\min}) \div 100$. For example, consider the application of Warrant 11 to an urban intersection with single lane approaches throughout and a major street hourly volume of 750 vehicles/h. In Table 1, polynomial 7 applies. The normalized X_7 value is calculated as $\{1 + (750 - 400) \times (15 - 1) \div (1{,}800 - 400)\} = 4.5$. Substituting X_7 in the polynomial function yields a minimum minor street volume warrant of 298 vehicles/h for peak hour (Warrant 11). All polynomials had an excellent fit to the curves in the MUTCD, as indicated by the high values of the determination coefficient.

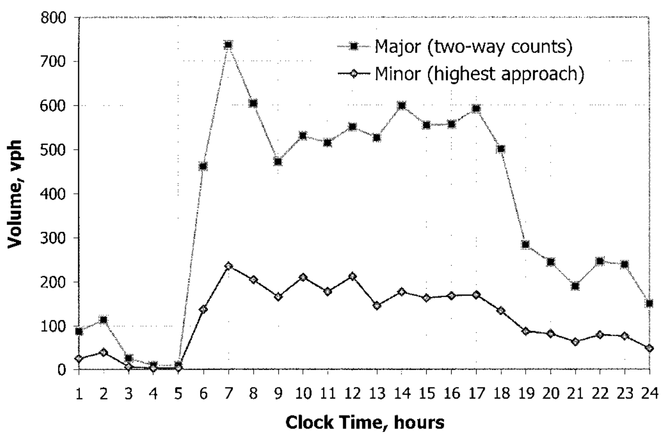


FIG. 2. Example of Urban Intersection Hourly Traffic Counts

TABLE 2. Numerical Example Comparing Deterministic and Probablistic Approaches to Implementing Signal Warrants

Warrant (1)	Probability of Meeting Indicated Signal Warrant: Single evaluation (current practice) (2)	Multiple evaluation (proposed) (3)
1	1.00	0.71
2	0.00	0.00
8	0.00	0.00
9	1.00	0.59
11	0.00	0.00

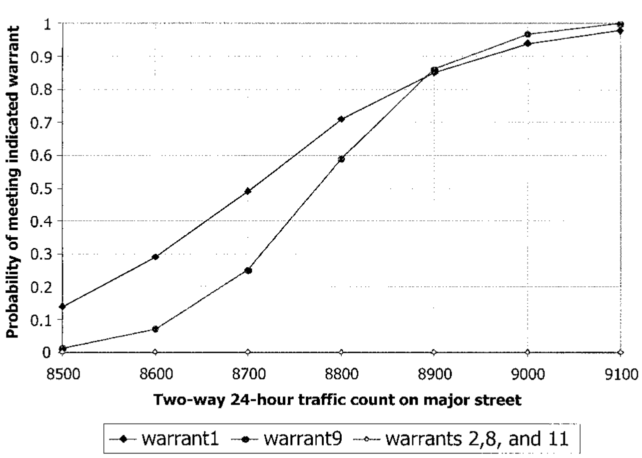


FIG. 3. Example of Probabilistic Approach to Implementing Signal Warrants (Note: Based on Traffic Profile in Fig. 2)

MODEL APPLICATIONS

Determining Probability of Meeting Specific Volume Warrants

The procedure for applying the model to determine the probability of meeting specific MUTCD volume-based warrants can be summarized and is detailed as follows:

1. User input
   - Intersection geometry
   - Hourly traffic counts (24 h, or highest 8 or 16 h)
   - Range of traffic flow variations (standard deviation of hourly counts is percent change)

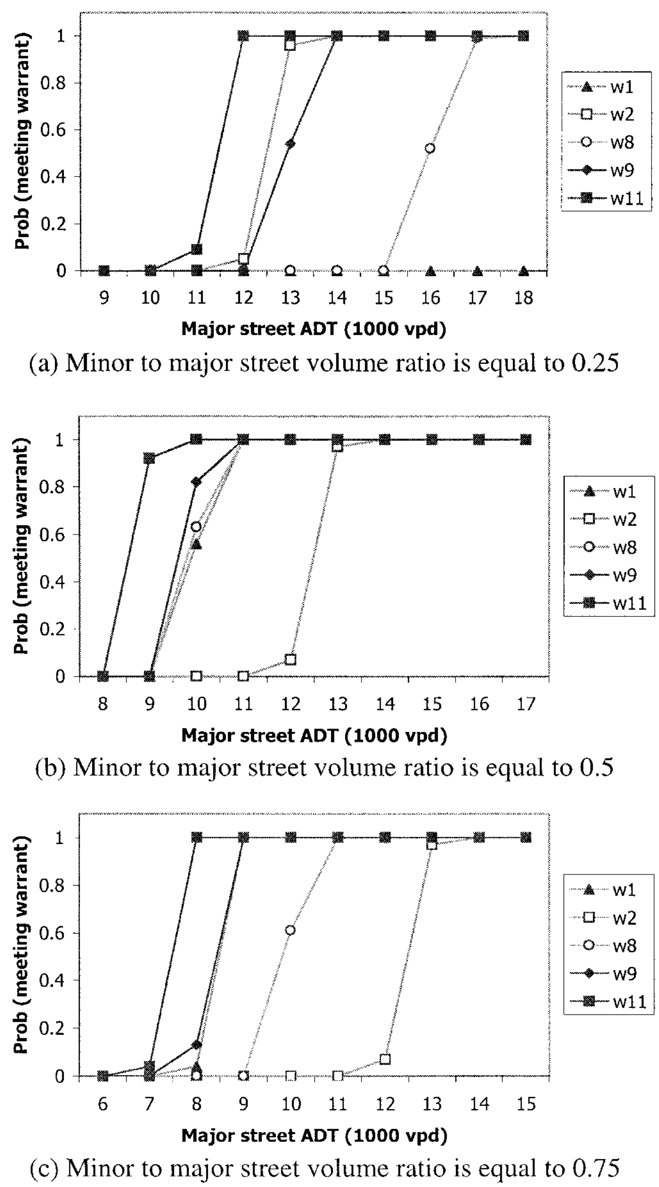
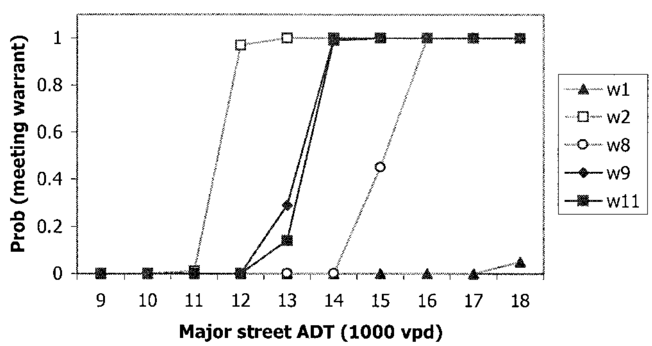


