Expected Traffic Conflict Rates and Their Use in Predicting Accidents

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ABSTRACT

The purpose of this research was to establish relationships between traffic conflicts and accidents and to identify expected and abnormal conflict rates given various circumstances. The data on which the conclusions and recommendations are based were collected during the summer of 1982 at 46 signalized and unsignalized intersections in the greater Kansas City area. The conclusions are limited to daytime (7:00 a.m. to 6:00 p.m.) and weekday (Monday-Thursday) traffic and to dry pavement conditions. Accident/conflict ratios have been statistically determined for several types of collisions for each of four types of intersections (signalized high volume, signalized medium volume, unsignalized medium volume, and unsignalized low volume). These ratios can be applied to comparable intersections to obtain an expected accident rate of a specific type after the appropriate conflict data are collected. Also, statistical procedures were developed to determine conflict rate values that could be considered abnormally high. Overall, traffic conflicts of certain types are good surrogates for accidents in that they produce estimates of average accident rates nearly as accurate, and just as precise, as those produced from historical accident data. Therefore, if there are insufficient accident data to produce an estimate, a conflicts study should be very helpful.

The traffic conflicts technique (TCT) has been studied and applied since its early development in 1967 by Perkins and Harris (1). Although it was originally developed to investigate whether General Motors vehicles were driven differently than others, the method was soon used by several agencies to evaluate accident potential and operational deficiencies of intersections. It was believed that a direct relationship existed between accidents and conflicts. However, efforts to verify such a relationship were generally unsuccessful, for a variety of reasons to be discussed subsequently. A review in 1980 by Glauz and Migletz (2) identified 33 previous studies that dealt, at least in part, with conflict-accident relationships.

The use of the TCT did not continue to increase in the United States in the late 1970s; in fact, it declined. However, research did become international in scope, led originally by Canada and England. Now the efforts are widespread and include those of many European and other countries.

Partly in recognition of the widespread interest in TCT and because of the diversity of opinions on its usefulness as well as the definitions and operational procedures, an international workshop was convened in Oslo, Norway, in 1977 (3). That workshop has been followed by others in France, Sweden, West Germany, and Belgium. Although investigators throughout the world have not agreed on the specific operational definitions of traffic conflicts, a universal, generalized definition was generated at the Oslo workshop (3):

> A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged.

Because the situations are observable and happen at a high frequency (relative to that of accidents, say), conflicts are an enticing traffic measure. The operational differences between investigators are primarily in relation to the severity of the situation--how great the potential risk of a collision was.

Despite such differences, most traffic engineers and analysts believe that traffic conflicts are of value in describing or identifying operational problems at intersections. However, there exist no standards or norms against which to base judgments. How many conflicts per hour or per day suggest a problem? One of the purposes of this paper is to suggest normal and abnormal levels of conflict rates in the United States for certain classes of intersections and types of conflicts.

Perhaps the most important potential application of the TCT, however, is in identifying safety deficiencies. Conventionally, safety is measured in terms of accidents and accident rates--the ultimate measures. Unfortunately, accidents are so rare, statistically, that one must often wait for years, and for many accidents to happen, before enough data are available to enable rational decisions. If a surrogate measure such as traffic conflicts could be used, decisions might be made much more quickly. As noted earlier, however, the heretofore lack of satisfactory agreement between conflicts and accidents has cast this role of the TCT in doubt. The second purpose of this paper is to illustrate that, in fact, a reasonable agreement does exist.

DATA COLLECTION

Definitions

To be useful, the TCT procedures must be formalized and standardized so that investigators can duplicate each other's work. This step was taken in the United States with NCHRP Project 17-3 (2). In that research, the TCT methodology was refined and a standardized set of operational definitions and procedures that were cost-effective was developed.

A traffic conflict was defined in that study, in general agreement with the 1977 international definition (3), as follows:

> A traffic conflict is a traffic event involving two or more road users, in which one user performs some atypical or unusual action, such as an change in direction or speed, that places another user in jeopardy of a collision unless an evasive maneuver is undertaken.

Given this overall conceptual definition, precise operational descriptions for a number of types of conflicts were developed. Of those, 12 were considered in this study:

1. Left turn same direction,
2. Slow vehicle,
3. Lane change,
4. Right turn same direction,
5. Opposing left turn,
6. Left turn from left,
7. Cross traffic from left,
8. Right turn from left,
9. Left turn from right,
10. Cross traffic from right,
11. Right turn from right,
12. Opposing right turn on red.

Detailed definitions of these and other conflicts can be found elsewhere (2). Let it suffice here to provide a few examples. All the conflicts become observable, by definition, when the offending or conflicted vehicle undertakes an evasive maneuver, typically by braking or swerving. Conflict 4, for example, occurs when a vehicle slows to make a right turn, which causes the following vehicle to evade a rear-end collision. Type 5 is instigated by a vehicle turning left in front of an oncoming vehicle. Type 7 involves a vehicle to the left, on a cross street, proceeding across in front of another vehicle, which causes the latter to take evasive action.

Experimental Plan

The methodology published in NCHRP Report 219 (2) was used by Migletz et al. (4) to produce the data required for this paper. The data were collected in the Kansas City metropolitan area (population about 1.5 million). The results are believed to be appropriate for much of the United States, but because of regional differences in driving habits, they may not be directly applicable elsewhere. The results are undoubtedly not usable, numerically, in many countries outside the United States. However, the research approach should be universally applicable.

Traffic conflict and accident data were collected at 46 urban intersections located in four cities in the greater Kansas City metropolitan area. These intersections were stratified, first, according to whether they were signalized and then within signalization class according to intersection traffic volume level (not accident history). The volume levels assigned were

- High: more than 25,000 vehicles per day,
- Medium: 10,000 to 25,000 vehicles per day,
- Low: 2,500 to 10,000 vehicles per day.

The assignment of the 46 intersections to the cells was as follows:

	High	Medium	Low
Signalized	14	12	0
Unsignalized	0	10	10

Traffic conflicts were observed and recorded at each of these intersections for 4 days (replicates) during the period from 7:00 a.m. to 6:00 p.m. over the summer months of 1982. The 11-hr period was sampled in 16 sets of 25-min periods, and the sample counts were then adjusted to be representative of the entire period. Three years of accident data (1979-1981) for these same intersections were also obtained and reduced, as well as special 1-day volume and turning-movement counts.

Conflict Data

Aside from a few rare instances of missing data (in most cases of difficulty, additional data were collected), a total of 576 observer-days of conflict data, representing nearly 90,000 traffic conflicts, was obtained. Table 1 shows the raw conflict counts (along with the accidents) obtained in the study. Of these, 64,210 conflicts were used in the analyses. There were comparatively few wet-pavement accidents and conflicts. Because it was suspected that traffic behavior might be different under dry and wet conditions, the latter were not analyzed in depth. Also, a number of secondary conflicts were observed. These are conflicts created or caused by a vehicle in the process of taking evasive action because of a prior conflicting event. They were dropped from further analysis because corresponding accidents were found to be very rare. Table 2 displays the adjusted conflict rates (conflicts per 11-hr day) by conflict type and intersection class.

