RELATIONSHIPS BETWEEN TRAFFIC CONFLICTS AND ACCIDENTS

Research, Development,
and Technology
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Research Center
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U.S. Department
of Transportation

**Federal Highway
Administration**

Report No.
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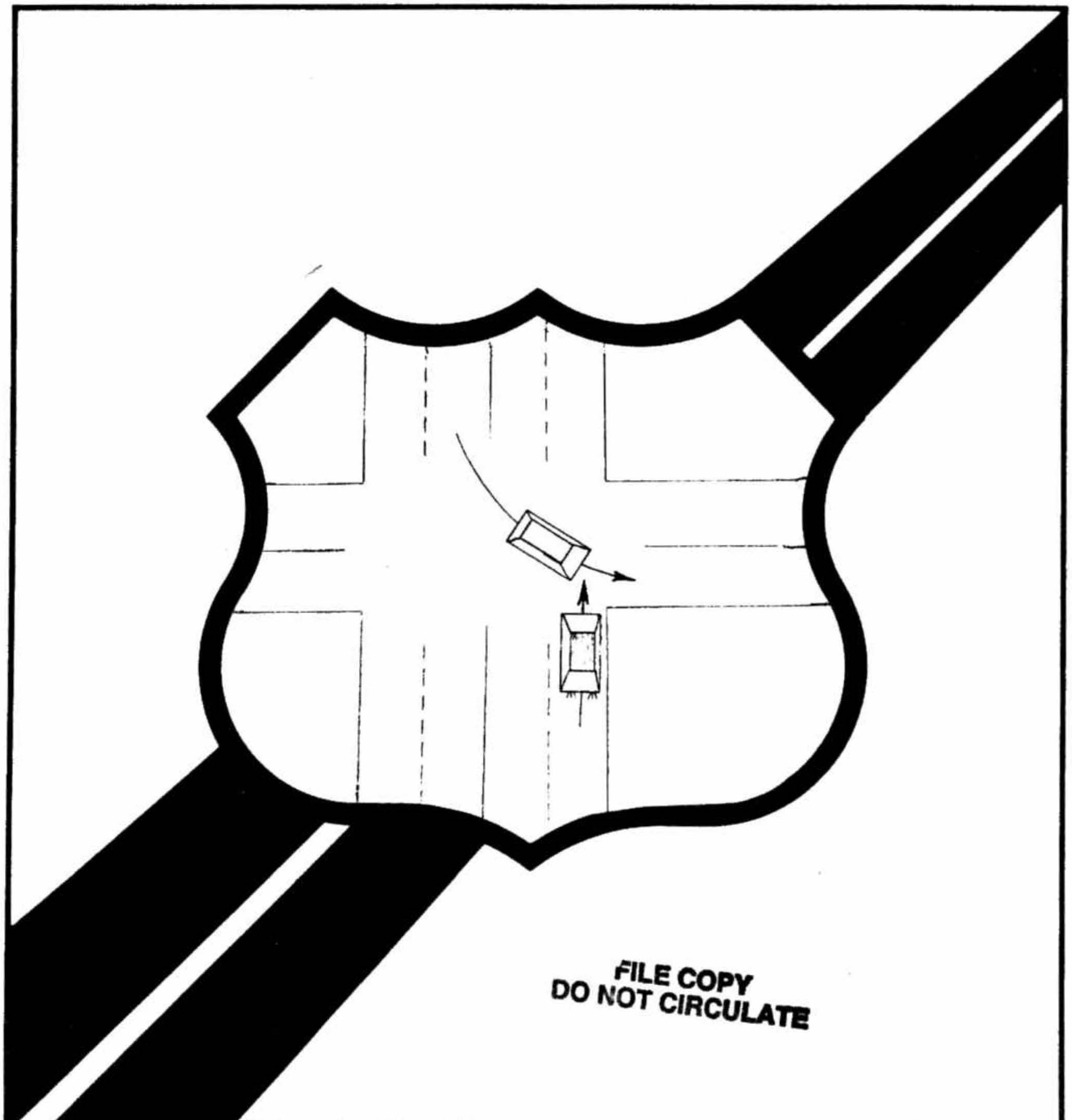
Final Technical Report
July 1985



FOREWORD

This report presents the results of research conducted for the Federal Highway Administration (FHWA), Office of Safety and Traffic Operations Research and Development under Contract No. DTFH61-81-C-00101. This work was part of current Federally Coordinated Program Project 1K, "Accident and Countermeasure Analysis." This study was initiated to establish relationships between traffic conflicts and accidents and to identify expected and abnormal conflict rates in various intersection situations.

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; 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 of 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.

Stanley R. Byington, Director
Office of Safety and Traffic Operations
Research and Development
Federal Highway Administration

NOTICE

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Technical Report Documentation Page

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16. Abstract

The purpose of the present research was to establish relationships between traffic conflicts and accidents, and to identify expected and abnormal conflict rates given various circumstances. The data upon 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 (0700 to 1800) 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; 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 of 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.

This is Volume 2 of a 3-Volume report. The other volumes are Volume 1 - Executive Summary and Volume 3 - Appendixes.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply by	To Find	Symbol
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t

VOLUME

Symbol	When You Know	Multiply by	To Find	Symbol
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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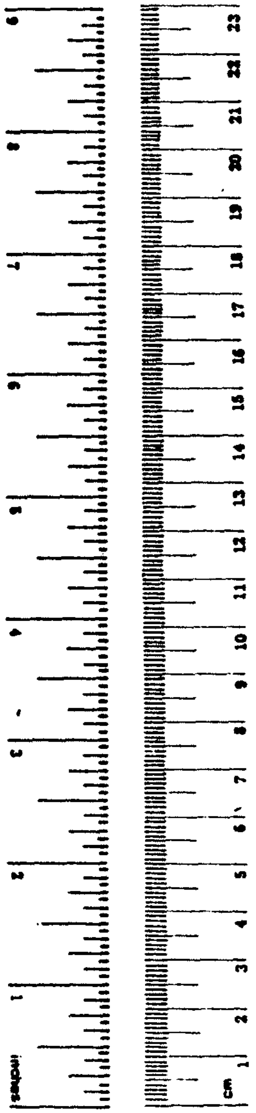
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

LENGTH

Symbol	When You Know	Multiply by	To Find	Symbol
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi

AREA

Symbol	When You Know	Multiply by	To Find	Symbol
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	

MASS (weight)

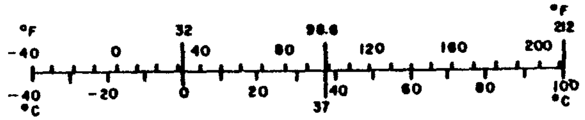
Symbol	When You Know	Multiply by	To Find	Symbol
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	

VOLUME

Symbol	When You Know	Multiply by	To Find	Symbol
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply by	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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I. INTRODUCTION

The research performed under this FHWA contract, "Identification and Quantification of Relationships Between Traffic Conflicts and Accidents" was a continuation of the traffic conflicts techniques (TCT) research started in NCHRP Project 17-3: Application of Traffic Conflict Analysis at Intersections.

The objective of the previous research was to:

> Develop a standardized set of definitions and procedures that would provide a cost-effective method for measuring traffic conflicts.

Within the scope of the previous research, Midwest Research Institute (MRI) developed traffic conflict definitions, training procedures, and data collection procedures. Products of that research included a Procedures Manual for Traffic Conflicts Observers and Instructor's and Engineer's Guide, which were included in NCHRP Report 219.[1]

The definition of a traffic conflict used in the current contract was developed in NCHRP Project 17-3 and is 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 a change in direction or speed, that places another user in jeopardy of a collision unless an evasive maneuver is undertaken.

The definition results in a set of operational definitions corresponding to different instigating maneuvers and is comprised of 12 basic primary conflicts.* For each of the 12 basic conflicts there are corresponding severe conflicts which have time-to-collision thresholds of less than 1.5 seconds. Also, there are other traffic events known as secondary conflicts which arise from the initial, instigating traffic. All operational definitions of traffic conflicts are defined in NCHRP Report 219,[1] and in Volume 3 of this report.

The objectives of the current research were as follows:

1. To quantify the relationship between specific types of traffic conflicts and analogous accident types for specific intersection conditions.

2. To identify the expected and abnormal conflict rates by the determination of means and variances of conflict types.

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* Conflicts involving pedestrians or pedalcyclists also can occur, but were not examined in this study.

Using the definitions and data collection procedures developed in NCHRP Project 17-3, objectives of the current research were planned to be accomplished by completion of the following tasks:

Phase I - Investigate Relevant Issues

Phase II -

- Task A - Develop Analysis Plan
- Task B - Develop Sampling Plan
- Task C - Data Collection
- Task D - Analysis of Data
- Task E - Synthesis of Study Results
- Task F - FCP Conference

Upon completion of Phase I an Interim Report[2] was prepared. Then, during Tasks A and B of Phase II, a sampling and analysis plan[3] was also prepared. This final report very briefly summarizes those earlier reports, but concentrates on the data collection and analysis of Phase II directed toward satisfying the contract objectives.

Section II of this report gives a brief review of the two previous reports, and then outlines the remaining research methodology. (The details are in Volume 3). Section III presents the results of the research, and is organized into 8 subdivisions according to the types of analyses/results being considered. The methodology for these analyses is included in Volume 3; the data are presented in a series of tables in Volume 3. The conclusions and recommendations constitute Section IV. The activity of Task F (FCP Conference) was changed via contract modification to cover participation in the third meeting and calibration study of the International Committee on the Traffic Conflicts Technique (ICTCT). This work is reviewed in Volume 3.

II. RESEARCH METHODOLOGY

The research performed in Phase I provided the direction and guidance needed for successful completion of the remainder of the contract. A presentation of the goals of the Phase I research and an overview of the Phase I report are presented first, followed by a description of the Phase II research.

A. Goals of the Phase I Research

1. Examine and describe statistical procedures, including correlation analysis, that can and have been used in highway safety estimation.

This involved an examination of procedures to evaluate the statistical relationships between accidents, exposure, and conflicts. Also examined were the thresholds of success or failure and various statistical procedures. As a measure of how well conflicts may predict accidents, we must first determine how well accidents predict accidents. The level of success at which accidents predict accidents may provide an upper bound on the accident-conflict relationships to be derived in Phase II of the contract. That is, can we expect conflicts to predict accidents better than accidents predict accidents?

The Phase I report also contained a discussion of the general philosophy of accident prediction, a description of accident and volume data obtained from Kansas City, Missouri, and Overland Park, Kansas, and also discussions of relationships between accidents and accidents, accidents and volume, and accidents and conflicts. The types of statistical tests performed included correlation analysis (e.g., Pearson product-moment correlation, Spearman rank correlation, and multiple correlation), and the use of the variance of the accident predictor according to the procedures presented in a working paper authored by project consultant, Professor Ezra Hauer.[4]

2. Examine the pitfalls or threats to validity that could hamper research involving traffic accidents, exposure, and conflicts.

The threats to the validity of the research and how these were to be addressed were discussed in the Phase I report. In conducting any study, the researcher must be aware of the pitfalls that could hamper the results and conclusions of the study. Several potential threats to the validity of the research were presented and discussed. The discussion was divided into three areas: traffic accident data, exposure data, and traffic conflict data.

3. Determine the validity of the TCT as an operational tool independent of its value as an accident surrogate. The TCT has been used by various highway agencies to identify operational traffic problems at intersections and to evaluate solutions to these problems. A discussion of operational uses of the TCT is presented in NCHRP Report 219.[1]

The current operational status of the TCT in the United States was discussed in the Phase I report. At the time of NCHRP Project 17-3, (1978) the TCT was applied regularly by a number of highway agencies in the country as a tool for operational evaluation and for the purpose of developing accident/conflict relationships. Today, the TCT is not being applied to the extent that it was previously.