FIG. 4. Likelihood of Meeting Volume-Based Signal Warrants (Single Lane Approaches, Profile X, Urban Area)

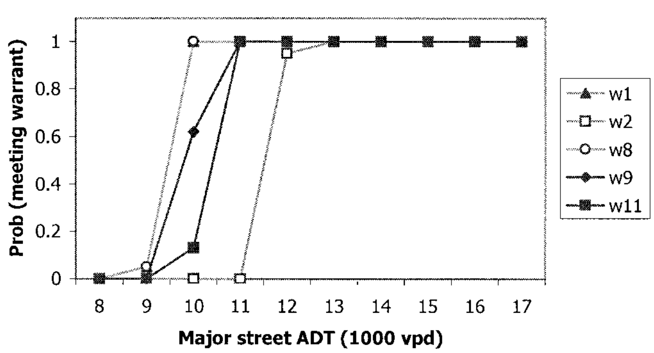
2. Monte Carlo simulation
   - Generate 1,000 replicates of hourly traffic volumes for given hourly traffic counts and flow variation
   - For each hour, Volume(h) = Base_Volume(h) + $F\{0.5 - RN[0, 1]\}$, where $F(\cdot)$ = generic distribution representing traffic flow variation; and h = index for flow in hth hour
3. Test volume-based MUTCD warrants
   - Warrants 1, 2, and 8—direction comparison
   - Warrants 9 and 11—polynomial approximation
4. Produce probability of meeting warrants
   - Probability of meeting individual warrants
   - Probability of meeting any warrant

The program requires as input intersection geometry information, hourly traffic volumes on the major and minor streets (either 8-, 16- or 24-h counts), and the range of expected daily traffic flow variations from day-to-day for a particular hour of the day. To find this range of expected daily flow variations, one needs to acquire traffic counts over several representative days. Because such data are not routinely available for urban intersections, we demonstrate our method using daily variability in counts for a freeway segment. The counts taken from the TransGuide surveillance system in San Antonio (TransGuide System 1998) were utilized. These data were collected over 24 days at a typical location. The traffic count variations for each time period do not follow a normal distribution. At any given time, there are typically more observations clustered on one side of the range of volumes than in the center of the range. For simplicity, it was decided to use a uniform distribution, although the simulation code can accept any other representative distribution. Based on the assumption of uniform distribution and the data from the TransGuide System, the actual hourly flows were allowed to vary uniformly between −8 and +13% from the mean from day-to-day through all the analyses in this paper.

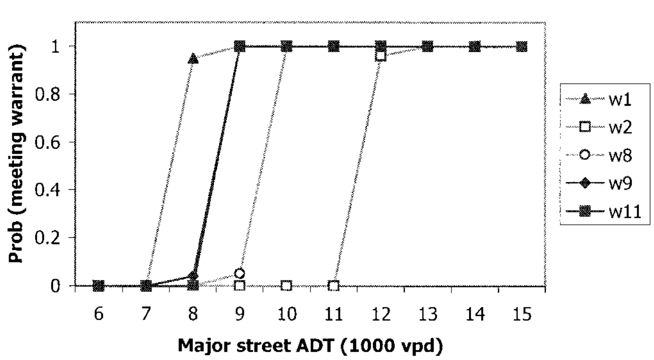
Once the volume and variability data are entered, the program simulates 1,000 daily volume profiles using different random number seeds. Data from each profile are then compared to the volume thresholds needed to trigger Warrants 1, 2, 8, 9, and 11. The proportion of simulated daily profiles that satisfies each warrant therefore gives the likelihood of the warrant