Accident Data

Hard-copy accident reports of all accidents occurring at the 46 intersections over the 3-year period (1979-1981) were reviewed. A total of 1,292 accidents made up this data base, given in Table 3. The following types were not used in the ultimate analyses, however:

- Secondary road accidents,
- Wet-road accidents,
- Other accidents such as single vehicle and pedestrian,
- Nighttime accidents (those not occurring between 7:00 a.m. and 6:00 p.m.),
- Weekend accidents (not occurring on Monday through Thursday), and
- Multiple-vehicle accidents not matching one of the 12 conflict types.

TABLE 1 Conflicted-Related Accidents and Conflicts by Road Condition

	Signalized Intersection (N = 26)		Unsignalized Intersection (N = 20)	
Road and Condition	No. of Accidents	No. of Conflicts	No. of Accidents	No. of Conflicts
Dry				
Primary	244	49,337	75	14,873
Secondary	2	14,111	1	3,933
Wet				
Primary	42	3,865	25	972
Secondary	0	1,274	2	255
Total	288	68,587	103	20,033

TABLE 2 Conflict-Related Accidents and Conflicts by Type

Conflict		Signalized Intersection				Unsignalized Intersection			
		High Volume (N = 12)		Medium Volume (N = 14)		Medium Volume (N = 10)		Low Volume (N = 10)	
No.	Type	Accidents/ 3 yr	Conflicts/ Day	Accidents/ 3 yr	Conflicts/ Day	Accidents/ 3 yr	Conflicts/ Day	Accidents/ 3 yr	Conflicts/ Day
1	Left turn same direction	5	1,003.73	3	1,886.14	6	1,327.45	2	706.45
2	Slow vehicle	4	8,028.61	3	5,291.13	1	1,518.31	1	1,018.61
3	Lane change	1	218.53	5	106.70	3	27.97	0	1.05
4	Right turn same direction	2	2,623.50	2	1,742.66	1	616.95	0	579.12
5	Opposing left turn	73	264.01	44	406.80	7	89.82	1	36.40
6	Left turn from left	0	7.57	0	6.48	0	39.13	1	33.66
7	Cross traffic from left	26	1.68	30	4.05	14	32.50	19	66.98
8	Right turn from left	0	0.75	2	4.67	0	1.65	0	5.67
9	Left turn from right	1	5.00	1	7.21	0	43.33	0	49.93
10	Cross traffic from right	19	3.47	14	3.21	6	33.27	12	52.28
11	Right turn from right	7	31.23	1	51.89	1	89.72	0	55.46
12	Opposing right turn on red	1	2.72	0	1.32	–	–	–	–

Note: The values tabulated are totals over the number of intersections in each class (e.g., there were 5/(12)(3) or 0.139 accident/yr of the Left-turn same-direction type of accident at an average high-volume, signalized intersection.

TABLE 3 Accidents by Road Condition

Signalization and Volume Class	Multiple-Vehicle Accidents by Road Condition						Other Accidents[a]	Total
	Dry		Wet		Other or Unknown			
	Primary	Secondary	Primary	Secondary	Primary	Secondary		
Signalized								
High (N = 12)	392	11	103	2	48	1	19	576
Medium (N = 14)	314	2	60	1	28	1	31	437
Unsignalized								
Medium (N = 10)	105	1	30	3	8	0	2	149
Low (N = 10)	82	1	29	0	14	1	3	130
Total	893	15	222	6	98	3	55	1,292

[a]For example, single-vehicle or pedestrian accidents.

A common example of the last type is a rear-end collision at a red traffic signal involving a stopped or stopping vehicle. (The conflict definition does not consider stopping for a red traffic signal to be an "atypical or unusual" action.) The 319 accidents retained are included in Table 3.

EXPECTED AND ABNORMAL CONFLICT RATES

One objective of this paper is to suggest, on the basis of data collected, conflict rates that might be expected or typical for intersections like those studied, as well as abnormal rates. "Abnormal" implies rates significantly greater than average, in a statistical sense. The user who finds such abnormal rates at an intersection should be suspicious, either of the data or of the traffic behavior at that intersection.

One defines abnormal or extreme values statistically by examining the probability distribution of a number of observations. This is typically done by calculating the mean and standard deviation, or variance, and using them to represent the properties of the distribution. However, whereas it is common to establish limits in terms of the mean plus or minus some number of standard deviations, this method is not correct for traffic conflicts or many other traffic measures because it indirectly assumes that the data follow a normal distribution. Traffic conflict data do not behave in that way. The counts can never be negative, for example, and their distribution tends to be skewed, with a longer tail at the higher conflict-count values.

This property of nonnormality for traffic data is well known. Researchers have long used the Poisson distribution for certain data, such as queue lengths, headways, and accidents. The Poisson distribution has a variance equal to its mean. Cursory examination shows this to be far from the truth for conflict data--the variance is often 10 to 100 times as large as the mean. Therefore, a more general distribution should be used.

Early in the research (4), it was suggested (E. Hauer, University of Toronto, unpublished data) that the gamma probability distribution be used. It is very general and can be made to fit a variety of data sets. However, it is more difficult to work with than are the normal or Poisson distributions. The probability density function [f(c)] for the gamma distribution is

$$f(c) = te^{-ct} (ct)^{s-1}/\Gamma(s) \quad (1)$$

where Γ is the gamma function, and t and s, both positive, are called the parameters of the distribution. The random variable c is taken to be the daily number of conflicts of a given type associated with one intersection in this paper.

The parameters t and s are defined in terms of the expected value or mean [E(c)] and variance [Var(c)] of the distribution through the following equations:

$$t = E(c)/Var(c) \quad (2)$$

$$s = t\,E(c) \quad (3)$$

An examination of some typical plots of Equation 1 for selected types of conflicts follows. Figure 1 shows the distribution of all-same-direction conflicts (the sum of types 1 through 4) for signalized medium-volume intersections; it looks much like a normal distribution. The mean value in this case is about 645, and the standard deviation is 159 [= $(25{,}338)^{1/2}$], so individual sample counts can be expected to be much greater than zero but fairly tightly clustered about the mean. Note, however, that the curve is not quite symmetrical. The average value for this type of conflict (645) is slightly to the right of the peak at 605. The value of c at the peak of the curve is called the mode of the distribution. The mode and the mean are the same for a normal distribution; the more they differ, the more the distribution is skewed.