B. Phase II, Tasks A and B--Develop Analysis and Sampling Plans

The basic plan that was developed involved collecting traffic conflict, accident, and volume data at 46 urban intersections located in four cities in the greater Kansas City metropolitan area. These intersections were stratified, first, according to whether or not they were signalized, and then within signalization class according to intersection traffic volume level. The volume levels assigned were:

High - over 25,000 vehicles per day
Medium - 10,000-25,000 vehicles per day
Low - 2,500-10,000 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

The sampling plan called for observing and recording various types of traffic conflicts at each of these intersections for four days (replicates) during the period from 0700 to 1800 over the summer months of 1982. Three years of accident data (1979-1981) for these same intersections would also be obtained and reduced, as well as special one-day volume and turning movement counts.

The analysis plan detailed how the accidents would be matched to the corresponding conflicts, and which accidents would not be matchable to any type of traffic conflicts. Then, a number of statistical techniques were identified to determine relationships between conflicts and matching accidents.

Finally, a procedure was described whereby a randomly selected sample of the study intersections would be set aside and used for validation purposes. Accident data for a fourth year (1982) would be compared with predicted values based on the conflict studies vis-à-vis predicted values based on the previous three years of accident data.

Appendix B includes many of the details about the conflict studies from the plan, as well as minor modifications made subsequent to the plan preparation. (For example, small sample sizes of accidents and/or conflicts necessitated some aggregations of data over time and conflict type.) Similarly, Appendix C describes the accident data collection process, and Appendix D covers the analysis procedures.

C. Phase II, Task C--Collect Data

The conflict, accident, and volume data were collected essentially as planned. Details are given in Volume 3.

D. Phase II, Task D--Analyze Data

During this task, accident/conflict ratios; conflict means and variances; and accident, conflict, and volume correlations were computed. In addition, predictions of expected numbers of accidents were computed for eight intersections using conflicts and accident/conflict ratios. These predictions were compared with predictions based on past accidents at the eight intersections. Volume 3 describes the analysis procedures.

E. Phase II, Task E--Synthesis of Results

The results of the data analysis were combined and the final report prepared in this task.

F. Phase II, Task F--International Conflict Study

The project leader was one of two representatives from the United States who participated in an international traffic conflict study in Denmark and Sweden. A description of the study is presented in Volume 3.

III. RESULTS

The results of the studies designed to develop accident/conflict relationships are presented and discussed in this chapter. The accident/conflict ratios developed in this research are intended to be used to produce estimates of system safety. (In this study, signalized and unsignalized urban intersections comprise the system.) System safety is defined as the expected number of accidents in each severity class occurring on the system per unit of time. The quality of the estimate of system safety is measured by the variance of the estimate.

The results of the research are presented in nine subsections. The first subsection presents summaries of traffic accidents, conflicts, and volume data arranged to show general relationships. The next subsection presents the means and variances of the various types of conflicts, arranged by signalization-volume class. The third subsection describes how accident/conflict ratios were derived and presents the ratios, also arranged by signalization-volume class of the experimental design. The fourth subsection develops and presents expected conflict rates, contrasted with rates considered statistically abnormal. The next subsection deals with the severity of accidents according to the corresponding conflict type. The sixth subsection presents volume data, and develops conflict/volume relationships. The seventh subsection presents the results of classical correlation techniques comparing accidents, conflicts, and volumes. The eighth subsection compares the results of accident predictions based on conflicts with accident predictions based on past accidents. The final subsection examines intersection accidents without corresponding "conflicts."

A. General Relationships

Four traffic conflict studies and one volume study were conducted at 46 urban intersections in four neighboring cities in the Kansas City metropolitan area. Accident data for three years (1979, 1980, and 1981) were retrieved for each intersection from police accident investigation reports. This section presents the general relationships between the accident, conflict, and volume data bases. Accident, conflict, and volume tabulations are presented in Volume 3.

The intersections studied were selected based on their traffic control devices (signalized or unsignalized) and traffic volume (high, medium, or low). In addition, each intersection was required to have a known accident history. A description of the site selection process is presented in Volume 3.

Figure 1 depicts the accident history of the study intersections. Intersection numbers are presented on the abscissa. The signalized intersections are numbered 1 through 26 and the unsignalized intersections are numbered 27 through 46. The yearly numbers of motor vehicle accidents of all types are represented on the ordinate. The range of accidents at each intersection is shown by a vertical line connecting the three yearly accident frequencies, which are represented by dots. The yearly accident frequencies of

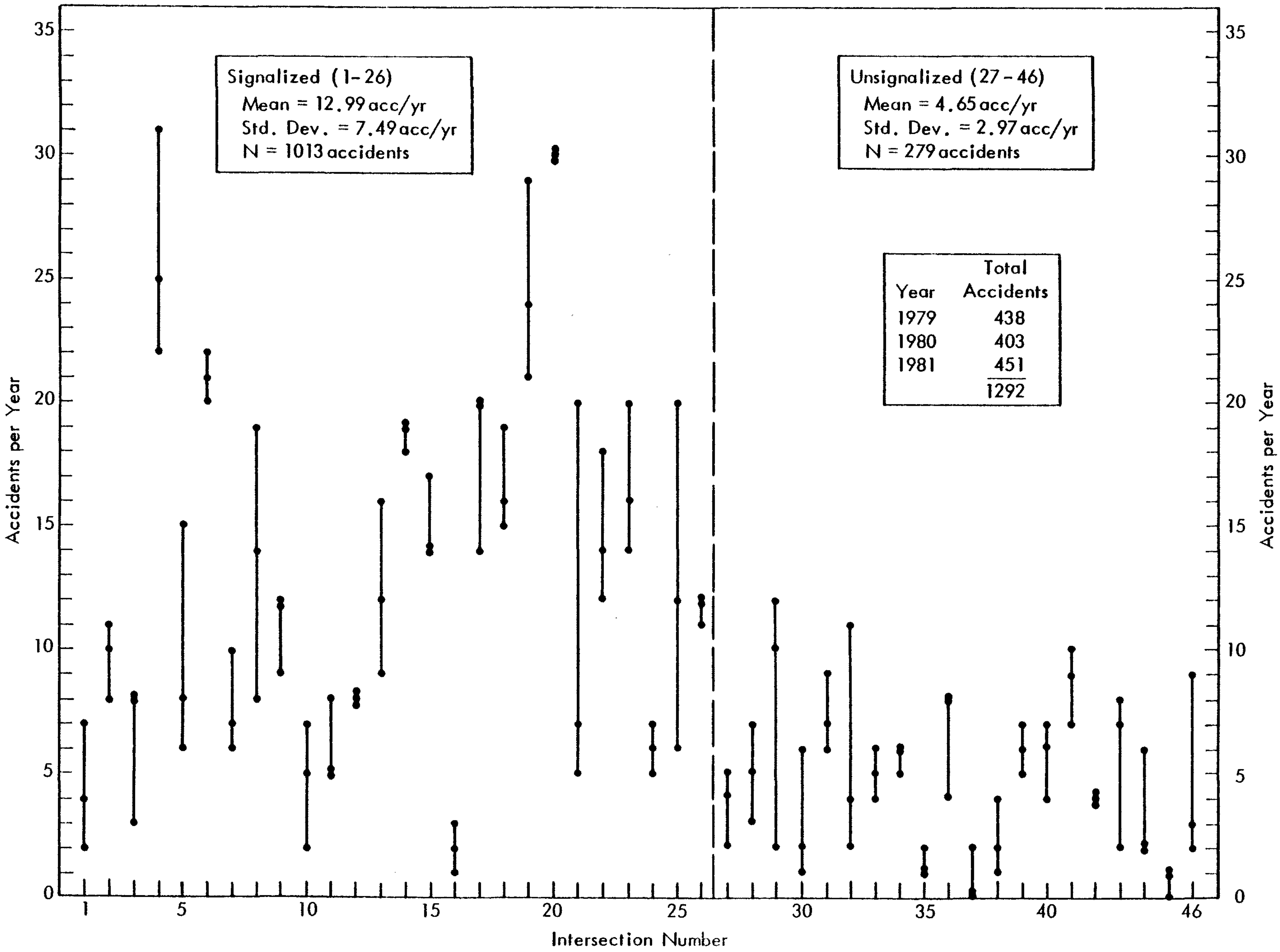

Figure 1 - Total Accidents by Intersection.

signalized intersections ranged from one accident in one year at intersection 16 to 31 accidents in a year at intersection 4. The average over all signalized intersections was 12.99 accidents per year. The yearly accident frequencies for unsignalized intersections ranged from zero at intersections 37 and 45 to 12 accidents in a year at intersection 29, and the mean value was 4.65 accidents per year for these intersections.

Table 1 presents the entire accident data base arranged by signalization, volume class and road condition. Within each road condition (dry, wet, and other/unknown) category, primary and secondary multiple motor vehicle in transport accidents, hereafter referred to simply as multiple vehicle accidents, are tallied. (Primary and secondary accidents correspond to primary and secondary conflicts and are defined in Volume 3.) Single vehicle and other accidents are also tallied, but were not used in the development of accident-conflict relationships.

Conflict studies were conducted during both dry and wet road conditions. The "other/unknown" road condition category refers to periods with snow, ice, mud, or oil on the road surface or to unknown road conditions. The majority of accidents (893) were primary, multiple vehicle accidents occurring on dry roads. A subset of these accidents was used in the development of accident/conflict ratios, discussed subsequently in Subsection III.C. Accidents occurring during periods of wet roads, and secondary accidents, were not used in the development of accident/conflict ratios. The reasons for discarding these accidents are also presented in Subsection III.C.

In terms of the intersection classes in Table 1, the signalized, high volume class had the most accidents (576) followed by the signalized medium (437), unsignalized medium (149), and unsignalized low volume (130) classes. The signalized high volume class was comprised of 12 intersections, but the signalized medium volume class (which included 14 intersections) had fewer accidents. The two unsignalized volume classes each contained 10 intersections.

Of the 1,292 accidents in the data base, 893 (69.1 percent) were primary, multiple vehicle accidents occurring during periods of dry road conditions. The 319 (24.7 percent) conflict-related accidents ultimately used in the development of accident/conflict ratios are a subset of these 893 accidents (conflict-related accidents are defined in Volume 3.)

Table 2 presents the entire accident data base arranged by reported accident severity. The table shows that 894 (69.2 percent) accidents resulted only in property damage and that 398 (30.8 percent) accidents resulted in injuries (including fatalities). Injuries were produced in 365 (28.3 percent) of the primary accidents, 9 (37.5 percent) of the secondary accidents, and 24 (43.6 percent) of the other accidents.

There were four primary, multiple vehicle fatal accidents, all right angle accidents that did not involve any turning movements. Two were of the Cross Traffic from Left and two of the Cross Traffic from Right collision types.

TABLE 1

ACCIDENTS BY ROAD CONDITION

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

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

TABLE 2

ACCIDENT SEVERITY

Accident Type	Severity Property Damage	Injury	Fatal	Total
Multiple Vehicle				
Primary	848	361	4	1,213
Secondary	15	9	0	24
Other[a]	31	24	0	55
Total	894	394	4	1,292

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[a] For example, single vehicle or pedestrian.

Table 3 presents a summary of all accidents which could, theoretically, be used for developing accident/conflict relationships. These "conflict-related" accidents were essentially those that occurred during the hours of conflict observation (0700-1800) on Mondays through Thursdays, and involved vehicle movements comparable to one of the basic 12 types of conflicts. (See Volume 3 for a more complete definition.) There was a total of 391 (39.3 percent) conflict-related accidents. However, only the 319 primary accidents and 64,210 primary conflicts that occurred during periods of dry road condition were used in the development of accident/conflict ratios. There were not enough accidents in the primary-wet, secondary-dry, or secondary-wet road condition categories to enable development of accident-conflict relationships.

TABLE 3

CONFLICT-RELATED ACCIDENTS AND CONFLICTS BY ROAD CONDITION

Traffic Control (Number of Intersections)	Road Condition Dry Primary	 Dry Secondary	 Wet Primary	 Wet Secondary	Total
Signalized (26)					
Accidents	244	2	42	0	288
Conflicts	49,337	14,111	3,865	1,274	68,587
Unsignalized (20)					
Accidents	75	1	25	2	103
Conflicts	14,873	3,933	972	255	20,033

Although a formal analysis of accidents, conflicts, and volume by time of day was not performed, it is nevertheless informative to examine the general time of day relationships between the three types of data collected in the study. Accidents, conflicts, and volume by time of day are presented in Figure 2, which is arranged as shown below:

a - Same Direction Accidents and Conflicts and Total Volume

b - Opposing Left Turn Accidents and Conflicts and Total Volume

c - Cross Traffic Accidents and Conflicts and Total Volume.