(a) Minor to major street volume ratio is equal to 0.25

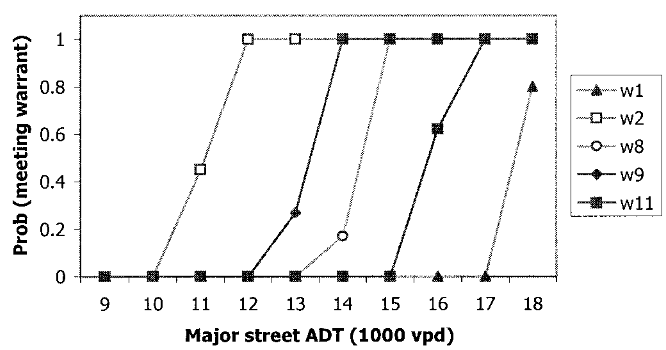


(b) Minor to major street volume ratio is equal to 0.5

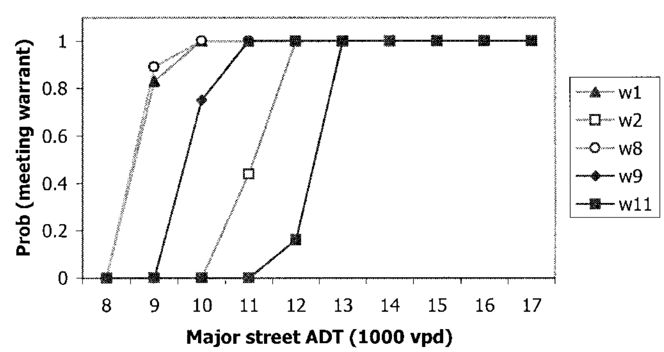


(c) Minor to major street volume ratio is equal to 0.75

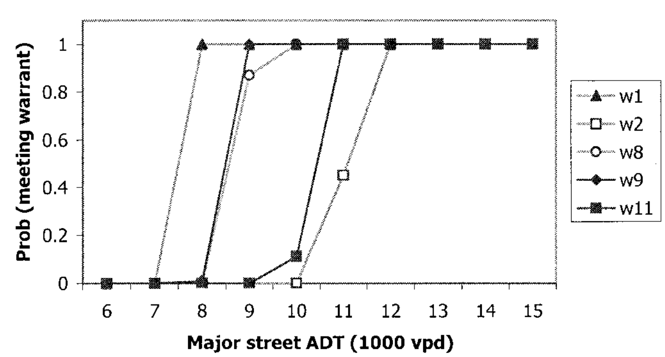
FIG. 5. Likelihood of Meeting Volume-Based Signal Warrants (Single Lane Approaches, Profile Y, Urban Area)



(a) Minor to major street volume ratio is equal to 0.25



(b) Minor to major street volume ratio is equal to 0.5



(c) Minor to major street volume ratio is equal to 0.75

FIG. 6. Likelihood of Meeting Volume-Based Signal Warrants (Single Lane Approaches, Profile Z, Urban Area)

being met in the long run. The probability that any of the warrants is met can be calculated by summing the individual warrant probabilities and subtracting all the interaction terms. In theory, the interaction terms can be computed by noting the proportion of daily profiles in which all possible combinations of warrants are met. As an example, if Warrants 1, 2, and 8 are being tested, the probability of meeting any of the three warrants is

$$P_1 + P_2 + P_8 - P_{12} - P_{18} - P_{28} + P_{128}$$

where P_i = proportion of daily profiles in which Warrant i is met; P_{ij} = proportion of daily profiles in which both Warrants i and j are met; and P_{ijk} = proportion of daily profiles in which Warrants i, j, and k are all met.

Because the same count estimates are used to test multiple warrants in each profile, the above probabilities are not independent (i.e., $P_{ij} \neq P_i \times P_j$). For practical purposes, however, it may be sufficient to establish a lower bound on the probability of meeting any warrant. This is done by taking the maximum value of the individual warrant probabilities.

Illustrative Example

The proposed approach can be illustrated through a numerical example. Given an urban intersection with single lane approaches, the observed hourly traffic counts for both major and minor streets are shown in Fig. 2. Note that these are not the same as Profiles X, Y, or Z discussed in this paper. The assumption made in this example is that one has sufficient knowledge to provide a distribution of flows given the mean of that distribution. In this example, hourly traffic volume varies between −8 and +13% from the mean given in Fig. 2. Of course, it would be desirable if multiple counts over several days were available to estimate the probability distribution. The simulation results of the flow profile in Fig. 2 of the five signal warrants are summarized in Table 2. A single evaluation, as in current practice, would conclude that Warrants 1 and 9 are met based on the counts. Thus, a traffic signal installation at that site should be considered if an engineering study indicates that the signal will improve overall safety and operation at the intersection. On the other hand, the simulation approach yields the probability of meeting each warrant based on the variability in traffic flow. In this case, Warrants 1 and