Also shown in Figure 1 are the 90th and 95th percentiles. In this case, 90 percent of all intersections of this class are expected to have less

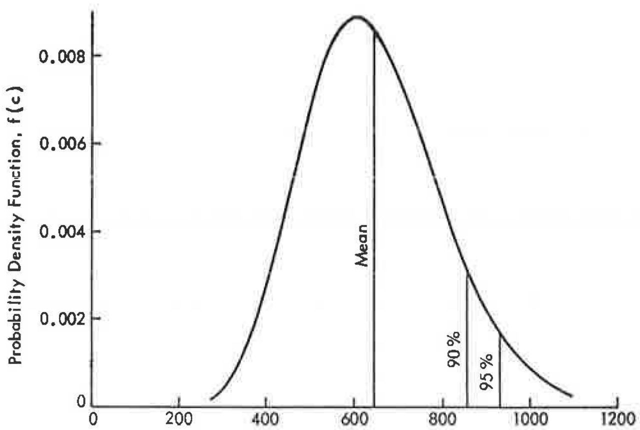

FIGURE 1 Distribution of all-same-direction conflicts for signalized medium-volume intersections.

than 860 conflicts per day of this type, and 95 percent are expected to have less than 930 conflicts per day. In other words, only 10 percent (or 5 percent) of all intersections should be worse than these values indicate. In the remainder of this discussion, limits of 10 and 5 percent will be used as alternative definitions of abnormal conflict rates.

A quite different shape results when the gamma distribution is applied, for example, to opposing-left-turn conflicts for signalized high-volume intersections, as shown in Figure 2. It is highly skewed, with the mean value 5 times as large as the mode (4.8). For this type of conflict, most of the intersections may be expected to have fairly low daily conflict rates--in fact, half will have less than 16 (the median). However, many will have quite large values, so the idea of abnormality takes on a different aspect. Whereas in the previous case the 95th percentile (930) was only 1.44 times as large as the average, in this case an intersection would be required to have nearly three times as many conflicts as the average to be considered abnormal.

A final example shows an even more extreme case (Figure 3). The variance for this type of conflict is so large that the standard deviation, 108 = $(11{,}613.7)^{1/2}$, is greater than the mean of about 84 conflicts per day. In such a case, the gamma distribution has no mode or peak. The value of f(c) becomes increasingly large as c approaches zero. The median is about 42 conflicts per day, so half the intersections should experience less than that rate. The average, however, is about twice as large as the median (~84), and the 95th percentile is nearly 4.5 times the average (360 conflicts per day).

It remains to explain how these limits and other numerical values are determined. The mode is easily calculated as

$$\text{Mode} = (s - 1)/t \qquad (4)$$

which is only meaningful if s is greater than 1. The 90th percentile is the value of c (say, c_{90}) for which

$$\int_{c_{90}}^{\infty} f(c)dc = 0.10 \qquad (5)$$

That is, c_{90} is chosen so that the area under the curve to the right of that point is only 10 percent of the total.

Equation 5 could be solved by numerical integration with the expression for f(c) given in Equation 1. Alternatively, the integral can be transformed to the probability integral $[Q(\chi^2/v)]$ of the χ^2-distribution, which has been tabulated by several authors (5, pp. 978-983).

To use these tables, simply replace v by 2s and χ^2 by 2tc. For example, for the data used in Figure 2, s and t are 1.281 and 0.05824, respectively. Interpolating in the table for v = 2.562, it is found that Q = 0.10 (approximately) for χ^2_{90} = 5.55. Then $c_{90} = \chi^2_{90}/2t = 47.6$. Values of c_{95}, and so on, are obtained in a similar fashion.

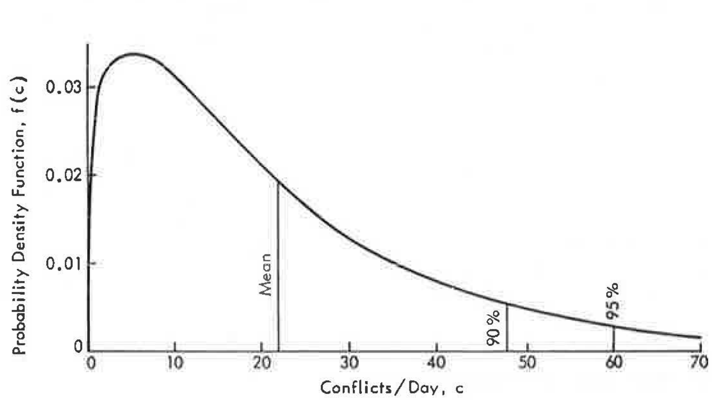

FIGURE 2 Distribution of opposing-left-turn conflicts for signalized high-volume intersections.

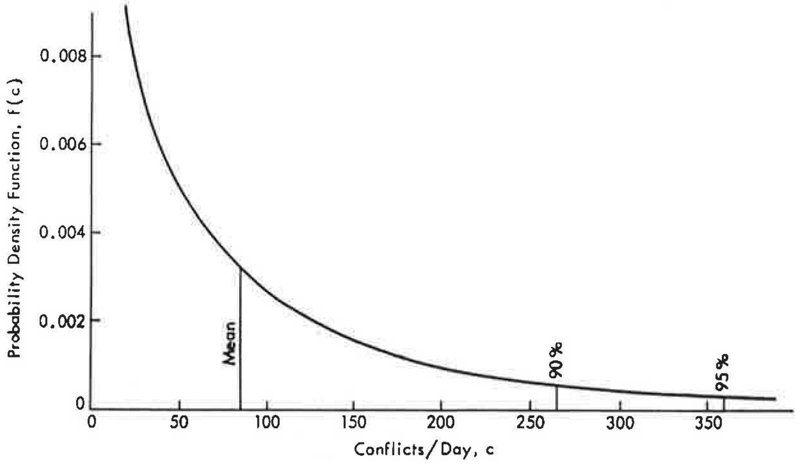

FIGURE 3 Distribution of left-turn-same-direction conflicts for signalized high-volume intersections.

Tables 4 through 7 summarize these calculations. The expected conflict rates (conflicts per 11-hr day) are given in the column headed Mean. The precision of an expected conflict rate is expressed as the standard error of the mean, or $(\text{Variance}/N)^{1/2}$, where N is the number of intersections in the sample. For example, from Table 4 the standard error of the mean for left-turn same-direction conflicts is $(11{,}613.7/14)^{1/2} = 28.8$. When conflict types are so rare that it might be considered abnormal to observe any, no quantitative percentile values are given.