The three portions of the figure are constructed in an identical format. The abscissa shows the 16 conflict and volume observation periods and corresponding time of day. Conflicts and volume are plotted by observation period. Those lines are discontinuous because of planned breaks in the data collection schedule. Accidents are plotted as hourly values and result in continuous graphs. The ordinate is the count (for example, conflicts in period 1) divided by its mean (for example, average conflicts per period), in percent.

Primary accidents and conflicts were utilized to prepare the graphs. The data for signalized and unsignalized intersections were combined. The accidents occurred between 0700 and 1800, inclusive. Conflicts were collected during the sixteen observation periods from Monday through Thursday.

The Same Direction category consists of Left Turn Same Direction, Slow Vehicle, Lane Change, and Right Turn Same Direction accidents and conflicts. The Cross Traffic category includes Left Turn from Left, Cross Traffic from Left, Right Turn from Left, Left Turn from Right, Cross Traffic from Right, and Right Turn from Right accidents and conflicts. The remaining conflict type, Opposing Right Turn on Red, was not used since there were only a few accidents and conflicts of this type.

Each graph presents the same plot of total traffic volume, to provide a means for comparing accident and conflict plots between graphs. The total accident, conflict, and volume counts are also given on the graphs.

The conflict counts tend to parallel the volume counts throughout the day, with conflicts occurring less frequently during the mid-morning (periods 4, 5, and 6) and more frequently at the end of the day (periods 14, 15, and 16). The general trend of conflict and volume occurrence is that there is a peak of activity during period 2 (0745 to 0810) which drops off during the mid-morning and then gradually rises throughout the day to a peak during period 15 (1645 to 1710).

The plots of Same Direction and Opposing Left Turn accidents are similar. Both have a peak between 0700 and 0800, and then a sharp decrease between 0800 and 0900. The remainder of the day shows peaks and valleys of accident occurrence, but with a general increase up to the 1700 to 1800 period.

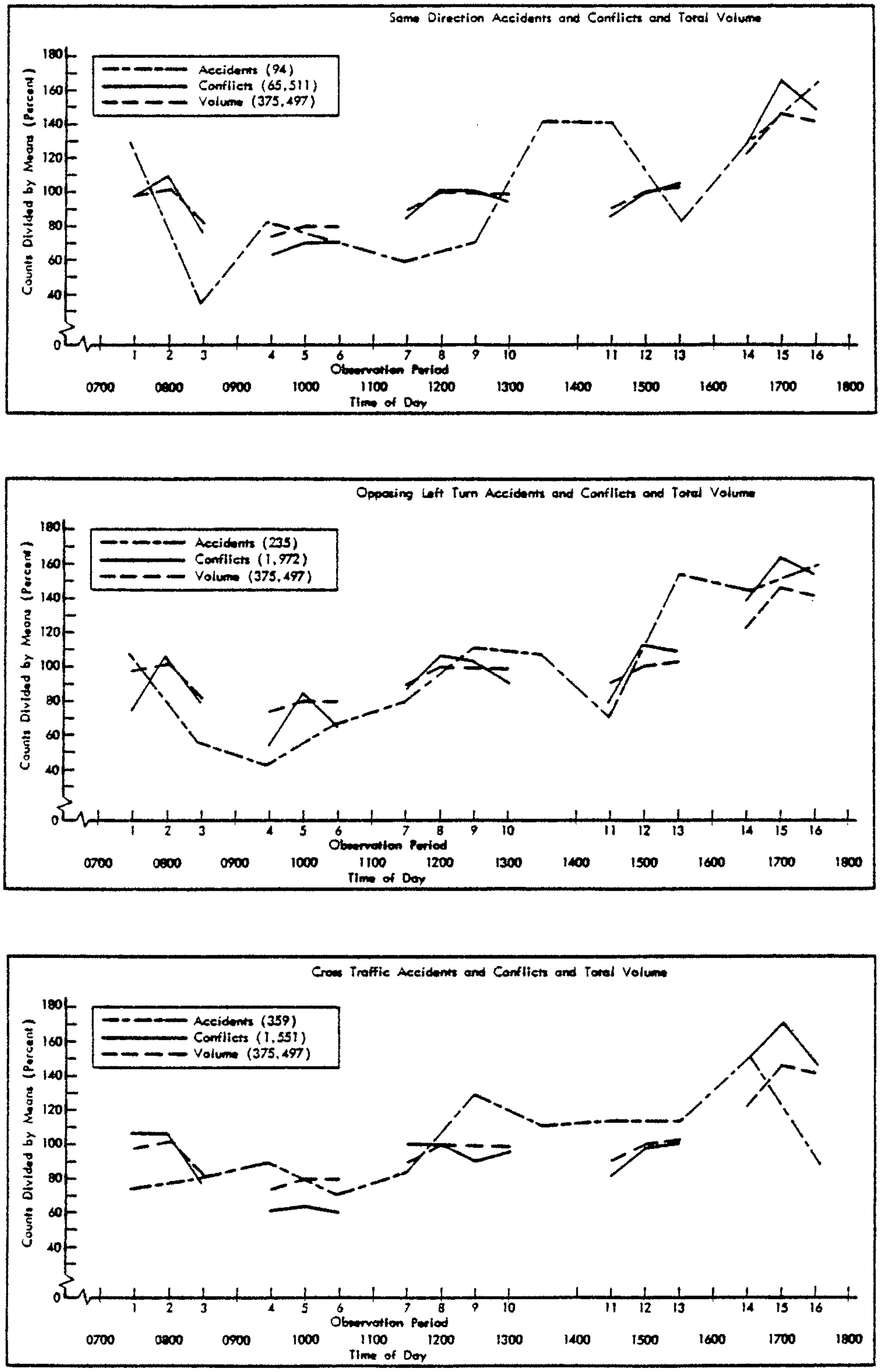


Figure 2 - Accidents, Conflicts and Volume by Time of Day.

The Cross Traffic accidents are distributed differently than the two previous accident types. The Cross Traffic accident plot starts at a low point of accident occurrence between 0700 and 0800 and gradually increases, with small peaks and valleys, throughout the day with a peak accident occurrence between 1600 and 1700. Cross Traffic accident occurrence drops off sharply between 1700 and 1800.

In a very general sense, conflict and volume counts tend to track the accident trends fairly well. All exhibit maxima during the morning and evening traffic peaks, except for the Cross Traffic accidents as noted earlier. There are, however, some small differences. Compared to the accident data, the relative conflict and volume values are higher early in the day (0700 to 0900) and lower in the mid-afternoon (1400 to 1600).

B. Traffic Conflict Statistics

This subsection presents statistics obtained from the traffic conflict data. They are arranged by signalization-volume classes of intersections. The data presented are daily averages for the time period from 0700 to 1800, and the days Monday through Thursday.

The conflict statistics for signalized intersections are presented in Table 4. The conflict statistics for unsignalized intersections are given in Table 5.

The Slow Vehicle conflict type was the type that had the highest daily average conflict count (101.86 to 669.05 conflicts per day). The Left Turn Same Direction and Right Turn Same Direction conflicts also were higher than the other types of conflicts. These three conflict types all involve vehicles moving in the same direction. Conflict type 3 (Lane Change) also involves same direction movements. At signalized intersections, this type of conflict was also quite common. However, it was relatively rare at unsignalized intersections, which often had fewer lanes and lower volumes.

For signalized intersections, the conflicts involving same direction vehicles were later pooled, and called "Same Direction" conflicts. They were the most common type of conflicts. The statistics for these are included in Table 4. Opposing Left Turn conflicts generally had the second highest daily average. The signalized medium volume intersections had the highest Opposing Left Turn average (29.06 conflicts per day), followed by the signalized high volume intersections (22.00 conflicts per day). The rates at unsignalized intersections were much lower (8.98 and 3.64 conflicts per day for medium and low volumes, respectively).

Of the remaining types of conflicts, the Right Turn from Right had the highest average at signalized intersections (2.60 and 3.71 conflicts per day), an indication of vehicles making right turns on a red signal. All other types of cross traffic conflicts at signalized intersections averaged less than one conflict per day (0.06 to 0.52 conflicts per day).

TABLE 4

DAILY CONFLICT STATISTICS - SIGNALIZED INTERSECTIONS

A. High Volume Intersection (N=12)

	Type of Conflict	Average Daily Conflicts (μ)[a]	Standard Deviation(S)	Variance	Standard Error $S/\sqrt{N}$	Coefficient of Variation (%) $100(S/\mu)$
1.	Left Turn Same Direction	83.64	107.77	11,613.7	31.11	128.8
2.	Slow Vehicle	669.05	154.90	23,994.7	44.72	23.2
3.	Lane Change	18.21	12.67	160.6	3.66	69.6
4.	Right Turn Same Direction	218.63	87.11	7,587.5	25.15	39.8
5.	Opposing Left Turn	22.00	19.43	377.7	5.61	88.3
6.	Left Turn from Left	0.63	0.91	0.8	0.26	143.8
7.	Cross Traffic from Left	0.14	0.37	0.1	0.11	262.1
8.	Right Turn from Left	0.06	0.15	0.0	0.04	239.1
9.	Left Turn from Right	0.42	0.51	0.3	0.15	122.7
10.	Cross Traffic from Right	0.29	0.46	0.2	0.13	160.1
11.	Right Turn from Right	2.60	1.51	2.3	0.43	57.8
-	Same Direction (1-4)	989.53	259.23	67,198.4	74.83	26.2

B. Medium Volume Intersections (N=14)

	Type of Conflict	Average Daily Conflicts (μ)[a]	Standard Deviation(S)	Variance	Standard Error $S/\sqrt{N}$	Coefficient of Variation (%) $100(S/\mu)$
1.	Left Turn Same Direction	134.72	101.48	10,298.3	27.12	75.3
2.	Slow Vehicle	377.94	70.21	4,928.9	18.76	18.6
3.	Lane Change	7.62	7.26	52.8	1.94	95.3
4.	Right Turn Same Direction	124.48	49.45	2,445.1	13.22	39.7
5.	Opposing Left Turn	29.06	14.53	211.2	3.88	50.0
6.	Left Turn from Left	0.46	0.68	0.5	0.18	147.6
7.	Cross Traffic from Left	0.29	0.49	0.2	0.13	169.5
8.	Right Turn from Left	0.33	0.43	0.2	0.12	130.1
9.	Left Turn from Right	0.52	0.35	0.1	0.09	68.4
10.	Cross Traffic from Right	0.23	0.34	0.1	0.09	149.7
11.	Right Turn from Right	3.71	1.69	2.8	0.45	45.5
-	Same Direction (1-4)	644.76	159.18	25,338.4	42.54	24.7

---

[a] For the time period from 0700 to 1800.