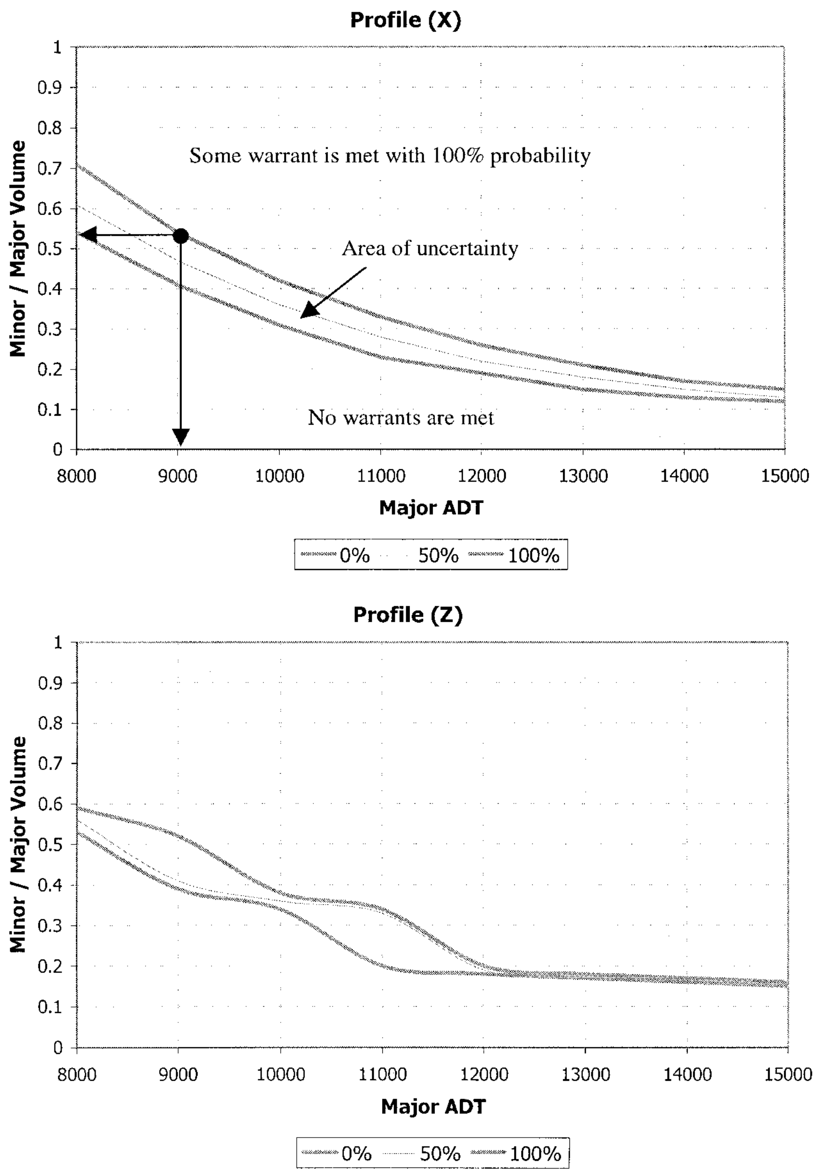


FIG. 7. Planning Guidelines for Urban Intersections with Single Lane Approaches

9 are met with probabilities of 71 and 59%, respectively, whereas Warrants 2, 8, and 11 are not met. Based on the above discussion, a lower bound on the likelihood that a signal is warranted at that intersection is 71%. These results provide more useful information in terms of the need of an engineering study. For instance, if there were multiple candidate intersections for which traffic signal warrant studies are needed, the probability of meeting any signal warrant could be used to prioritize the site selection process for further investigation. The transportation agency may automatically trigger an engineering study for all intersections having a lower bound likelihood value of meeting any warrant of, say, 85%.

Fig. 3 depicts the probability of meeting the MUTCD volume-based warrants for a series of 24-h traffic counts on the main road described above, with the highest minor street traffic set at 32% of the major street flow. The information is depicted for a range of major street counts from 8,500 to 9,100 vehicles/day. It is noted that the profile used in this example is based on Fig. 2. The indicated probability curve may be different if the actual 24-h hourly flow profile, the minor to major street volume ratio, or ADT levels varied. For the 24-h hourly traffic volumes discussed above, it appears that Warrant 1 has the highest probability of being met until the major street 24-h traffic count reaches 8,900 vehicles/day, at which point Warrant 9 reveals the highest probability of being met. Assuming the transportation agency's criterion for selecting candidate sites is based on an 85% probability, the minimum traffic count on the main road to trigger a study is 8,900 vehicles/day. The corresponding trigger volume for the minor street (two-direction volume) would be 5,700 vehicles/day.

NUMERICAL EVALUATION OF CURRENT MUTCD WARRANTS

For the three representative hourly traffic flow profiles shown in Fig. 1 and the day-to-day uniform volume distribution from −8 to +13%, the current MUTCD volume-based warrants were tested at three different levels of minor to major street volume ratios (0.25, 0.50, and 0.75). It is noted that the minor to major street volume ratio is obtained on the basis of ADT volumes (i.e., both directional volumes). The current warrants use the higher volume approach for the minor street volume and two-way counts for the major street. Thus, if the directional distribution on minor street traffic were known, the

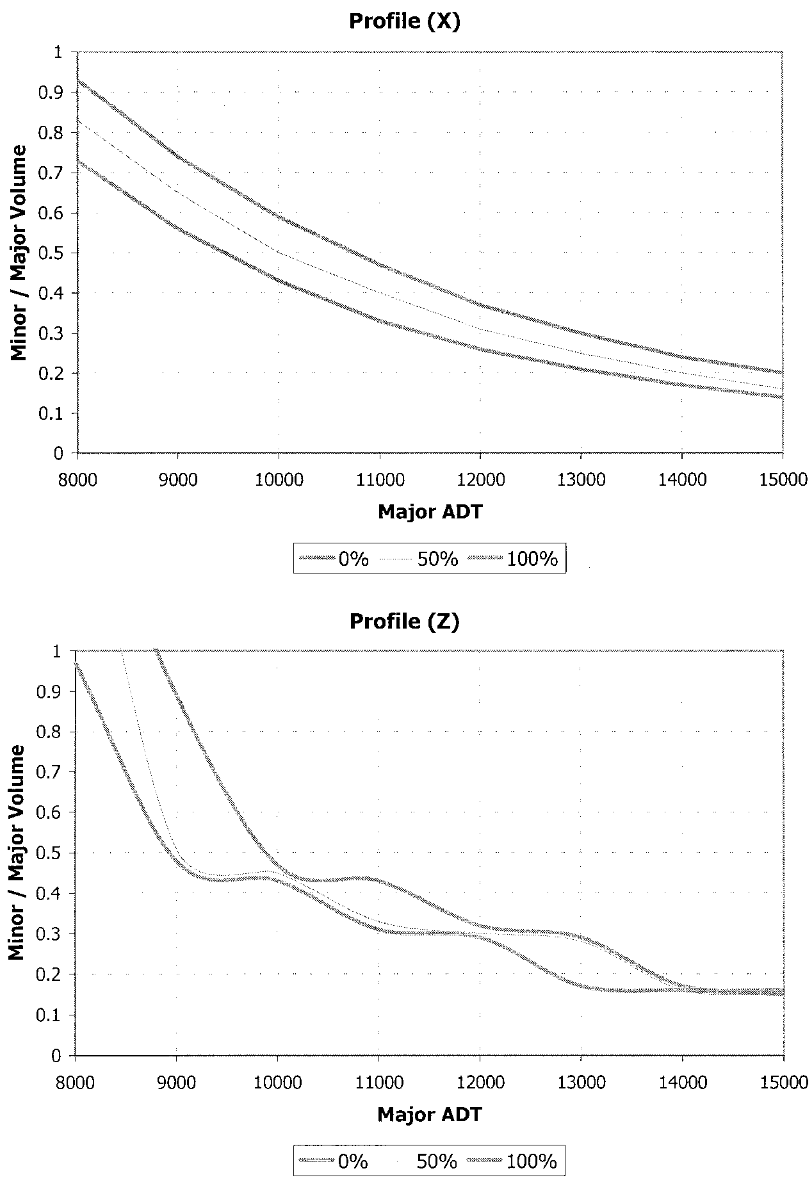


FIG. 8. Planning Guidelines for Urban Intersections with Two Lanes in Each Direction on Major Street and One Lane in Each Direction on Minor Street