The results given here are based on data obtained from the sample of intersections in this study. It is expected that other users, at least in the United States, should obtain roughly comparable values,

TABLE 4 Daily Conflict Rates for Signalized High-Volume Intersection

Conflict No.	Type	Mean	Variance	Mode[a]	Percentile[b] 90th	95th
1	Left turn same direction	83.644	11,613.7	–	265.0	360.0
2	Slow vehicle	669.051	23,994.7	633.0	870.0	940.0
3	Lane change	18.211	160.6	9.4	35.0	43.0
4	Right turn same direction	218.625	7,587.5	184.0	470.0	510.0
5	Opposing left turn	22.001	377.7	4.8	48.0	60.0
6	Left turn from left	0.631	0.824	–	1.7	2.5
7	Cross traffic from left	0.140	0.135	–	–	–
8	Right turn from left	0.062	0.022	–	–	–
9	Left turn from right	0.417	0.261	–	1.1	1.4
10	Cross traffic from right	0.290	0.215	–	–	–
11	Right turn from right	2.603	2.268	0.9	4.6	5.4
12	Opposing right turn on red	0.227	0.124	–	–	–
1-4	All same direction	989.531	67,198.4	921.0	1,340.0	1,460.0
7+10	Through cross traffic	0.430	0.335	–	1.1	1.5

[a]Maximum value of the gamma distribution of conflicts (c) for $f(c) = te^{-ct}(c)^{s-1}/\Gamma(s)$, if a maximum exists.
[b]For the rarest types of conflicts, no values are given; any observed conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 5 Daily Conflict Rates for Signalized Medium-Volume Intersection

Conflict No.	Type	Mean	Variance	Mode[a]	Percentile[b] 90th	95th
1	Left turn same direction	134.724	10,298.3	58.0	270.0	340.0
2	Slow vehicle	377.938	4,928.9	365.0	470.0	500.0
3	Lane change	7.621	52.8	0.7	17.0	22.0
4	Right turn same direction	124.476	2,445.1	105.0	190.0	220.0
5	Opposing left turn	29.057	211.2	22.0	49.0	56.0
6	Left turn from left	0.463	0.466	–	1.3	1.9
7	Cross traffic from left	0.289	0.240	–	–	–
8	Right turn from left	0.333	0.188	–	0.8	1.1
9	Left turn from right	0.515	0.125	0.3	1.0	1.2
10	Cross traffic from right	0.229	0.118	–	0.7	1.0
11	Right turn from right	3.707	2.839	2.9	6.0	7.0
12	Opposing right turn on red	0.094	0.058	–	–	–
1-4	All same direction	644.760	25,338.4	605.0	860.0	930.0
7+10	Through cross traffic	0.519	0.215	0.1	1.1	1.4

[a]Maximum value of the gamma distribution of conflicts (c) for $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$, if a maximum exists.
[b]For the rarest types of conflicts, no values are given; any observed conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 6 Daily Conflict Rates for Unsignalized Medium-Volume Intersection

Conflict					Percentile[b]	
No.	Type	Mean	Variance	Mode[a]	90th	95th
1	Left turn same direction	132.745	11,643.4	45.0	275.0	350.0
2	Slow vehicle	151.831	5,921.8	113.0	255.0	290.0
3	Lane change	2.797	22.6	–	–	–
4	Right turn same direction	61.695	1,156.5	43.0	105.0	125.0
5	Opposing left turn	8.982	39.8	4.6	17.0	21.0
6	Left turn from left	3.913	6.452	2.3	7.0	9.0
7	Cross traffic from left	3.250	4.644	1.8	6.0	7.5
8	Right turn from left	0.165	0.077	–	–	–
9	Left turn from right	4.333	21.2	–	10.0	14.0
10	Cross traffic from right	3.327	4.297	2.0	6.0	7.5
11	Right turn from right	8.972	99.4	–	21.0	29.0
12	Opposing right turn on red	–	–	–	–	–
1-4	All same direction	319.068	28,650.5	229.0	540.0	640.0
7+10	Through cross traffic	6.577	15.7	4.2	12.0	14.0

[a]Maximum value of the gamma distribution of conflicts (c) for $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$, if a maximum exists.
[b]For the rarest types of conflicts, no values are given; any observed conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 7 Daily Conflict Rates for Unsignalized Low-Volume Intersection

Conflict					Percentile[b]	
No.	Type	Mean	Variance	Mode[a]	90th	95th
1	Left turn same direction	70.645	1,005.0	56.0	110.0	130.0
2	Slow vehicle	101.861	9,648.2	7.1	225.0	295.0
3	Lane change	0.105	0.050	–	–	–
4	Right turn same direction	57.912	2,197.3	20.0	120.0	150.0
5	Opposing left turn	3.640	8.300	1.4	7.5	9.0
6	Left turn from left	3.366	7.790	1.1	7.0	9.0
7	Cross traffic from left	6.698	42.0	0.4	1.5	19.0
8	Right turn from left	0.567	0.828	–	–	–
9	Left turn from right	4.993	72.7	–	16.0	23.0
10	Cross traffic from right	5.228	11.6	3.0	10.0	12.0
11	Right turn from right	5.546	12.1	3.4	10.0	12.0
12	Opposing right turn on red	–	–	–	–	–
1-4	All same direction	230.523	17,929.2	153.0	410.0	490.0
7+10	Through cross traffic	11.926	75.2	5.6	24.0	29.0

[a]Maximum value of the gamma distribution of conflicts (c) for $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$, if a maximum exists.
[b]For the rarest types of conflicts, no values are given; any observed conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

although this statement is made without proof. If other parts of the country produce different conflict rates, the user can establish his own expected and abnormal conflict rates by using the procedures explained here.

ACCIDENT PREDICTION

Philosophy

If one wants to know how many accidents have occurred at a specified location, one should review the accident records. Bypassing such records and using a surrogate such as traffic conflicts cannot possibly produce the correct answer.

Unfortunately, this rather obvious concept has usually been overlooked or is unappreciated by researchers and practicing traffic engineers in their search for some measure that might supplant accident data and be used to support difficult decisions. The general approach used to validate a surrogate measure has been to compare observed accidents with the observed surrogate measure, and then to be quickly discouraged and disappointed by the lack of agreement. For example, correlation coefficients of 0.4, 0.6, or even 0.8 are quickly rejected as not being large enough to adequately estimate or predict accidents. Any attempt to match conflicts (or any other surrogate) with accidents in this manner is doomed to failure.

To look at this differently, why would one even want to consider using surrogates? It would not be to identify high-accident locations--the accident data do this. It might be to identify locations with a high accident potential--locations that may be suspected to have safety problems although the accident data do not yet support this. Perhaps it is to determine whether a redesign or countermeasure can be expected to be effective in improving safety without a wait of months or years to establish an accident data base. It might be to determine whether the recent occurrence of a few accidents at an intersection previously presumed safe means that, in fact, the intersection is becoming or has become less safe, for whatever reason. All these potential applications require an estimation or prediction of what may happen in the future--not a duplication of what has happened in the past. In reality, engineers commonly use accident data not just to determine what has already happened; they surmise that the history predicts the future unless changes are made.

Accidents are, in a way, random events. They cannot be predicted except in a statistical sense. Given a substantial accident history for an intersection, one can estimate the expected number of accidents for that intersection in a succeeding year. The actual number of accidents in the succeeding year will undoubtedly be numerically different from this expectation, either higher or lower, but the number will normally be within statistically expected bounds.