TABLE 5

DAILY CONFLICT STATISTICS - UNSIGNALIZED INTERSECTIONS

A. Medium Volume Intersections (N=10)

	Type of Conflict	Average Daily Conflicts $(\mu)^a$	Standard Deviation(S)	Variance	Standard Error $S/\sqrt{N}$	Coefficient of Variation (%) $100(S/\mu)$
1.	Left Turn Same Direction	132.75	107.91	11,643.4	34.12	81.3
2.	Slow Vehicle	151.83	76.95	5,921.8	24.33	50.7
3.	Lane Change	2.80	4.75	22.6	1.50	169.8
4.	Right Turn Same Direction	61.70	34.01	1,156.5	10.75	55.1
5.	Opposing Left Turn	8.98	6.31	39.8	1.99	70.2
6.	Left Turn from Left	3.91	2.54	6.5	0.80	64.9
7.	Cross Traffic from Left	3.25	2.16	4.6	0.68	66.3
8.	Right Turn from Left	0.17	0.28	0.1	0.09	168.4
9.	Left Turn from Right	4.33	4.60	21.2	1.45	106.1
10.	Cross Traffic from Right	3.33	2.07	4.3	0.66	62.3
11.	Right Turn from Right	8.97	9.97	99.4	3.15	111.1
-	Through Cross Traffic (7+10)	6.58	3.97	15.7	1.25	60.3

B. Low Volume Intersections (N=10)

	Type of Conflict	Average Daily Conflicts $(\mu)^a$	Standard Deviation(S)	Variance	Standard Error $S/\sqrt{N}$	Coefficient of Variation (%) $100(S/\mu)$
1.	Left Turn Same Direction	70.65	31.70	1,005.0	10.02	44.9
2.	Slow Vehicle	101.86	98.23	9,648.2	31.06	96.4
3.	Lane Change	0.11	0.22	0.1	0.07	213.5
4.	Right Turn Same Direction	57.91	46.88	2,197.3	14.82	80.9
5.	Opposing Left Turn	3.64	2.88	8.3	0.91	79.1
6.	Left Turn from Left	3.37	2.79	7.8	0.88	82.9
7.	Cross Traffic from Left	6.70	6.48	12.0	2.05	96.8
8.	Right Turn from Left	0.57	0.91	0.8	0.29	160.5
9.	Left Turn from Right	1.99	8.53	72.7	2.70	170.7
10.	Cross Traffic from Right	5.22	3.41	11.6	1.08	65.3
11.	Right Turn from Right	5.55	3.48	12.1	1.10	62.7
-	Through Cross Traffic (7+10)	11.93	8.67	75.2	2.74	72.7

---

[a] For the time period from 0700 to 1800.

The cross traffic conflict rates were higher at unsignalized intersections than at signalized intersections. The Right Turn from Right rates were 5.55 and 8.97 conflicts per day, respectively, while others ranged from 0.17 to 6.70 conflicts per day.

The Cross Traffic from Left and Cross Traffic from Right conflicts at unsignalized intersections were pooled to form the Through Cross Traffic category. The rate of 11.93 Through Cross Traffic conflicts per day at unsignalized low volume intersections was higher than the 6.58 conflicts per day rate at unsignalized medium volume intersections.

A twelfth type of conflict, Opposing Right Turn on Red, only occurred at signalized intersections with left turn lanes and protected left turn signal phasing. Few of the 26 signalized intersections met these requirements. Mean Opposing Right Turn on Red conflict rates were not computed or tabulated.

Secondary conflicts were also recorded but were not analyzed in detail because of the fewness of corresponding accidents. Only 24 of the 1,292 accidents in the total data base were of a secondary nature, too small a number to allow analysis.

C. Accident/Conflict Ratios

Accident/conflict ratios are used to calculate the expected number of accidents over a specified period of time. The accident estimation for an intersection is the product of a conflict count collected during a field study and the accident/conflict ratio applicable to that class of intersections. This ratio and its variance are also used to calculate the variance of the accident prediction. The appropriate equations are:

$$\hat{A}_o = C_o \hat{R} \tag{1}$$

and

$$\mathrm{Var}(\hat{A}_o)=\mathrm{Var}(C)\mathrm{Var}(\hat{R})+C_o^2\mathrm{Var}(\hat{R})+\hat{R}^2\mathrm{Var}(C), \tag{2}$$

where $\hat{A}_o$ is the expected number of accidents, C_o the expected conflict rate obtained from the field study at the intersection, and $\hat{R}$ the estimate of the accident/conflict ratio for that class of intersections.

In developing accident/conflict ratios, not all types of collisions were analyzed because of a lack of accident and/or conflict data, and some types were pooled to facilitate analysis. The reasons for the choices of the types of collisions analyzed are presented first, followed by accident and conflict data by type, accident versus conflict graphs, and accident/conflict ratio statistics.

First, as noted earlier, accident and conflict data were compiled for both wet and dry road conditions. A review of the compilations showed several differences in the distributions of the wet and dry data. For example, unsignalized intersections experienced proportionately more wet-pavement accidents than did signalized intersections. The distribution of accident types was not greatly changed under wet pavement conditions, except for an increase in Left Turn Same Direction accidents. Conflicts, on the other hand, showed a relative decrease under wet pavement conditions for the Left Turn Same Direction type, as well as a decrease in Right Turn from Right conflicts. For these reasons, and the fact that wet-pavement-condition data were a small part of the total data base (see Table 3), it was decided not to pool these data but to limit the analyses to the dry-pavement-condition data.

The accident and conflict data were initially compiled, for each intersection, by time of day and by intersection approach. After reviewing the accident and conflict data, it was decided to pool (combine) the data across time periods and approaches. The pooling resulted in a single accident value and a single conflict value for each type of collision for each intersection. It was also decided to combine some types of collisions and conflicts, respectively, and eliminate others from further analysis. The reasons for these decisions are discussed subsequently.

Accident/conflict ratios were determined based on 3 years of reported accident data and 4 days of observed conflict data, adjusted to 3 years. The accidents and conflicts of a group of similar intersections (for example, signalized high volume) were used to calculate accident/conflict ratios of 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.

A summary of conflict-related accidents and conflicts by type and class of intersection is presented in Table 6. For each type of collision the accident value is the total number of accidents per 3 years summed for all the intersections in the class. Likewise, the values of the conflicts are the average daily conflict counts summed for all intersections in the class. The fractional values arise both from the averaging and from the interpolation process used to cover the time periods when conflict observations were not made, as described in Volume 3.

The numbers of accidents and corresponding conflicts varied considerably from type to type. For most types there was less than one accident per intersection. For both signalized and unsignalized intersections, Opposing Left Turn, Cross Traffic from Left, and Cross Traffic from Right (types 5, 7, and 10, respectively) had the most accidents. Left Turn, Slow Vehicle, and Right Turn Same Direction (types 1, 2, and 4, respectively) had the most conflicts.

TABLE 6

CONFLICT-RELATED ACCIDENTS AND CONFLICTS BY TYPE[a]

	Signalized				Unsignalized			
	High Volume (12 Intersections)		Medium Volume (14 Intersections)		Medium Volume (10 Intersections)		Low Volume (10 Intersections)	
Type	Accidents per 3 yr	Conflicts per day	Accidents per 3 yr	Conflicts per day	Accidents per 3 yr	Conflicts per day	Accidents per 3 yr	Conflicts per 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	-	-	-	-

---

[a] The values tabulated are totals for the number of intersections in each class.

We now consider the accident-conflict categories of signalized intersections in detail. Because there were so few accidents of types 1, 2, 3 and 4--too few to enable meaningful rate calculations--a category entitled Same Direction was formed by combining the Left Turn Same Direction, Slow Vehicle, Lane Change, and Right Turn Same Direction types of collisions/conflicts. In each case, the vehicle interactions are a result of vehicles traveling in the same direction. Although the accident totals of the four individual types are not equal, each type contributes to the sum. Even for this pooled category, however, 12 of the 26 signalized intersections did not have any accidents.

The Opposing Left Turn accidents and conflicts (type 5) showed the best distribution of all the types. Even here, 7 of the 26 signalized intersections experienced no Opposing Left Turn accidents in the 3 years studied.

Next, let us examine the accidents and conflicts involving cross traffic, which are those of types 6 through 11. 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. These conflicts were observed only rarely. For example, there were a total of only 14 Cross Traffic from Right conflicts observed in four days for the 26 signalized intersections (see Volume 3). This is an average of about 0.13 conflict per day per intersection. Stated differently, one would have to observe all four approaches of an intersection during 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 would be necessary to make cross traffic conflicts practical. Upon examination of Table 6, the most frequent cross traffic conflict at signalized intersections is type 11, Right Turn from Right, which commonly occurs upon illegal right-turn-on-red maneuvers. However, only six of the 26 intersections experienced any accidents of this type, 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. Aside from the Right Turn from Left conflict type, the rarest conflict types were the two involving through movements of cross traffic (types 7 and 10). However, accidents of this type were the most common.

In summary, although it would appear desirable to pool the cross traffic conflicts and accidents, respectively, like we did with the same direction events, it does not seem 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 (a total of 9 for 26x4=104 site-days of observation) and just one accident. (This type involves right turning vehicles conflicting with opposing left turn vehicles with a protected phase--see definitions in Volume 3.) Therefore this type, too, was dropped from further analyses.

Examination of the data from the unsignalized intersections also led to decisions about the subsequent accident/conflict ratio analyses. 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. There were almost no accidents for types 2 and 4. There were very few conflicts of type 3, and although there were three accidents, all occurred at the same intersection. At that intersection, queued vehicles behind a left turn vehicle would often attempt to pass on the shoulder, a maneuver that led to three lane-change accidents.

The Opposing Left Turn (type 5) data were retained for the medium volume intersections, but not for the low volume sites.

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 (types 7 and 10), they were retained; the other cross traffic data were dropped from further analyses.

To recapitulate, the following accident and conflict data were used for analysis of accident/conflict ratios:

<u>For signalized high and medium volume locations</u>

- Same Direction, pooling:

  - Left Turn Same Direction
  - Slow Vehicle
  - Lane Change
  - Right Turn Same Direction

- Opposing Left Turn

<u>For unsignalized medium volume locations</u>

- Left Turn Same Direction
- Opposing Left Turn
- Through Cross Traffic, pooling:

  - Cross Traffic from Left
  - Cross Traffic from Right

<u>For unsignalized low volume locations</u>

- Through Cross Traffic, pooling

  - Cross Traffic from Left
  - Cross Traffic from Right.

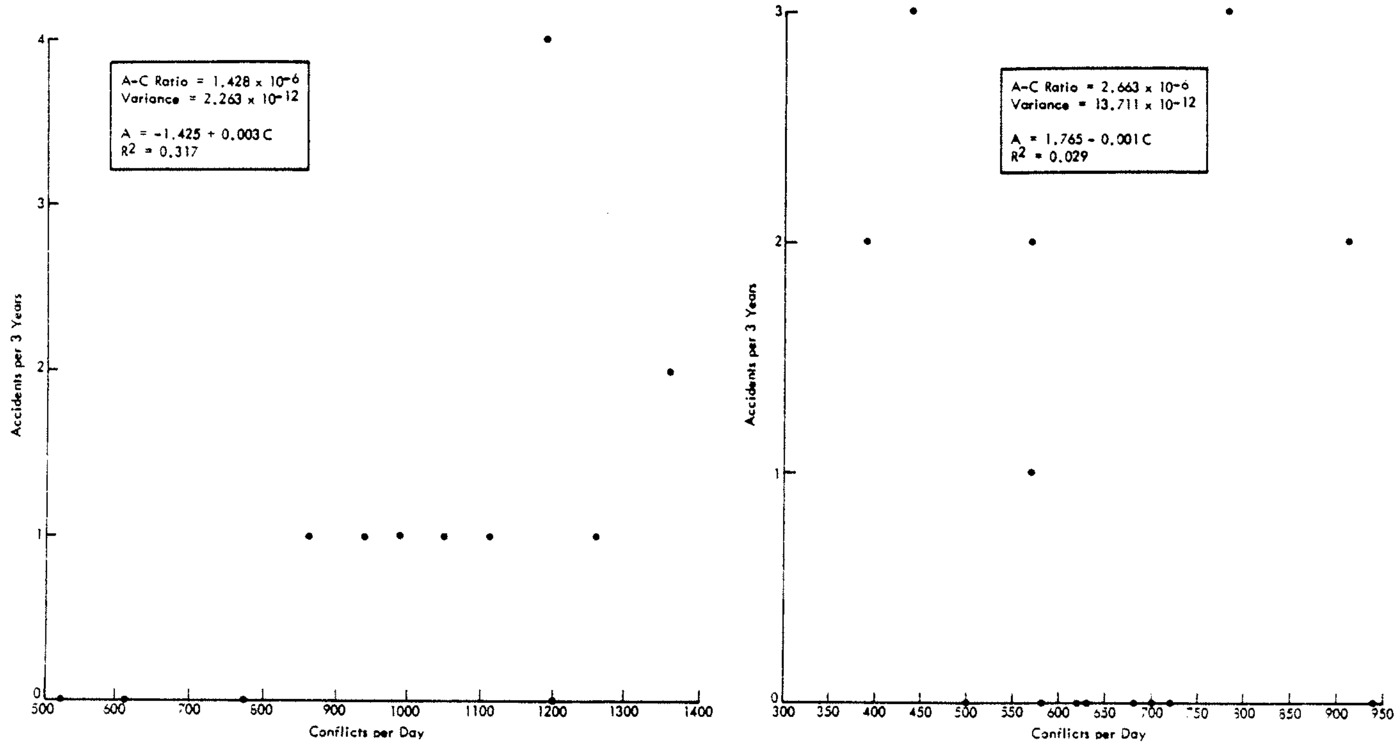
Graphs of accidents and conflicts for those types of collision used to develop accident/conflict ratios are given in the following set of figures. Figure 3 presents three graphs of Same Direction accidents and conflicts. The graphs show that the relationships are based on few accidents and many conflicts. For the signalized, high volume intersections, the accident rates ranged from zero per 3 years at four intersections to four accidents per 3 years at one intersection. The conflict rates ranged from an average of 530.77 conflicts per day to 1,357.35 conflicts per day.