minor to major street volume ratio should be calculated as follows:

$$\text{minor to major street volume ratio} = \frac{2 \times \text{highest directional volume on minor street}}{\text{ADT on major street}}$$

The likelihood of meeting the individual volume-based signal warrants for three traffic flow patterns (Profiles X, Y, and Z) is shown in Figs. 4–6, respectively, for urban intersections with single lane approaches. A general pattern emerges after looking at similar figures for all geometric and area types simulated. It is found that the warranting ADT volumes are extremely dependent on the ratio of the minor street to the major street count. For example, Figs. 4–6 indicate that as the minor to major street volume ratio increases from 0.25 to 0.75, the ADT warranting a signal in 100% of the trials decreases from 12,000 to 8,000. The hourly traffic flow profiles also play an important role in determining which signal warrant is dominant. As shown in Figs. 4–6, for an ADT of 9,000 with a 50% minor to major street volume ratio, the likelihood of meeting any signal warrant under Profiles X and Z is about 90%, whereas the corresponding value for Profile Y is <10%. This indicates that even with identical geometry and ADT, the outcome of a warrant study is very sensitive to the assumed hourly traffic flow profile. Further examination of these results showed that due to the high peaks in Profile X, Warrant 11 was more easily met. For Profile Z, the 8-h counts were high enough to satisfy Warrants 1 and 8 more quickly. In fact, it appears that all five volume-based warrants play an important role in determining the need for a traffic signal at one type of intersection or another.

PLANNING GUIDELINES FOR TRAFFIC SIGNAL INSTALLATION

Generation of Planning Guidelines for Volume-Based Warrants

For the purpose of developing planning-level guidelines, however, only the most plausible set of field conditions was run. These included these representative hourly flow profiles (shown in Fig. 1), three different geometric conditions (combinations of the number of lanes on the major and minor streets), ranges of major street ADT volume levels from 8,000 to 15,000 for urban street and 5,000 to 12,000 for rural highways, and a range of minor to major volume ratios. The prob-

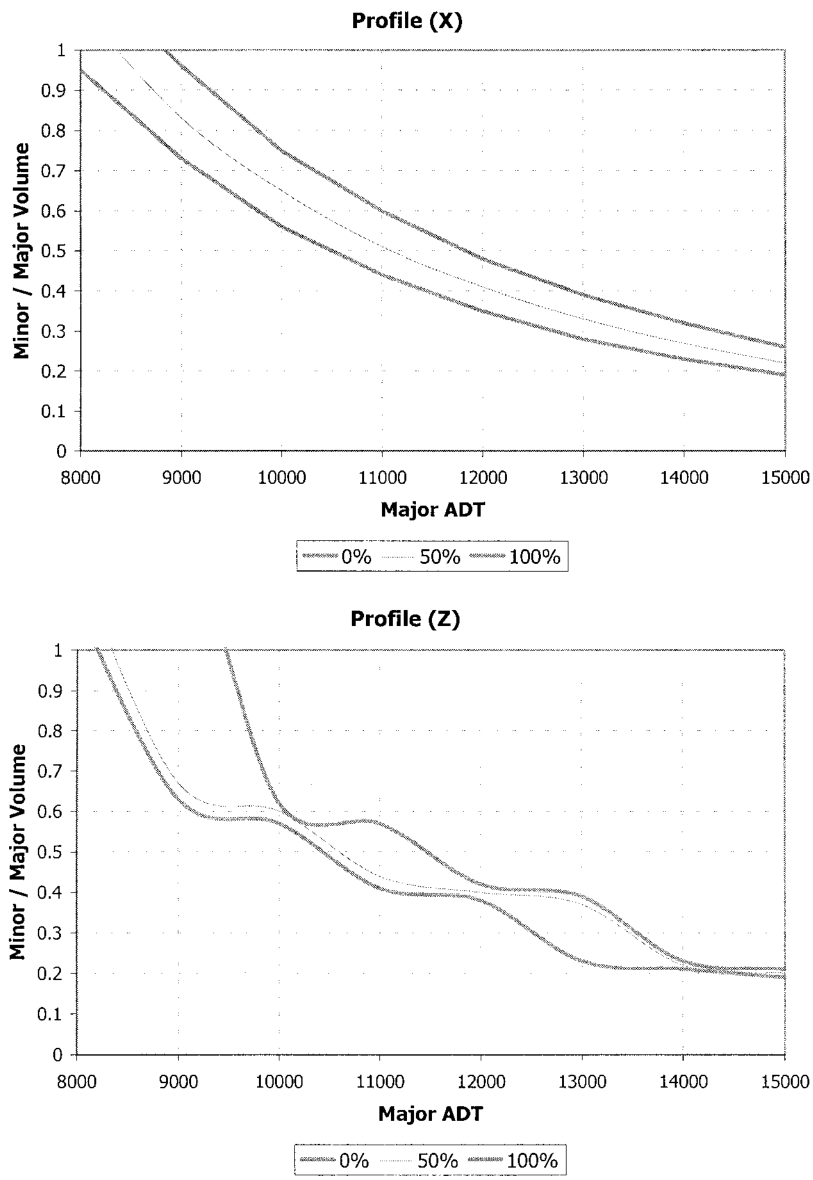


FIG. 9. Planning Guidelines for Urban Intersections with Two Lanes in Each Direction on Both Major and Minor Streets