It is a major purpose of this research to determine how well traffic conflicts can be used to estimate expected accident rates as distinguished from the number or rate actually observed in any given period. A difficulty then arises--what is the expected accident rate? Two viewpoints will be taken. One is to compare the expected accident rate as predicted by traffic conflict data with the expected accident rate as predicted by historical accident data. The latter is, in effect, the traditional approach; the degree to which the two predictions agree will provide an indication of the validity of traffic conflicts as an accident surrogate. Second, by pooling actual accident data from a number of intersections, years, and so on, another estimate of accident expectations can be derived; both of the foregoing predictions can be compared with this expectation.

In addition to a comparison of estimates of the expected accident rates based on conflicts and on accidents, the quality of the estimates will be assessed as measured by the variance of the estimate. The smaller the variance, the better is the estimate. Whether a certain variance of the estimate is deemed acceptable depends on the variance obtained by other methods of estimation and on the relative costs of estimation by different methods.

Finally, it may be noted that many attempts to prove that conflicts or other measures are satisfactory surrogates failed because the accidents were not suitably disaggregated. Reference to Table 2 shows that most of the conflicts at signalized intersections, for example, involve vehicles traveling in the same direction (types 1 through 4), whereas most of the accidents involve vehicles crossing or meeting head on. If one compared total conflicts and total accidents, one would in effect be comparing conflict movements of one type with accident movements of another type. They are basically unrelated, so no valid statistical relationship should be expected.

Therefore, in this paper only like types of events were analyzed. This has the obvious advantage that if the surrogate (conflicts) is found to be statistically acceptable, it is also logical and defensible. The disadvantage is that it does not deal with total accidents, the ultimate measure that most people feel most comfortable with.

Use of Accident/Conflict Ratios

It is proposed that accident expectation be predicted for an intersection by using conflict data from that intersection in conjunction with accident and conflict data from other intersections of the same class (signalization and volume level). The appropriate equations are

$$\hat{A}_0 = C_0\hat{R} \quad (6)$$

$$\mathrm{Var}(\hat{A}_0) = \mathrm{Var}(C)\mathrm{Var}(\hat{R}) + C_0^2\mathrm{Var}(\hat{R}) + \hat{R}^2\mathrm{Var}(C) \quad (7)$$

where

$\hat{A}_0$ = expected number of accidents,
C_0 = expected conflict rate obtained from the field study at the intersection, and
$\hat{R}$ = estimate of the accident/conflict ratio for that class of intersections (6).

A summary of conflicts and conflict-related accidents by type and class of intersection was given in Table 2. The fractional conflict values arise primarily from the interpolation process used to cover the time periods when conflict observations were not made (7).

Accident/conflict ratios were determined on the basis of reported accident data for 3 years and observed conflict data for 4 days adjusted to 3 years. The accidents and conflicts from a group of similar intersections (for example, signalized high volume) were used to calculate accident/conflict ratios for types of collisions within that group of intersections. Each accident/conflict ratio for a signalization-volume class is the mean value of the accident/conflict ratios of the intersections in that class. The variance of the ratio was taken to be the sample variance of the individual intersection ratios.

Accident Types Subject to Prediction

In the development of accident/conflict ratios, not all types of collisions were analyzed because of a lack of accident or conflict data or both, and some types were pooled to facilitate analysis. The reasons for the choice of the types of collisions analyzed are briefly presented next.

The number of accidents and corresponding conflicts varied considerably from type to type. For most types there was less than one accident per intersection in 3 years. For signalized intersections, because there were so few accidents of types 1, 2, 3, and 4--too few to enable meaningful rate calculations--they were pooled to form a category entitled All Same Direction. In each case, the conflicts are the result of vehicles traveling in the same direction. Even for this pooled category, however, there were no accidents at 12 of the 26 signalized intersections. The opposing-left-turn accidents and conflicts (type 5) showed the best distribution of all the types at signalized intersections. Even here, 7 of the 26 signalized intersections experienced no opposing-left-turn accidents in the 3 years studied.

Note that for signalized intersections, a red-light violation must occur if there is to be a cross-traffic conflict or accident of any kind (types 6 through 11). Such conflicts were observed only rarely. For example, there was a total of only 14 cross-traffic-from-right conflicts observed in 4 days for the 26 signalized intersections (7). This is an average of about 0.13 conflict/day per intersection. To state it differently, one would have to observe all four approaches of an intersection for an average of 7 days to see one conflict of this type. Clearly, such a rare event would not be economically practical as an accident surrogate.

Thus, it is obvious that some sort of pooling is necessary to make cross-traffic conflicts practical. Examination of Table 2 revealed that the most frequent cross-traffic conflict at signalized intersections is type 11, right turn from right, which commonly occurs with illegal right-turn-on-red maneuvers. However, only 6 of the 26 intersections experienced any accidents of this type in 3 years, and none had more than two. The second most common cross-traffic conflicts are those involving left turns, either from the left or from the right (types 6 and 9). Yet there were only two accidents altogether for these two types over the set of 26 intersections. The two conflict types involving through movements of cross traffic (types 7 and 10) were exceedingly rare yet represent the most common type of cross-traffic accident.

In summary, although it might appear desirable to pool the cross-traffic conflicts and accidents, it does not appear legitimate to do so. If pooling did occur, it would be almost equivalent to comparing through-cross-traffic accidents with right-turn-from-right conflicts. Therefore, no further work on cross-traffic accident/conflict ratios at signalized intersections appears warranted.

Finally, the opposing-right-turn-on-red category (type 12) yielded very few conflicts and just one accident. This type involves right-turning vehicles conflicting with opposing-left-turn vehicles with a protected phase (2). Therefore this type, too, was dropped from further analyses.

Examination of the data from the unsignalized intersections also led to decisions about the subsequent analyses of accident/conflict ratios. The left-turn-same-direction data (type 1) for the medium-volume intersections were deemed adequate (marginally) for analysis. They were not combined with the data from the other three same-direction types (2-4), or the type 1 data from low-volume intersections, however. Accidents for conflict types 2 and 4 were very rare. There were very few conflicts of type 3, and although there were three accidents, all occurred at one intersection when one vehicle sideswiped a left-turning vehicle when the first vehicle attempted to pass the second on the shoulder.

As expected, the unsignalized intersections experienced more cross-traffic conflicts than the signalized intersections. Inasmuch as all but one of the cross-traffic accidents involved through movements (conflict types 7 and 10), they were retained; the other cross-traffic data were dropped from further analyses. The opposing-left-turn (type 5) data were retained for the medium-volume intersections but not for the low-volume sites.