The accident/conflict ratio for the group of intersections is the mean of the individual accident/conflict ratios, which are the slopes of the lines drawn from the origin of the graph through the point representing the accident-conflict pairs. The figure includes the accident/conflict ratio and the variance of the ratio. The ratio quoted has units of accidents per 3 years divided by conflicts per 3 years or, simply, accidents per conflict (on equal time scales). The regression equation is also given, but in the units, accidents per 3 years as a function of conflicts per day, along with the correlation coefficients squared (R^2). It should be noted that the regression slope in the signalized medium volume category is found to be negative, suggesting that the more conflicts the fewer accidents will occur. This is illogical and is obviously due to the poor fit of the regression model, as reflected in the very low R^2-value of 0.029; these regression results should be discarded.

Opposing Left Turn accidents and conflicts are presented in Figure 4. Accidents at the 12 signalized high volume intersections ranged from zero per 3 years at three intersections to 25 accidents per 3 years at one intersection, a much wider range than the Same Direction accidents. Conflicts ranged from as few as 0.45 conflict per day to 55.48 conflicts per day. The three intersections with no Opposing Left Turn accidents all had left turn lanes on all approaches. Two of those intersections averaged less than one conflict per day, but the third averaged 29.02 conflicts per day. The intersection with 25 Opposing Left Turn accidents (intersection 19) did not have left turn lanes. The intersection with the most conflicts (55.48 conflicts per day) had two left turn lanes and experienced 18 accidents.

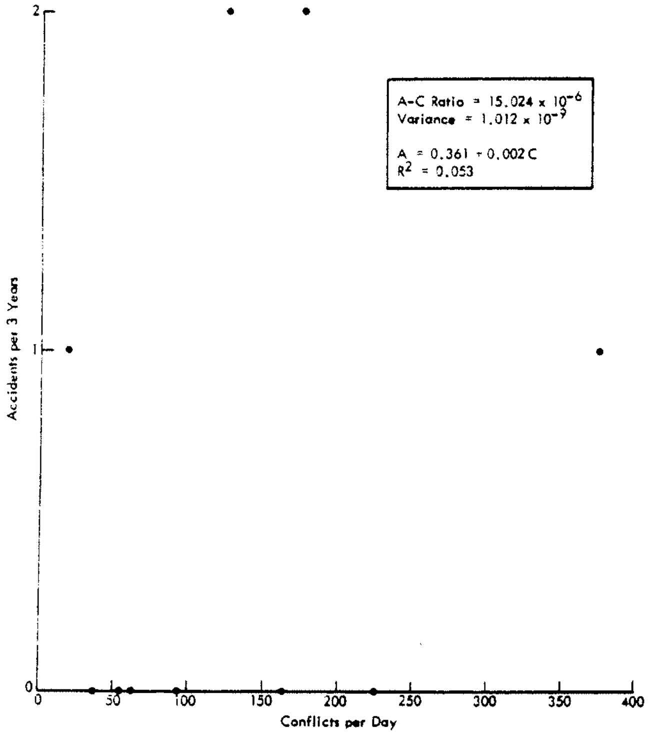
The Opposing Left Turn accident data for signalized, medium volume intersections are also fairly well dispersed. However, most of the unsignalized, medium volume intersections had zero or one accident in three years, with no relationship to conflict rates. Again, the regression analysis resulted in a negative slope in the medium volume category. As noted earlier, these results should be discarded due to the poor fit of the model (R^2=0.077).

Through Cross Traffic accidents and conflicts at unsignalized intersections are presented in Figure 5. For the medium volume intersections there is basically no relationship between accidents and conflicts of this type. The slope of the regression line is essentially zero. However, a fairly strong relationship appears in the low volume intersection data. (One intersection--number 32--had no Through Cross Traffic conflicts or accidents, so a ratio could not be calculated. That datum is omitted from the plot.)



a. Same Direction
Signalized High Volume

b. Same Direction
Signalized Medium Volume

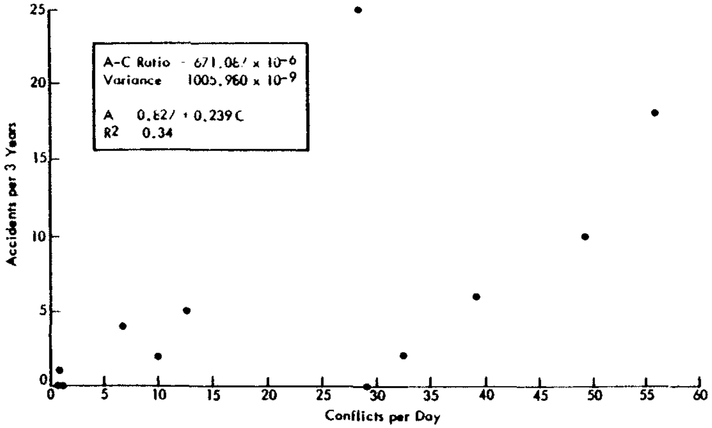


c. Left Turn Same Direction
Unsignalized Medium Volume

A-C Ratio: A/3-yr ÷ C/3-yr

Regression: A/3-yr = f(C/day)

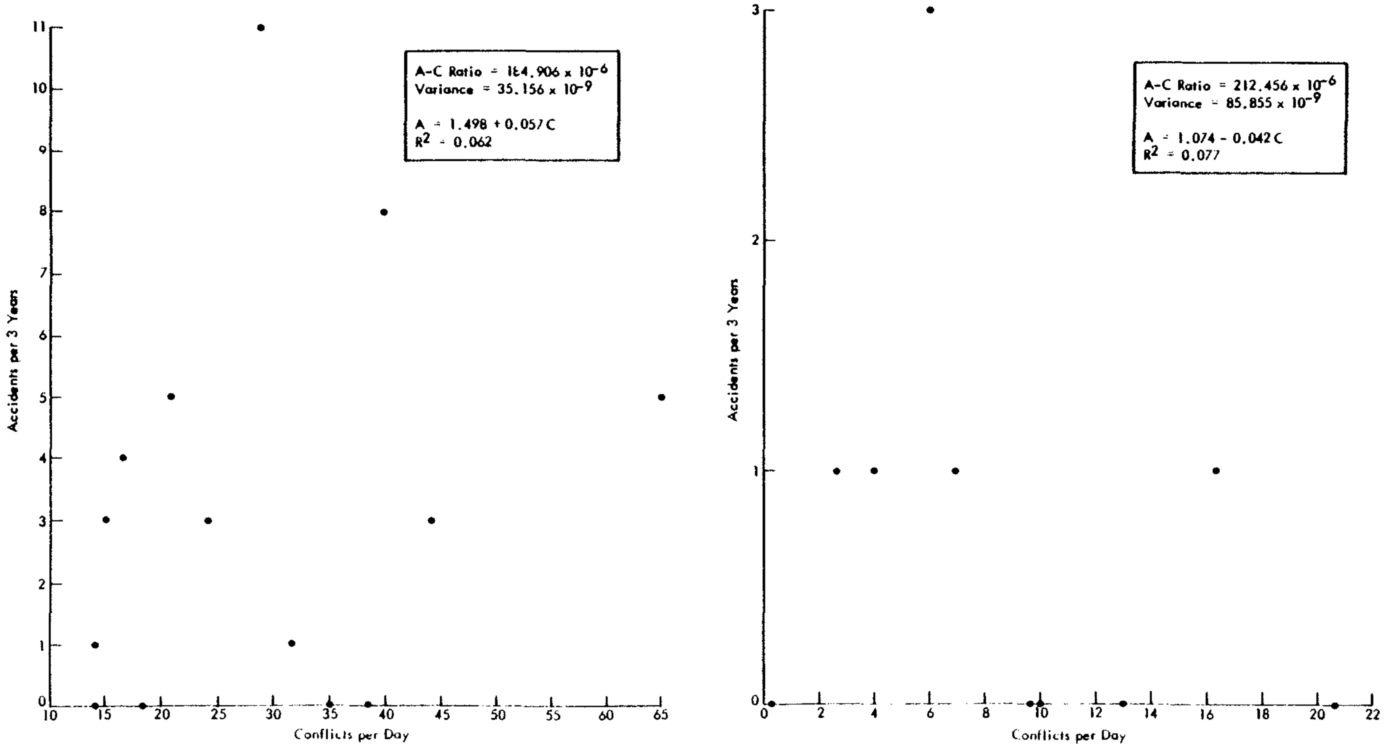
Figure 3 - Same Direction Accidents and Conflicts.



A-C Ratio: A/3-yr + C/3-yr

Regression: A/3-yr = f(C/day)

a. Opposing Left Turn
Signalized High Volume



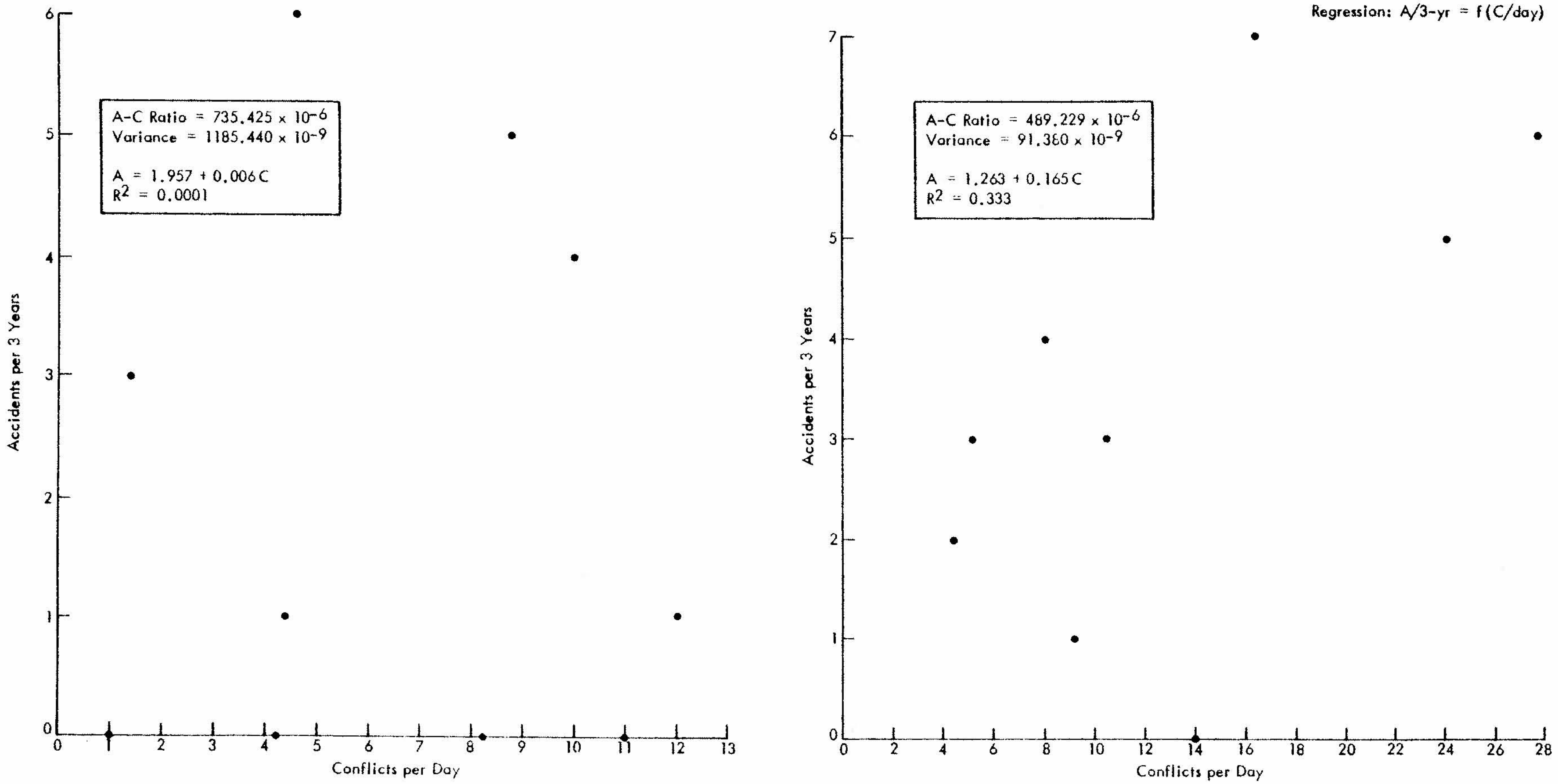
b. Opposing Left Turn
Signalized Medium Volume

c. Opposing Left Turn
Unsignalized Medium Volume

Figure 4 - Opposing Left Turn Accidents and Conflicts.