ability of meeting the MUTCD vehicle volume (Warrants 1, 2, 8, 9, and 11) is calculated using the procedure in the model applications section. The probability of meeting any warrant is conservatively defined as the maximum value among the five probabilities obtained for Warrants 1, 2, 8, 9, and 11. To understand why this is a conservative yet plausible overall probability, consider an intersection that meets Warrant *X* 20% of the time and meets Warrant *Y* 10% of the time. Chances are good that the times that Warrant *Y* are met are included in the times that Warrant *X* are met, so the overall probability of meeting either warrant will remain close to 20%.

Illustration of Results

The proposed planning level guidelines are depicted in Figs. 7–9 for urban intersections and Figs. 10–12 for rural intersections. The latter guidelines are based on meeting a volume warrant equivalent to 70% of the volume given for urban areas. Only guidelines related to Profiles X and Z are shown in Figs. 7–12 as Profile Y can be interpolated from Profiles X and Z. In each figure, the two solid lines demarcate the 0 and 100% probability contours for a given combination of major and minor street ADTs and profile. Thus, the area above the 100% line depicts the region where serious consideration should be given to traffic signal installation because at least one volume-based warrant is almost certainly met. The area below the 0% line is the region where no signal installation should be considered from a traffic volume perspective. Between the two lines is the area of uncertainty. The broken line represents a 50% chance of meeting any of the five signal warrants. Thus, Figs. 7–12 can be readily used for planning purposes to ascertain the need for traffic signal installation based on ADTs, selected traffic profiles, and proposed geometrics.

A closer examination of these graphs indicates that under Profile X, Warrant 11 is dominant at all ADT levels and minor to major street volume ratios. Thus, the probability contours appear smooth. On the other hand, the contours for Profile Z exhibit a very discontinuous pattern, because the dominant warrant varies when either the ADT or the minor to major street volume ratios vary.

By comparing the probability contours across different intersection geometric conditions, one can consider the potential ''trade-off'' between adding a lane and installing a traffic signal. For example, consider an urban intersection where the major street ADT is 9,000, and the minor to major street ADT ratio is 0.55 for Profile X. As shown in the top graph in Fig.