To recapitulate, the following accident and conflict types were used in the analysis of accident/conflict ratios:

1. Signalized high- and medium-volume intersections
   a. All same direction (pooled)
      (1) Left turn same direction
      (2) Slow vehicle
      (3) Lane change
      (4) Right turn same direction
   b. Opposing left turn
2. Unsignalized medium-volume intersections
   a. Left turn same direction
   b. Opposing left turn
   c. Through cross traffic (pooled)
      (1) Cross traffic from left
      (2) Cross traffic from right
3. Unsignalized low-volume intersections: through cross traffic (pooled)
   a. Cross traffic from left
   b. Cross traffic from right

Accident Prediction Data

The accident/conflict ratios in Table 8 reveal the large differences from type to type. The all-same-direction type has the smallest accident/conflict ratios, with an average of about 2×10^{-6} accident/conflict. The opposing-left-turn and through-cross-traffic types have ratios of the order of 500×10^{-6} accident/conflict. Thus, it is evident that some types of conflicts are far more likely to yield an accident than other types. Indeed, the differences are of 2 to 3 orders of magnitude.

One might be tempted to impute meanings to the differences in accident/conflict ratios for a given type between intersection classes. For example, the mean all-same-direction ratio for signalized medium-volume intersections is twice that for signalized high-volume intersections (2.663×10^{-6} versus 1.428×10^{-6}). However, the corresponding standard deviations are fairly large compared with the means, which indicates that the data have a lot of scatter. Therefore, the apparent difference might not be statistically significant.

To test for differences in means, one commonly uses the t-test, which is not applicable in this instance because the data are not from a normal distribution, a requirement for using the t-test. Instead, the distributions of the two sets of accident/conflict ratios were compared by using the Kolmogorov-Smirnov test (8), which did not show a significant difference in the distributions. However, this test is known to be conservative when the data sets contain many ties. In this case, 12 of the 26 signalized intersections had no accidents in the all-same-direction category. Repeating the test on the remaining 14 intersections indicated that the two distributions were significantly different at the 5 percent significance level. That is, for signalized intersections having accidents of this type, those with medium volume had higher accident/conflict ratios than those with high volume.

There is a legitimate argument against deleting intersections without accidents--these data are just as valid as those for intersections with accidents. In this case, the accident data base is just too sparse to enable strong conclusions to be drawn. Despite the fact that the difference in the two complete data sets is not statistically significant, combination of the two sets is not believed to be appropriate. Given more data, one might be able to show that a difference exists.

TABLE 8 Accident/Conflict Ratio Statistics

Type of Conflict and Intersection Class	No. of Intersections	Mean Accident/Conflict Ratio[a]	Standard Deviation[a]	Variance		Coefficient of Variation (%)		
				$\mathrm{Var}(\hat{R})$[b]	Var(C)[c]	Ratio	Accidents	Conflicts
Left turn same direction, unsignalized medium volume	10	15.024×10^{-6}	31.810×10^{-6}	101.204×10^{-12}	11,643	211.8	151.8	81.3
All same direction								
Signalized high volume	12	1.428×10^{-6}	1.500×10^{-6}	0.189×10^{-12}	67,198	105.4	112.8	26.2
Signalized medium volume	14	2.663×10^{-6}	3.703×10^{-6}	0.979×10^{-12}	25,338	139.1	129.9	24.7
Opposing left turn								
Signalized high volume	12	671.087×10^{-6}	$1{,}002.990 \times 10^{-6}$	83.832×10^{-9}	337.7	149.5	130.3	88.3
Signalized medium volume	14	184.906×10^{-6}	187.500×10^{-6}	2.511×10^{-9}	211.2	101.4	105.1	50.0
Unsignalized medium volume	10	212.456×10^{-6}	293.010×10^{-6}	8.586×10^{-9}	39.8	137.9	135.5	70.2
Through cross traffic								
Unsignalized medium volume	10	735.425×10^{-6}	$1{,}088.780 \times 10^{-6}$	118.544×10^{-9}	15.7	148.0	115.5	60.3
Unsignalized low volume	9	489.229×10^{-6}	302.292×10^{-6}	10.153×10^{-9}	75.2	61.8	78.2	72.7

[a](Accidents/3 yr) ÷ (conflicts/3 yr).
[b][(Accidents/3 yr) ÷ (conflicts/3 yr)]^2.
[c](Conflicts/day)^2.

The same arguments can be made regarding the opposing-left-turn ratios at signalized high- and medium-volume intersections and those for through cross traffic at unsignalized medium- and low-volume intersections. Although the mean values differ considerably, statistical tests are unable to prove the differences to be significant. Nevertheless, it is probably wise not to pool the data.

The standard deviations of the accident/conflict ratios are fairly large. Another way of examining the variability in these ratios is through the coefficients of variation (CVs). The CV is the standard deviation divided by the mean of the accident/conflict ratio. It gives a measure of the relative variation, or imprecision, of the ratio. The CVs obtained are rather high, ranging from 61.8 to 211.8 percent (see Table 8).

A more careful review of the raw data suggests that these high values are largely the result of the variability in the accident data rather than in the conflict data, as is seen in Table 8. In general, higher relative variations in accidents parallel higher relative variations in accident/conflict ratios. The CVs of the conflicts are about half those of the corresponding ratios.

Validation

The procedure for validating the use of traffic conflicts as accident surrogates was as follows. Within each class of intersections, two locations were randomly selected. Accident/conflict ratios were then computed as described earlier but based only on the data from the remaining 38 locations. With the conflict rates and variances obtained from the study, the expected accident rates and their variances were then computed for the selected intersections and compared with those based on the average of the actual accident counts during the years 1979, 1980, and 1981. (No corrections were made for other covariates, such as volume changes, accident trends, etc.)

The computations of the expected accident rates and their variances will be demonstrated on the all-same-direction type of conflict at one of the signalized high-volume sites (Location 19). With the notations given earlier, the computation is as follows:

C_0 = 1,386 conflicts/day from the study;
$\hat{R} = 1.308 \times 10^{-6}$, the average accident/conflict ratio for signalized high-volume intersections (note that this is not the finally recommended value in Table 8, based on all intersections);
$Var(\hat{R}) = 2.6462 \times 10^{-13}$; and
$Var(C) = 65{,}697.8$ (conflicts/day)^2.

Thus, the expected accident rate per 11-hr day will be

$\hat{A}_0 = C_0 \times \hat{R} = 1{,}386 \times 1.308 \times 10^{-6} = 1.813 \times 10^{-3}$ accident/day.

$Var(\hat{A}_0) = Var(C)\ Var(\hat{R}) + C^2_0\ Var(\hat{R}) + \hat{R}^2\ Var(C) = 0.6381 \times 10^{-6}$ (accident/day)^2.