A-C Ratio: A/3-yr ÷ C/3-yr

Regression: A/3-yr = f(C/day)



a. Through Cross Traffic
Unsignalized Medium Volume

b. Through Cross Traffic
Unsignalized Low Volume

Figure 5 - Through Cross Traffic Accidents and Conflicts.

The accident and conflict data plots in Figures 3, 4, and 5 present the data utilized to calculate accident/conflict ratios. In calculating accident/conflict ratios, each daily conflict count was adjusted to represent 3 years of conflicts. A daily conflict count of an intersection is an average of the four counts collected on Monday through Thursday. The adjustment factor applied was:

$$\begin{aligned}\text{Conflicts/3 years} &= (4/7)(365 \text{ days/year})(3 \text{ years})(\text{conflicts/day}) \\ &= 625.7 \ (\text{conflicts/day})\end{aligned}$$

The fraction, 4/7, reflects the fact that the conflict (and accident) data only apply for Mondays through Thursdays. Accident/conflict ratios are summarized in Table 7. The types of collision for which ratios were calculated are arranged by signalization-volume class. The following statistics are presented: number of intersections (pairs of accidents and conflicts) used to calculate a ratio, mean accident/conflict ratio, standard deviation, variance, standard error and coefficient of variation (a measure of relative variation).

The accident/conflict ratios in Table 7 illustrate the large differences from type to type. The Same Direction type has the smallest accident/conflict ratios, with an average of about 2×10^{-6} accidents per conflict. The Left Turn Same Direction type has a ratio of about 15×10^{-6} accidents per conflict. The Opposing Left Turn and Through Cross Traffic types have ratios on the order of 500×10^{-6} accidents per conflict. Thus, it is evident that some types of conflicts (e.g., Through Cross Traffic) are far more likely to yield an accident than other types (e.g., Same Direction). Indeed, the differences are 2 to 3 orders of magnitude.

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

To test for significant differences, one commonly uses the t-test. It is not applicable, in this instance, because the data are clearly not from a normal distribution, which is a requirement for using the t-test. Instead, the distributions of the two sets of accident/conflict ratios were compared using the Kolmogorov-Smirnov test.[5] The test did not indicate that a significant difference exists in the distributions. However, the 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 Same Direction category. Repeating the test on the remaining 14 intersections indicated that the two distributions were significantly different ($\alpha = 0.005$). That is, for signalized intersections <u>having accidents</u> of this type, the medium volume intersections had higher accident/conflict ratios than the high volume ones.

TABLE 7

ACCIDENT/CONFLICT RATIO STATISTICS

Type of Collision/ Intersection Class	Number of Intersections	Mean Accident/ Conflict Ratio[a]	Standard Deviation[a]	Variance[b]	Standard Error	Coefficient of Variation (100%)	
	N	$\hat{R}$	S	Var (R)	$\sqrt{Var(\hat{R})}$[c]	Ratio	Accidents
Left Turn Same Direction							
Unsignalized Medium Volume	10	15.024×10^{-6}	31.810×10^{-6}	1.012×10^{-9}	10.060×10^{-6}	211.8	151.8
Same Direction							
Signalized High Volume	12	1.428×10^{-6}	1.500×10^{-6}	2.263×10^{-12}	0.434×10^{-6}	105.4	112.8
Signalized Medium Volume	14	2.663×10^{-6}	3.703×10^{-6}	13.711×10^{-12}	0.990×10^{-6}	139.1	129.9
Opposing Left Turn							
Signalized High Volume	12	671.087×10^{-6}	1002.990×10^{-6}	1005.980×10^{-9}	289.537×10^{-6}	149.5	130.3
Signalized Medium Volume	14	184.906×10^{-6}	187.500×10^{-6}	35.156×10^{-9}	50.111×10^{-6}	101.4	105.1
Unsignalized Medium Volume	10	212.456×10^{-6}	293.010×10^{-6}	85.855×10^{-9}	92.658×10^{-6}	137.9	135.5
Through Cross Traffic							
Unsignalized Medium Volume	10	735.425×10^{-6}	1088.780×10^{-6}	1185.440×10^{-9}	344.303×10^{-6}	148.0	115.5
Unsignalized Low Volume	9	489.229×10^{-6}	302.292×10^{-6}	91.380×10^{-9}	100.764×10^{-6}	61.8	78.2

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[a] Accidents/3-yr ÷ conflicts/3-yr.

[b] $(\text{Accidents/3-yr} \div \text{conflicts/3-yr})^2$.

[c] $Var(\hat{R}) = Var(R)/N$.

There is a legitimate argument against deleting intersections without accidents--they represent data just as valid as intersections with accidents. The situation is perhaps made clearer in the upper third of Figure 6. Plotted are the accident/conflict ratios for the individual intersections comprising the two data sets. (These are the values from which the means were calculated.) The clusters of points on the ordinate correspond to the intersections experiencing no accidents of this type. It is apparent that disregarding these, the remaining clusters are different for the two sets, as the statistical test confirmed. But, including the zeros masks any potential differences. Finally, it should be noted that, for the high volume intersections, the six non-zero points clustered on the left each represent just 1 accident; the other two points represent 2 and 4 accidents, respectively. The accident data base is just too sparse to enable strong conclusions to be drawn. Despite the fact that the apparent difference in the two (complete) data sets is not significant, we feel it would be inappropriate to combine the two sets (as one often does after tests for significant differences fail). We feel that, given more data, one might show that a difference does exist.

The same arguments can be made regarding the Opposing Left Turn ratios at signalized, high and medium volume intersections, and for Through Cross Traffic ratios at unsignalized, medium and low volume intersections. And similar answers are obtained. 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 fairly large standard deviations of the accident/conflict ratios were noted earlier. 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 percent to 211.8 percent (see Table 7).

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. The last column of Table 5 gives the CVs of the intersection accidents, which may be compared with the CVs of the accident/conflict ratios. In general, the two sets of CVs track one another--higher relative variances in accidents parallel higher relative variances in accident/conflict ratios. Further, the CVs of the conflicts (see Tables 4 and 5) are on the order of half those of the corresponding ratios.

D. Expected and Abnormal Conflict Rates

The second objective of the research was to determine, based on data collected, conflict rates that might be expected or typical for intersections like those studied, as well as "abnormal" rates. By abnormal, we mean 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.

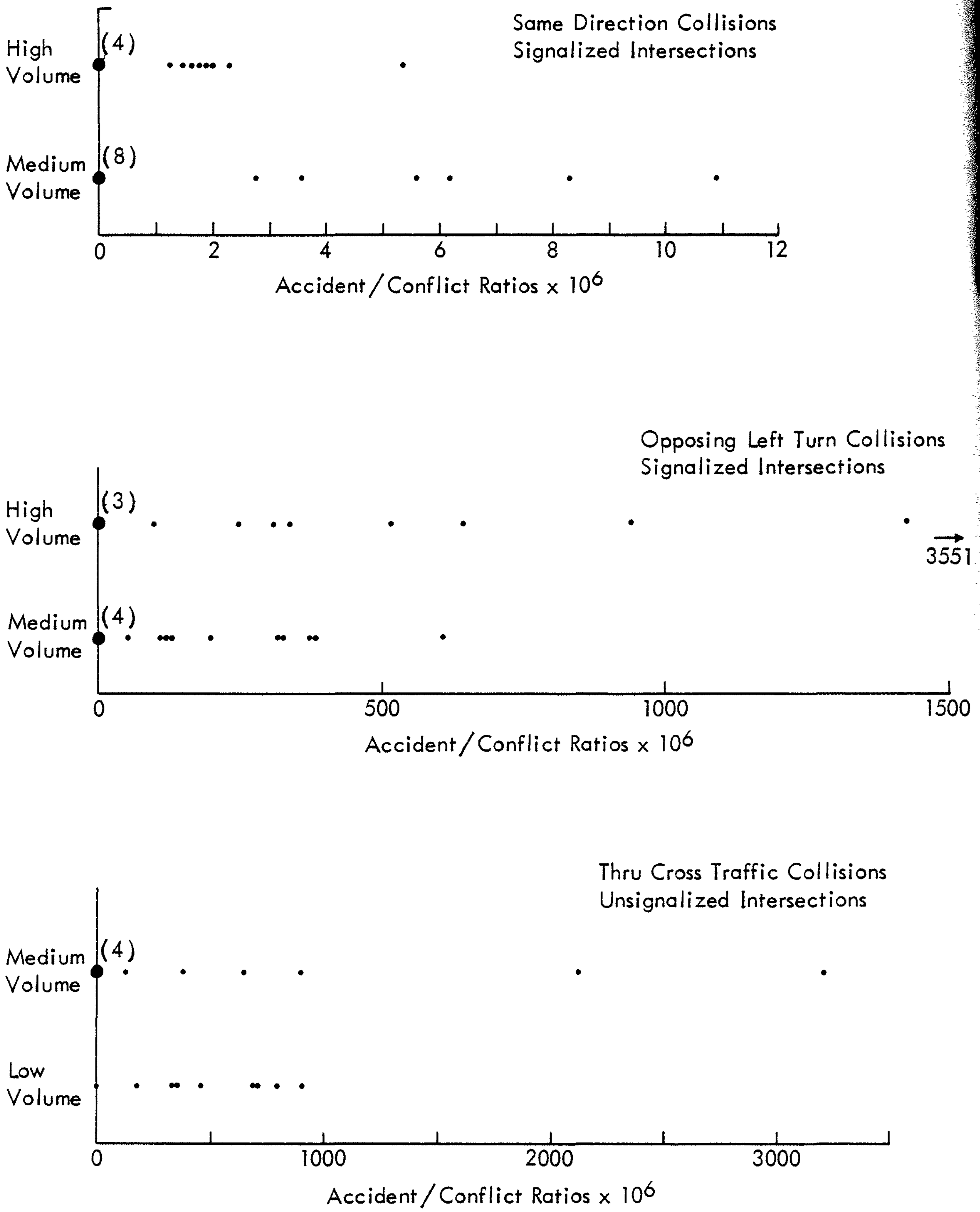

Figure 6 - Comparison of Accident/Conflict Rates for Individual Intersections.

As before, the conflict rates described here are "daily" rates--the total number of conflicts of each type at all applicable approaches from 0700 to 1800. The user must be sure to adjust his counts to reflect a full 11 hr if the data are for a lesser time period.

Earlier in this chapter the means and variances of the various types of conflicts were tabulated. They are repeated in Tables 8 through 11, along with additional data to be described subsequently. The means are the expected values obtained from the sample of intersections in this study. As such, they are proposed as the normal or average values to be used. Other users, at least in the United States, should obtain roughly comparable values--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 using the procedures explained here provided he has a reasonable number of intersections to do so.