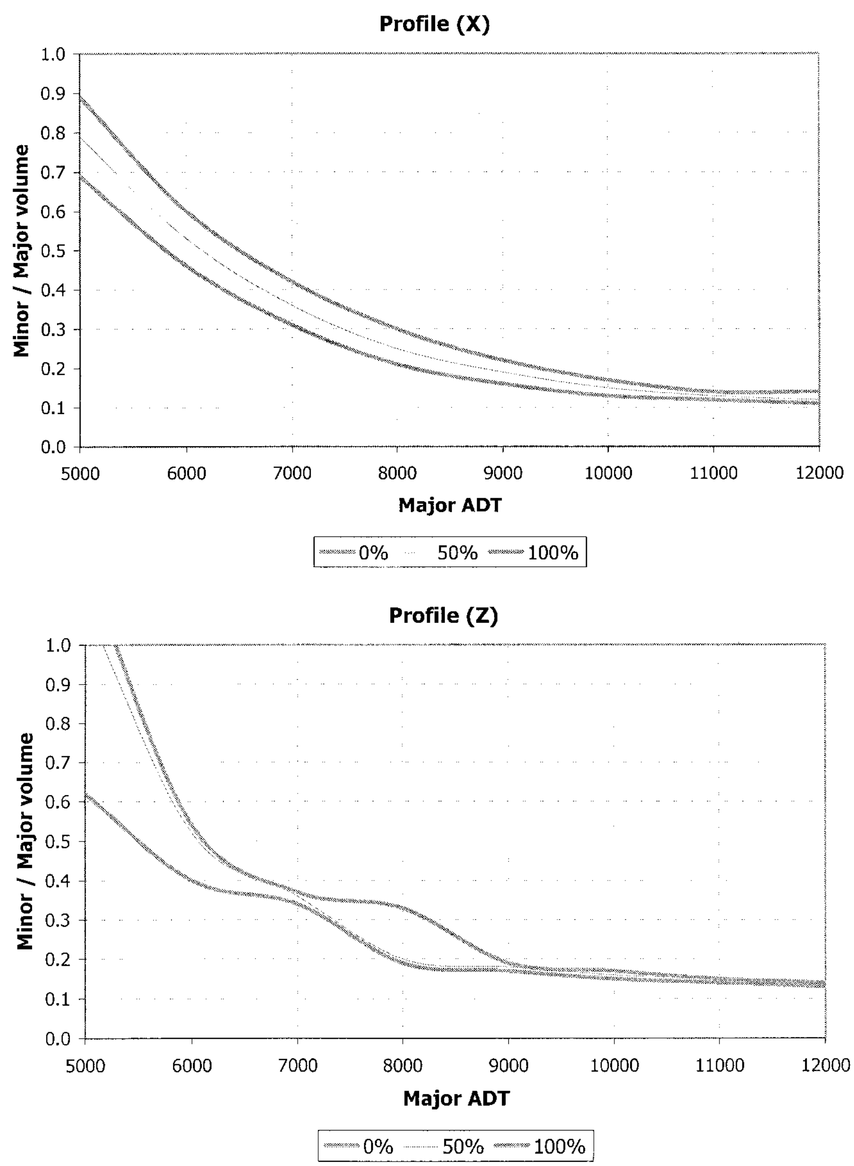


FIG. 10. Planning Guidelines for Rural Intersections with Single Lane Approaches

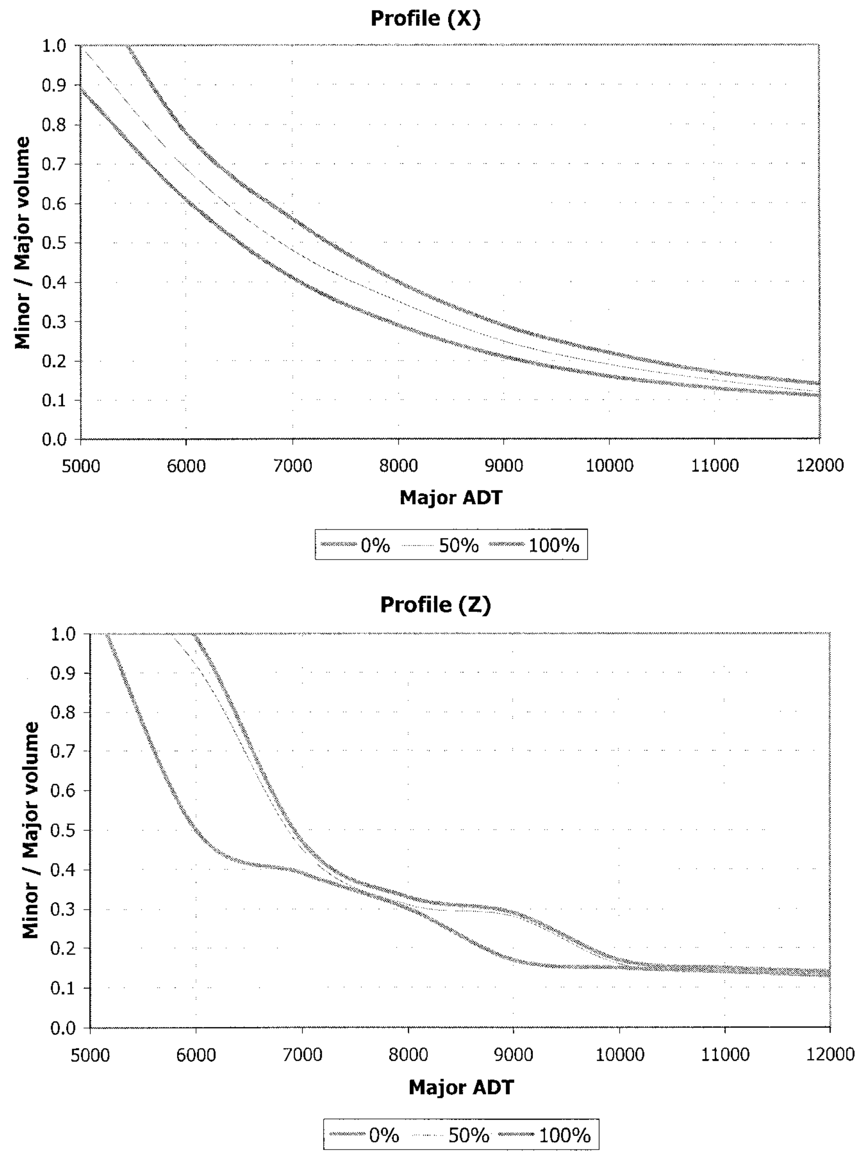


FIG. 11. Planning Guidelines for Rural Intersections with Two Lanes in Each Direction on Major Street and One Lane in Each Direction on Minor Street

7, a combination of major street ADT of 9,000 and minor to major street volume ratio of 0.55 satisfies some signal warrant with a 100% probability. However, with two lanes in each direction on the major street, the same volume combination would not meet any signal warrant (top graph in Fig. 8). Thus, in a planning level analysis, one could consider the implementation of geometric improvements in lieu of traffic signal installation.

Comparison with Current Practice

Fig. 13 compares the proposed guidelines with those currently in use in California and Texas for intersections with single lane approaches. The two broken lines represent the California and Texas thresholds, and the curves represent the proposed guidelines. Traffic signal warrants are met if the coordinate describing the major and minor street traffic volumes lie above the threshold. The area below the 100% curve and above the California warrants line depicts the case where warrants are not always met but signal installation is recommended by California guidelines. The area above the 100% curve and below the Texas warrants line indicates that warrants are always met, but signal installation is not recommended by the Texas guidelines. Clearly, use of the Texas guideline will tend to suppress signal installations even though some of the warrants may be clearly met using our probabilistic approach. The current planning level guidelines from Texas and California do not match the proposed guideline curves developed in this research very well, in part because the Texas and California guidelines are based on only three coordinate values taken from Warrants 1, 2, and 8.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, a probabilistic approach is proposed to ascertain whether a signal installation is warranted using volume-based warrants in the MUTCD. A method for generating the probability of meeting individual and combined signal warrants has been developed. The proposed approach can account for the hourly and/or daily traffic flow variations. The method has been extended to generate new planning level guidelines that take into account all five volume-based signal warrants. One of the key assumptions in this proposed approach was a uniform distribution of day-to-day variations in traffic volume, based on freeway data. Users of this approach, who have ac-