In summary, the expected daily all-same-direction accident rate at Location 19 is 0.0018 accident/day, with a standard deviation of 0.0008 accident/day [square root of $Var(\hat{A}_0)$]. In units of accidents per year on weekdays (Monday-Thursday), these results are adjusted by a multiplication factor of 4/7 x 365, giving 0.38 accident/year with a standard deviation of 0.17 accident/year. This prediction is for that specific type of accident on dry pavement and during daylight hours only. The CV of the expected number of accidents of this type at this intersection is 44.1 percent. These values, based on conflicts and conflict/accident ratios, are to be compared with the expected accident rate of 0.67 accident/year, standard deviation of 1.15, and CV of 173.2 percent based on previous accident rates. These results, along with those for the other validation locations and conflict types, are given in Table 9.

Overall, for this set of intersections and these types of conflicts, the total number of expected accidents based on conflicts is 18.20, very close to the expected number based on accidents (19.67). Both expectations are in good agreement with the observed

TABLE 9 Expected Accident Rates

			Expected Accidents/Yr					
			Based on Conflicts			Based on Accidents		
Intersection and Volume Class	Validation Intersection No.	Type of Conflict	Accidents/ Yr	Standard Deviation	Coefficient of Variation (%)	Accidents/ Yr	Standard Deviation	Coefficient of Variation (%)
Signalized								
High volume	19	All same direction	0.38	0.17	44.1	0.67	1.15	173.2
	20		0.26	0.13	48.8	0.33	0.58	173.3
	19	Opposing left turn	3.88	3.54	91.2	8.33	1.53	18.3
	20		6.51	4.52	69.4	3.33	2.08	62.5
Medium volume	12	All same direction	0.39	0.19	48.6	0.0	0.0	-
	26		0.35	0.18	50.9	0.33	0.58	173.3
	12	Opposing left turn	0.67	0.64	95.4	1.33	0.58	43.3
	26		1.14	0.70	61.3	0.33	0.58	173.3
Unsignalized								
Medium volume	34	Left turn same direction	0.24	0.56	233.4	0.0	0.0	-
	46		0.26	0.56	220.7	0.0	0.0	-
	34	Opposing left turn	0.12	0.24	205.6	0.33	0.58	173.3
	46		0.08	0.23	299.7	0.33	0.58	173.3
	34	Through cross traffic	1.42	1.13	79.5	1.67	1.15	69.3
	46		0.70	0.88	126.6	0.33	0.58	173.3
Low volume	27	Through cross traffic	0.93	0.97	104.4	1.0	1.0	100.0
	33		0.87	0.97	111.4	1.33	1.15	86.6
Total[a]			18.20			19.67		

[a]Actual total in 1982 = 20.

number of 20 in 1982. This suggests that conflicts are nearly as good as accidents in predicting expected accidents, at least for the total from this sample of 16 predictions.

One can then ask how the two sets of 16 predictions fit the set of 16 observations. Do the predictions from one set tend to be better (closer) than those from the other? The expectations based on accidents were closer in nine cases, the expectations based on conflicts were closer in six cases, and there was one tie. Statistically, there is no evidence that either set of predictions is more likely to be closer more often than the other. Pursuing this a little farther, one can ask whether the magnitudes of the errors in fitting the two predictions to the set of observations are the same. Wilcoxon's signed rank test (8) was used to test this hypothesis, showing no significance at the 95 percent level. At the 90 percent confidence level, the accident-based predictions are marginally closer than the conflict-based predictions. It is noted that the conflict-based expectations were closer than the accident-based expectations more often for unsignalized intersections, and the reverse was true for signalized intersections. However, the data set is too small to allow convincing generalizations.

Another way of comparing the two estimation procedures is to examine their variances (precision). This can be done by comparing the CVs (standard deviation/mean) obtained in both cases. Again, Wilcoxon's signed rank test was used. It showed no evidence that one method produces, on the average, more precise predictions than the other method. In some instances the conflict-based expected value is more precise, and in other instances the accident-based value is more precise.

Effect of Volume

It has been noted that conflicts and accidents are both correlated with intersection volumes (2), suggesting that conflict-accident relationships may exist because of this volume effect. In order to minimize the influence of volume, the intersections were stratified by volume level, as discussed earlier. It is nevertheless appropriate to question whether the stratification effectively removed the volume effect.

Volume counts were obtained during the research. The actual volumes in any cell of the design differed only by a factor ranging from 1.85 to 2.50 (7). Correlation analyses were performed, within cells, between the conflict types in Table 8 and the corresponding intersection volumes, with the results shown in Table 10. In most cases the correlations are far from significant, and in some instances they appear to be negative. The exception is for signalized medium-volume intersections where the correlations for the two conflict types considered are significant ($p = 0.07$ and 0.04, respectively). In these cases the regression accounts for 25 or 31 percent (R^2) of the variance in the conflict counts.

Thus, although some of the variation in conflict counts can be explained by differences in volumes for signalized medium-volume intersections, the amount explained is not large. And for the other intersections there is no detectable effect of volume.

Minimum Variance Predictions

Two sets of predictions (expectations) have been discussed--one based on conflicts and one based on accidents. There is no conclusive evidence that one is more accurate or precise than the other. However, the two sets of expectations can be combined to yield expected values with variances less than those for either set alone. If $\hat{A}_a$ is the expected accident rate based on accident data, then $\hat{A}_m$, the expected accident rate with minimum variance, can be computed as follows:

$$\hat{A}_m = [\hat{A}_0/\mathrm{Var}(\hat{A}_0) + \hat{A}_a/\mathrm{Var}(\hat{A}_a)]\mathrm{Var}(\hat{A}_m) \quad (8)$$

where

$$\mathrm{Var}(\hat{A}_m) = 1/[1/\mathrm{Var}(\hat{A}_0) + 1/\mathrm{Var}(\hat{A}_a)] \quad (9)$$

Thus, Equation 8 yields a more precise estimate of the expected accident rate than do either accidents or conflicts alone. The results are shown in Table 11.

CONCLUSIONS

This study culminated in the following conclusions:

1. A fundamental difficulty with a study of this kind is the rarity of accidents, the very reason that one searches for accident surrogates in the first place. The 1,292 total accidents in the 3-year, 46-intersection data base yielded an average of only about 28 accidents per intersection. After those accidents that involved single vehicles, nighttime, adverse pavement conditions, and so on, were deleted, only 319 accidents (about 7 per intersection in 3 years) remained that could be considered conflict-related. Further subdivision into 12 conflict types yielded a sparse data set indeed.