One defines abnormal or extreme values of conflict rates, statistically, by examining the probability distribution of conflict rates from a number of similar intersections. 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 for that matter. That method assumes that the data follow a normal distribution--the familiar bell-shaped curve. Traffic conflict data do not behave that way. The counts can never be negative, for example, and the distribution tends to be skewed with a longer tail at 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. This distribution is nonnegative, and otherwise looks similar to conflict distributions, except for one important distinction. The Poisson distribution has a variance equal to its mean. Cursory examination of Tables 8 through 11 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 must be used.

In earlier work[2] it was suggested 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 the normal or Poisson distributions. The probability density function, f(c), for the Gamma distribution of conflicts, c, is:

$$f(c) = te^{-ct} (ct)^{s-1}/\Gamma(s) \qquad (3)$$

where Γ is the Gamma function, and t and s, both positive, are called the parameters of the distribution. The Gamma function has the property that, for integer values of s, $\Gamma(s) = (s-1)!$ For example, $\Gamma(5) = 1 \cdot 2 \cdot 3 \cdot 4 = 24$.

TABLE 8

SIGNALIZED, HIGH VOLUME INTERSECTION DAILY CONFLICT RATES

	Type	Mean	Variance	s[a]	t[a]	Mode[b]	Percentile[c]	
							90th	95th
1.	Left Turn Same Direction	83.644	11,613.7	0.602	0.00720	-	265.0	360.0
2.	Slow Vehicle	669.051	23,994.7	18.655	0.02789	633.0	870.0	940.0
3.	Lane Change	18.211	160.6	2.065	0.11339	9.4	35.0	43.0
4.	Right Turn, Same Direction	218.625	7,587.5	6.299	0.02881	184.0	470.0	510.0
5.	Opposing Left Turn	22.001	377.7	1.281	0.05825	4.8	48.0	60.0
6.	Left Turn from Left	0.631	0.824	0.483	0.76578	-	1.7	2.5
7.	Cross Traffic From Left	0.140	0.135	0.145	1.03704	-	-	-
8.	Right Turn from Left	0.062	0.022	0.175	2.81818	-	-	-
9.	Left Turn from Right	0.417	0.261	0.666	1.59770	-	1.1	1.4
10.	Cross Traffic from Right	0.290	0.215	0.391	1.34884	-	-	-
11.	Right Turn from Right	2.603	2.268	2.987	1.14771	0.9	4.6	5.4
12.	Opposing Right Turn on Red	0.227	0.124	0.416	1.83065	-	-	-
1-4	Same Direction	989.531	67,198.4	14.571	0.01473	921.0	1,340.0	1,460.0
7+10	Through Cross Traffic	0.430	0.335	0.552	1.28358	-	1.1	1.5

---

[a] Parameters of the Gamma distribution of conflicts, c, for: $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$.

[b] Maximum value of f(c), if a maximum exists.

[c] For the most rare types of conflicts, no values are given; any observed number of daily conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 9

SIGNALIZED, MEDIUM VOLUME INTERSECTION DAILY CONFLICT RATES

	Type	Mean	Variance	s[a]	t[a]	Mode[b]	Percentile[c]	
							90th	95th
1.	Left Turn Same Direction	134.724	10,298.3	1.762	0.01308	58.0	270.0	340.0
2.	Slow Vehicle	377.938	4,928.9	28.980	0.07668	365.0	470.0	500.0
3.	Lane Change	7.621	52.8	1.100	0.14434	0.7	17.0	22.0
4.	Right Turn, Same Direction	124.476	2,445.1	6.337	0.05091	105.0	190.0	220.0
5.	Opposing Left Turn	29.057	211.2	3.998	0.13758	22.0	49.0	56.0
6.	Left Turn from Left	0.463	0.466	0.460	0.99356	-	1.3	1.9
7.	Cross Traffic From Left	0.289	0.240	0.348	1.20417	-	-	-
8.	Right Turn from Right	0.333	0.188	0.590	1.77128	-	0.8	1.1
9.	Left Turn from Right	0.515	0.125	2.122	4.12000	0.3	1.0	1.2
10.	Cross Traffic from Right	0.229	0.118	0.444	1.94068	-	0.7	1.0
11.	Right Turn from Right	3.707	2.839	4.840	1.30574	2.9	6.0	7.0
12.	Opposing Right Turn on Red	0.094	0.058	0.152	1.62069	-	-	-
1-4	Same Direction	644.760	25,338.4	16.407	0.02545	605.0	860.0	930.0
7+10	Through Cross Traffic	0.519	0.215	1.253	2.41395	0.1	1.1	1.4

---

[a] Parameters of the Gamma distribution of conflicts, c, for: $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$.

[b] Maximum value of f(c), if a maximum exists.

[c] For the most rare types of conflicts, no values are given; any observed number of daily conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 10

UNSIGNALIZED, MEDIUM VOLUME INTERSECTION DAILY CONFLICT RATES

	Type	Mean	Variance	s[a]	t[a]	Mode[b]	Percentile[c]	
							90th	95th
1.	Left Turn Same Direction	132.745	11,643.4	1.513	0.01140	45.0	275.0	350.0
2.	Slow Vehicle	151.831	5,921.8	3.893	0.02564	113.0	255.0	290.0
3.	Lane Change	2.797	22.6	0.346	0.12376	-	-	-
4.	Right Turn, Same Direction	61.695	1,156.5	3.291	0.05335	43.0	105.0	125.0
5.	Opposing Left Turn	8.982	39.8	2.027	0.22568	4.6	17.0	21.0
6.	Left Turn from Left	3.913	6.452	2.373	0.60648	2.3	7.0	9.0
7.	Cross Traffic From Left	3.250	4.644	2.274	0.69983	1.8	6.0	7.5
8.	Right Turn from Right	0.165	0.077	0.354	2.14286	-	-	-
9.	Left Turn from Right	4.333	21.2	0.886	0.20439	-	10.0	14.0
10.	Cross Traffic from Right	3.327	4.297	2.576	0.77426	2.0	6.0	7.5
11.	Right Turn from Right	8.972	99.4	0.810	0.09026	-	21.0	29.0
12.	Opposing Right Turn on Red	-	-	-	-	-	-	-
1-4	Same Direction	319.068	28,650.5	3.553	0.01114	229.0	540.0	640.0
7+10	Through Cross Traffic	6.577	15.7	2.755	0.41892	4.2	12.0	14.0

---

[a] Parameters of the Gamma distribution of conflicts, c, for: $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$.

[b] Maximum value of f(c), if a maximum exists.

[c] For the most rare types of conflicts, no values are given; any observed number of daily conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

TABLE 11

UNSIGNALIZED, LOW VOLUME INTERSECTION DAILY CONFLICT RATES

	Type	Mean	Variance	s[a]	t[a]	Mode[b]	Percentile[c] 90th	Percentile[c] 95th
1.	Left Turn Same Direction	70.645	1,005.0	4.966	0.07029	56.0	110.0	130.0
2.	Slow Vehicle	101.861	9,648.2	1.075	0.01056	7.1	225.0	295.0
3.	Lane Change	0.105	0.050	0.221	2.10000	-	-	-
4.	Right Turn, Same Direction	57.912	2,197.3	1.526	0.02636	20.0	120.0	150.0
5.	Opposing Left Turn	3.640	8.300	1.596	0.43855	1.4	7.5	9.0
6.	Left Turn from Left	3.366	7.790	1.454	0.43209	1.1	7.0	9.0
7.	Cross Traffic From Left	6.698	42.0	1.068	0.15948	0.4	1.5	19.0
8.	Right Turn from Right	0.567	0.828	0.388	0.68478	-	-	-
9.	Left Turn from Right	4.993	72.7	0.343	0.06868	-	16.0	23.0
10.	Cross Traffic from Right	5.228	11.6	2.356	0.45069	3.0	10.0	12.0
11.	Right Turn from Right	5.546	12.1	2.542	0.45835	3.4	10.0	12.0
12.	Opposing Right Turn on Red	-	-	-	-	-	-	-
1-4	Same Direction	230.523	17,929.2	2.964	0.01286	153.0	410.0	490.0
7+10	Through Cross Traffic	11.926	75.2	1.891	0.15859	5.6	24.0	29.0

---

[a] Parameters of the Gamma distribution of conflicts, c, for: $f(c) = te^{-ct}(ct)^{s-1}/\Gamma(s)$.

[b] Maximum value of f(c), if a maximum exists.

[c] For the most rare types of conflicts, no values are given; any observed number of daily conflicts should be viewed with suspicion. Otherwise, values given suggest limits, at two levels, for normally expected conflict rates.

For other positive (noninteger) values of s, $\Gamma(s)$ defines a smooth curve through these points, and it is tabulated in many books of mathematical tables. However, as will be shown, the user will not need to refer to such tables.

Now, the parameters t and s are defined in terms of the mean, E(c), and variance, Var(c) of the distribution through the simple equations:

$$t = E(c)/Var(c), \tag{4}$$

and

$$s = t\ E(c). \tag{5}$$

These values are shown in Tables 8 through 11, along with the mean and variance, for each type of conflict and for each signalization-volume class studied, using the sample means and variances in equations (4) and (5).

Before completing the description of these tables, it is helpful to examine some typical plots of equation (3) for selected types of conflicts. Figure 7 shows the distribution of All Same Direction conflicts, which looks much like a normal distribution. The mean value in this case is about 645, and the standard deviation is $159(=\sqrt{25,338})$, 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 (which is at 605). The value of c at which the curve is highest 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 7 are the 90th and 95th percentiles. In this case, 90 percent of all intersections of this class should have less than 860 conflicts per day of this type, and 95 percent should 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, we use these limits of 10 percent and 5 percent 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 8. It is highly skewed, with the mean value of about 22 being 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 (which can be shown to be the median). However, many will have quite large values, so the idea of abnormality takes on a different light. 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 have to have nearly three times as many conflicts as the average to be considered abnormal.

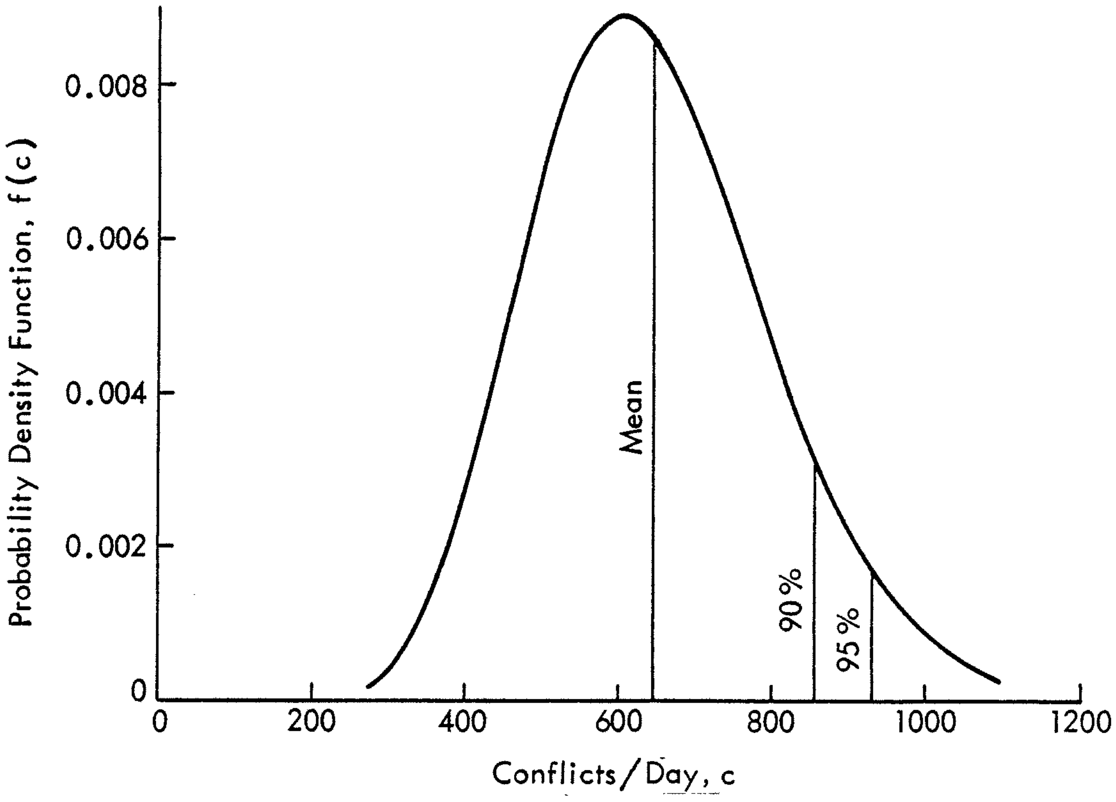

Figure 7 - Distribution of All Same Direction Conflicts for Signalized, Medium Volume Intersections.