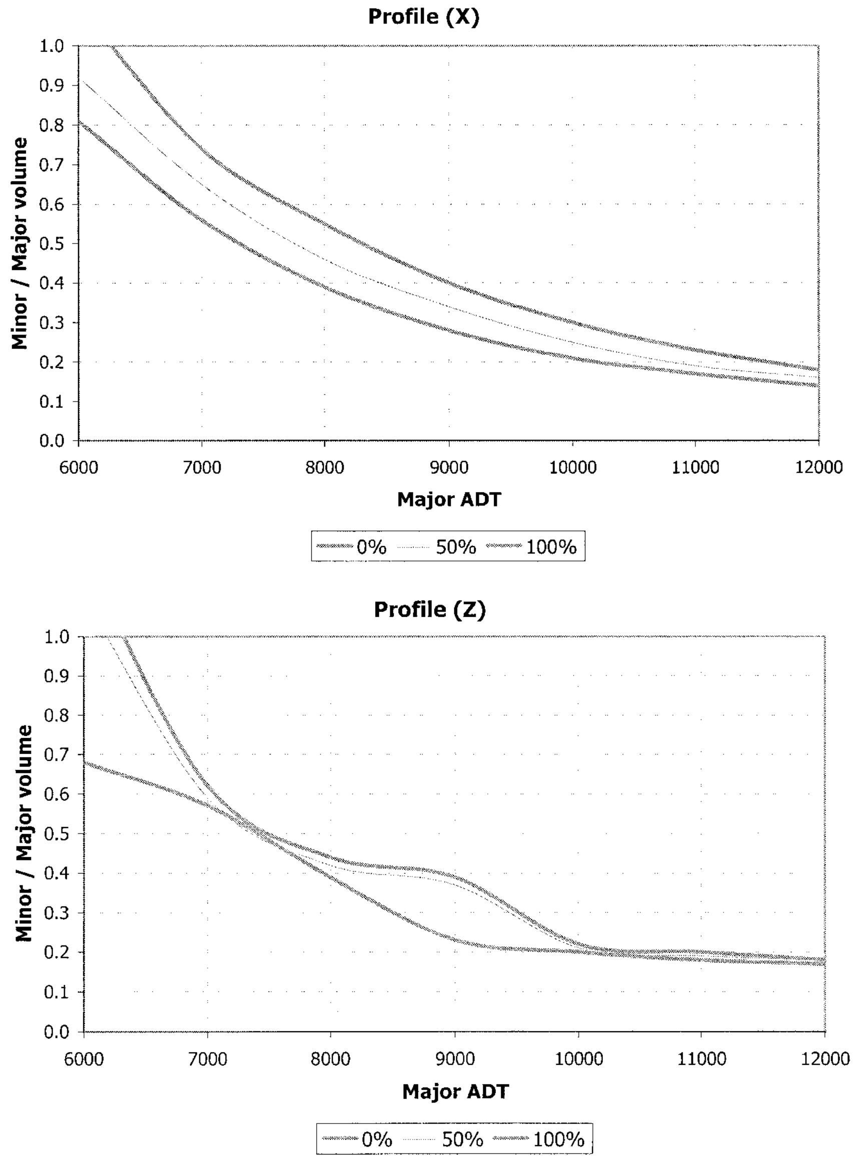


FIG. 12. Planning Guidelines for Rural Intersections with Two Lanes in Each Direction on Both Major and Minor Streets

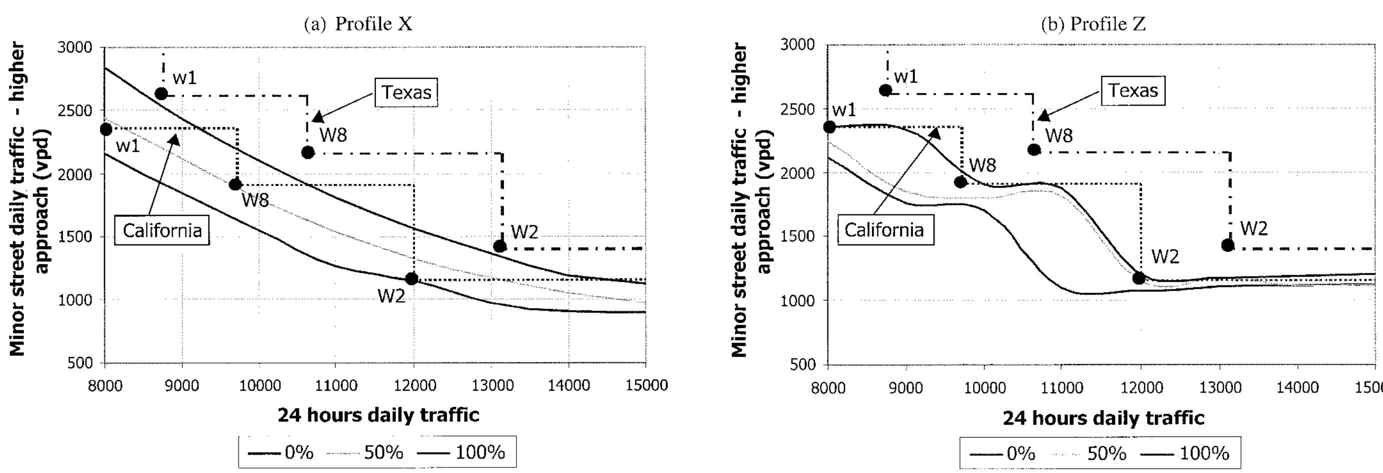


FIG. 13. Comparison with Current Guidelines from Texas and California, Urban Intersection with Single Lane Approaches

cess to their own continuous count data for surface streets, should generate their own distributions.

The evaluation of current signal warrants indicates that each warrant plays an important role in determining the need for a traffic signal, depending on the intersection geometry, the flow profiles, ADT levels, and minor to major street volume ratios. In other words, each of the five signal warrants was found to dominate all other warrants under some plausible operating condition. Thus, discarding Warrants 1 and 2 in the MUTCD, as proposed by some, would not be appropriate in many cases.

Current planning guidelines used in Texas and California do not compare very well to the method developed here. This is due to the fact that they have been established based on limiting assumptions regarding the hourly distribution of ADT (using Warrants 1, 2, and 8 only), and they do not account for the inherent variability in traffic flows. It may be useful for these and other states to consider the proposed probabilistic approach as a viable alternative.

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