2. There are 12 basic conflict types that are possible, according to NCHRP Report 219 (2). Of these, some are fairly common, but others are so rare that they are impractical for operational applications. At signalized intersections same-direc-

TABLE 10 Correlations Between Intersection Volumes and Conflicts

Intersection and Volume Class	Type of Conflict	N	Correlation Coefficient (R)	Probability (p)
Signalized				
High volume	All same direction	12	0.34	0.28
	Opposing left turn	12	−0.26	0.41
Medium volume	All same direction	14	0.50	0.07
	Opposing left turn	14	0.55	0.04
Unsignalized				
Medium volume	Left turn same direction	10	−0.04	0.91
	Opposing left turn	10	−0.04	0.91
	Through cross traffic	10	0.10	0.77
Low volume	Through cross traffic	10	0.37	0.30

TABLE 11 Minimum Variance Accident Expectations

Intersection and Volume Class	Validation Intersection No.	Type of Conflict	Expected Accidents/Yr Conflict-Based	Expected Accidents/Yr Accident-Based	Expected Accidents/Yr With Minimum Variance	Variance Conflict-Based	Variance Accident-Based	Variance Minimum
Signalized								
High volume	19	All same direction	0.38	0.67	0.39	0.029	1.32	0.028
	20		0.26	0.33	0.26	0.017	0.34	0.016
	19	Opposing left turn	3.88	8.33	7.63	12.5	2.34	1.97
	20		6.51	3.33	3.88	20.4	4.33	3.57
Medium volume	12	All same direction	0.39	0.0	0.0	0.036	0.0	0.0
	26		0.35	0.33	0.35	0.032	0.34	0.029
	12	Opposing left turn	0.67	1.33	1.03	0.41	0.34	0.19
	26		1.14	0.33	0.66	0.49	0.34	0.20
Unsignalized								
Medium volume	34	Left turn same direction	0.24	0.0	0.0	0.31	0.0	0.0
	46		0.26	0.0	0.0	0.31	0.0	0.0
	34	Opposing left turn	0.12	0.33	0.15	0.058	0.34	0.050
	46		0.08	0.33	0.11	0.053	0.34	0.046
	34	Through cross traffic	1.42	1.67	1.54	1.28	1.32	0.65
	46		0.70	0.33	0.44	0.77	0.34	0.24
Low volume	27	Through cross traffic	0.93	1.00	0.96	0.94	1.00	0.48
	33		0.87	1.33	1.06	0.94	1.32	0.55

tion conflicts are common, as are opposing-left-turn conflicts. Cross-traffic conflicts at signalized intersections can occur only if a driver violates the red signal phase and are exceedingly rare (with the exception of the right-turn-from-right conflict, which is observed more frequently although it still indicates a violation of the usual right-turn-on-red ordinances). At unsignalized intersections, all-same-direction conflicts are also common, except for those resulting from lane changes. Cross-traffic conflicts are much more prevalent at such intersections compared with signalized intersections.

3. Considering the rarity of certain conflict types and the infrequent occurrence of some accident types, emphasis in applying the TCT as a safety indicator must be placed on a limited subset of conflict types. It is not practical to use conflict types that require excessively long periods to observe adequate samples. Likewise, there is little incentive to collect data on conflict types for which corresponding accidents hardly ever occur. Thus, the practical, usable conflict types are the following:

1. Signalized intersections
   a. Same direction (pooled types 1, 2, 3, and 4)
   b. Opposing left turn (type 5)
2. Unsignalized intersections [through cross traffic from left and right (pooled types 7 and 10)]
3. Unsignalized intersections, medium volume only
   a. Opposing left turn (type 5)
   b. Left turn same direction (type 1)

4. An estimate of the expected rate of accidents of a specified type and for a specified class of intersections can be computed from data obtained in a field conflict study. If the conflict study at the intersection produces an average conflict rate of C_0, the expected accident rate is $\hat{A}_0 = C_0\hat{R}$. Values of $\hat{R}$, which are the accident/conflict ratios obtained in this research for the various conflict types and intersection classes, are presented in Table 8, along with their variances. The latter can be used to estimate the variance in the expected accident rate by using Equation 7.

5. Accident/conflict ratios differ substantially from conflict type to conflict type, ranging from as low as 1 or 2 accidents/million conflicts for same-direction conflicts at signalized intersections to as high as about 700 accidents/million conflicts of the opposing-left-turn and through-cross-traffic types. (The latter ratios are for unsignalized intersections only; at signalized intersections there are about 10,000 accidents/million through-cross-traffic conflicts, but the rarity of this type of conflict precludes an accurate estimate.)

6. The variation in accident/conflict ratios is generally quite large (CVs up to about 200 percent), indicating a substantial difference among intersections of normally the same type. This variance arises primarily from the intersection-to-intersection differences in accidents, whose CVs match those of the ratios quite well. The CVs of the conflicts, on the other hand, are only about half as large.

7. Comparisons of accident/conflict ratios between classes of intersections suggest that there are differences, but statistical tests, for the most part, are not able to establish this with confidence. This is because of the large variances noted earlier, as well as the substantial number of intersections having no accidents of a specified type during the 3 years analyzed. Despite the lack of proof of such differences between intersection classes, it is probably unwise to combine the data from different classes of intersections to obtain universal ratios.

8. The conflict rates obtained and used to determine the accident/conflict ratios are the average or expected values. Procedures were developed to determine values that could be considered abnormally high. Basically, the procedure utilized calculated probability distributions (the gamma distribution) and accepted as abnormal by definition those rates that exceeded the 90th percentile (alternatively, the 95th percentile). The values obtained are given in Tables 4 through 7.

9. If a potential TCT user determines that his conflict rates and variances differ substantially from those obtained in the U.S. Midwest during this study, he will have to adjust the values given in Tables 4 through 7. The procedure is described in the text.

10. The proper use of conflicts is to estimate an expected rate of accidents as opposed to predicting the actual number that might occur in a particular year. Accident data fluctuate greatly from year to year; the best one should expect is to be able to estimate the average (expected) value with acceptable accuracy and precision.

11. An additional year of accident data (1982) for eight intersections was used to determine the validity of the proposed accident estimation procedure. Accident estimates based on conflicts were compared with accident estimates based on accident history. Overall, for the eight intersections, both methods produced about the same estimates--18.20 accidents on the basis of conflicts, 19.67 on the basis of previous accidents. (There were actually 20 conflict-related accidents in 1982 at the eight intersections.) Breaking these down to the 16 possible combinations of intersections and conflict types indicated that both procedures sometimes overestimated and sometimes underestimated the actual number of accidents. In this respect, the accident-based procedure yielded closer estimates more often than the conflict-based procedure, but only marginally so.

12. Of the 13 out of 16 sets of accident estimates for which CVs could be calculated, those based on accidents were more precise in 8 cases and those based on conflicts were more precise in 5 cases. This difference is not statistically significant; in other words, the conflicts procedure produces estimates equally as precise as those based on accident histories.

13. If one has estimates of expected accidents based on both accident history and conflict data, they can be combined to produce an estimate that is more precise (smaller variance) than would be obtained by using either one separately.

14. Overall, traffic conflicts of certain types are indeed good surrogates of accidents in that they produce estimates of average accident rates nearly as accurate and precise as those produced from historical accident data. Therefore, if there are insufficient accident data to produce an estimate, a TCT study should be very helpful.

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