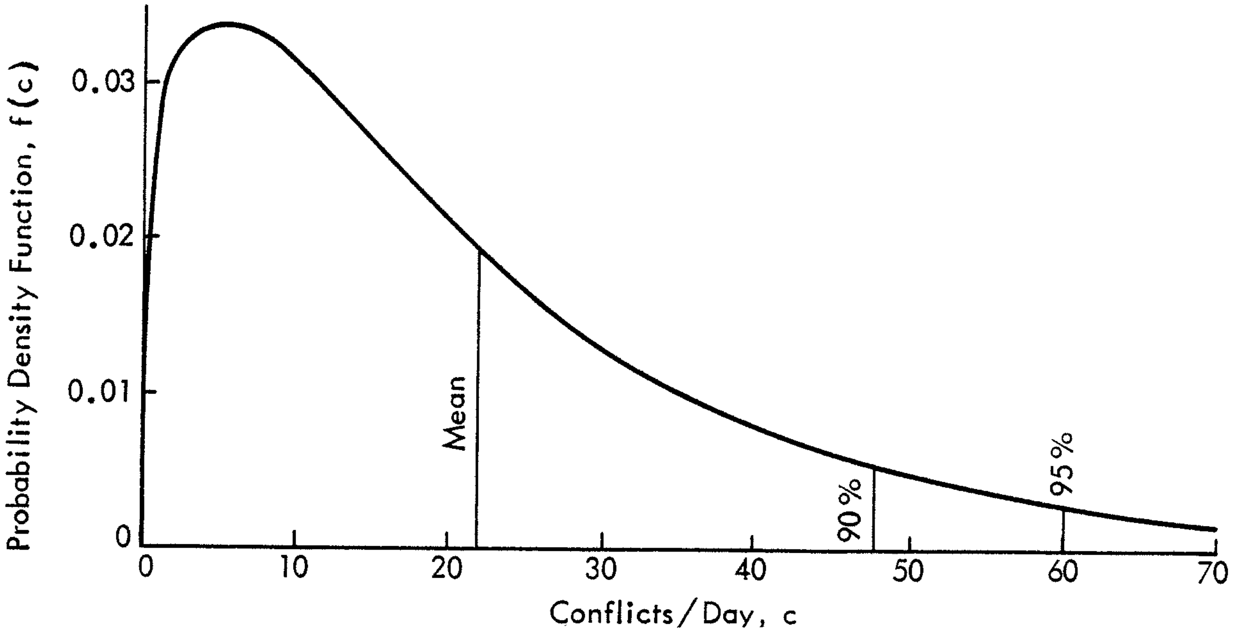

Figure 8 - Distribution of Opposing Left Turn Conflicts for Signalized, High Volume Intersections.

A final example shows an even more extreme case (Figure 9). The variance for this type of conflict is so large that the standard deviation, 108 = $\sqrt{11,613.7}$, 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 the closer 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 that (~ 84), and the 95th percentile is nearly 4-1/2 times the average (360 conflicts per day).

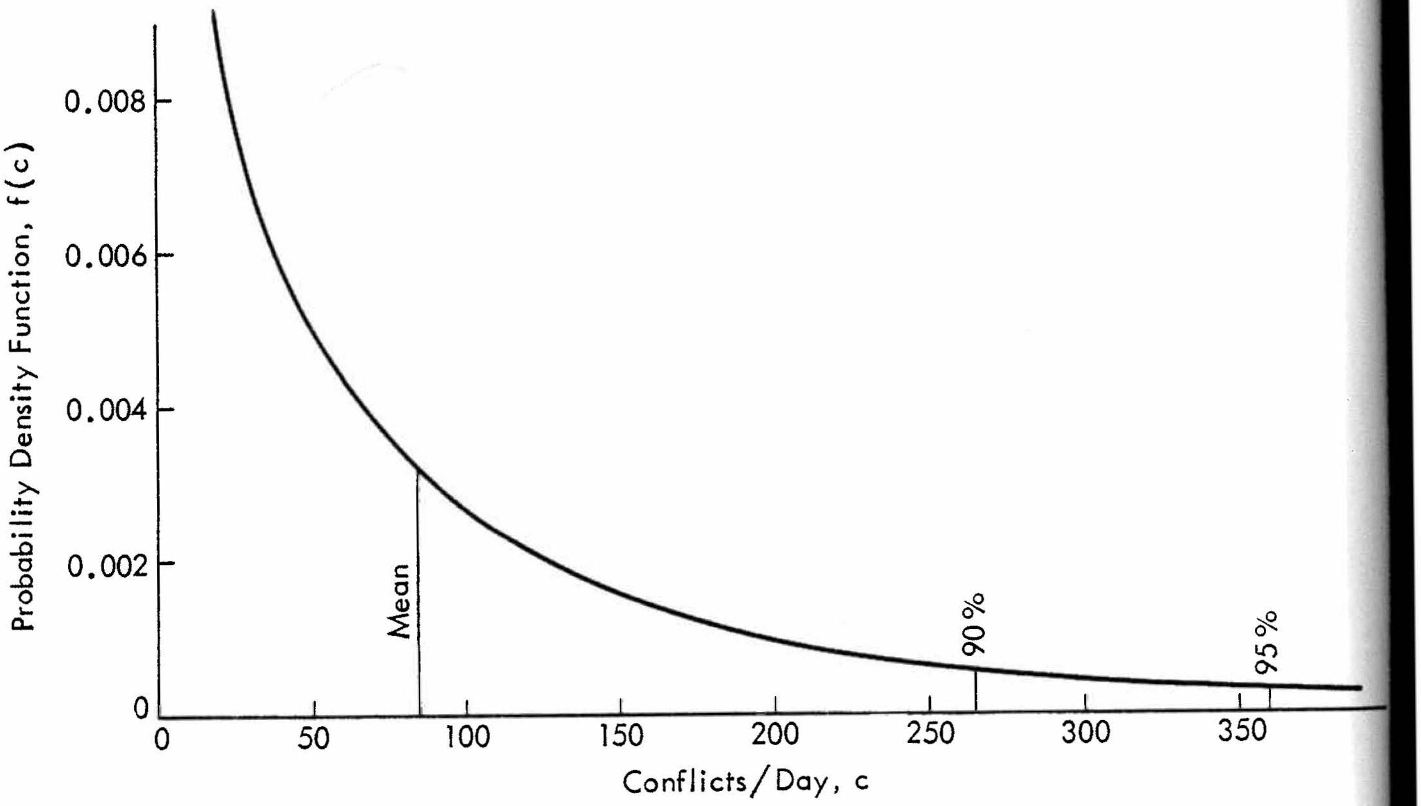

Figure 9 - Distribution of Left Turn, Same Direction Conflicts for Signalized, High Volume Intersections.

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

$$\text{Mode} = (s-1)/t, \tag{6}$$

which is only meaningful if s is greater than one. The various percentiles such as 95th, 90th, and 50th (which is the median) are more difficult to compute. Theoretically, the 90th percentile, for example, is the value of c, say c_{90}, for which:

$$\int_{c_{90}}^{\infty} f(c)dc = 0.10 \tag{7}$$

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. (Alternatively, one could use:

$$\int_{o}^{c_{90}} f(c)dc = 0.90,$$

but equation (7) is more convenient.)

Now solving equation (7), using the expression for f(c) given in equation (3), would pose a fairly formidable problem in numerical integration were it not for an important fact. The integral is very much like the probability integral of the Chi-squared distribution, which is tabulated by several authors. (See, for example, the National Bureau of Standards Handbook of Mathematical Functions.[6]) The tabulation is of an integral, Q, from χ^2 to ∞ (infinity), called $Q(\chi^2/\nu)$. The parameter, ν, is the number of degrees of freedom.

To use these tables, simply replace ν by 2s and χ^2 by 2tc. For example, for the data used in Figure 8, s and t are 1.281 and 0.05824, respectively. Thus, 2s is 2.562. Interpolating in the table for $\nu = 2.561$ we find Q = 0.10 (approximately) for $\chi^2_{90} = 5.55$. Then,

$$c_{90} = \frac{\chi^2_{90}}{2t} = 47.6$$

In Table 8 this was rounded to 48. Values of c_{95}, etc., are obtained in the same way.

Tables 8 through 11, then, summarize these calculations. The expected conflict rates (conflicts per 11-hr day) are given in the column headed Mean. The 90th and 95th percentile rates are alternative recommendations to define abnormally high conflict rates. Some conflict types are so rare for certain intersection classes that observing nearly any might be considered abnormal; for these, no quantitative values are given.

E. Severity Factors

The probability that a given accident results in an injury is known as the severity factor. Severity factors, which can be applied to the expected number of accidents to produce the expected number of injury accidents, are presented in Table 12. (Severity factors for all types of collisions are presented in Volume 3.)

Although there were little data for a few collision types, for most types the computed factors are probably quite accurate representations of accidents in general. It is clear that some types of intersection collisions are more likely to produce injuries than others. The Through Cross Traffic accidents (types 7 and 10) and the Opposing Left Turn accidents (type 5) all result in injuries about one third of the time. The Same Direction conflicts (1 through 4) have an injury rate of only about 0.25 percent. The other Cross Traffic conflicts, as a group (types 6 through 12, except 7 and 10), have a severity factor of 0.167. These various severity factors all seem reasonable, in view of the typical dynamics and relative vehicle speeds associated with each type of conflict/collision.

These factors can be applied to the accident/conflict ratios given in Table 7, to produce expected injury accidents per conflict. The two sets of ratios are given in Table 13.

F. Conflict/Volume Relationships

Within each of the four signalization-volume cells, conflict per unit volume rates were computed for three conflict types: Same Direction (types 1 through 4), Opposing Left Turn (type 5), and Through Cross Traffic (types 7 and 10).

The rates are expressed as conflicts per 1,000 vehicles, where the volume count depends on the type of conflict. The Same Direction volume is the sum of the entering volumes on all four study approaches at signalized intersections, or the total volume. At unsignalized intersections, it is the sum of the entering volumes on the two approaches with the right-of-way. The Opposing Left Turn volume is the square root of the product of the left turn volume and the opposing through volume summed over the four or two approaches at signalized or unsignalized intersections, respectively. The Through Cross Traffic volume is the square root of the product of through cross traffic from right (or left) volume with the through volume summed over the four approaches at both signalized and unsignalized intersections.

TABLE 12

SEVERITY FACTORS BY TYPE OF COLLISION[a]

	Type of Collision	Severity				Severity[b] Factor
		PDO	Injury	Fatal	Total	
1.	Left Turn Same Direction	30	17		47	0.362[c]
2.	Slow Vehicle	33	6		39	0.154
3.	Lane Change	23	3		26	0.115
4.	Right Turn Same Direction	10	4		14	0.286
5.	Opposing Left Turn	208	97		305	0.318
6.	Left Turn from Left	4	3		7	0.429
7.	Cross Traffic from Left	173	93	2	268	0.354
8.	Right Turn from Left	17	2		19	0.105
9.	Left Turn from Right	11	3		14	0.214
10.	Cross Traffic from Right	129	74	2	205	0.371
11.	Right Turn from Right	15	2		17	0.118
12.	Opposing Right Turn on Red	3	0		3	0.0
	Total	656	304	4	964	0.320
	Same Direction (1-4)	96	30		126	0.238
	Through Cross Traffic (7+10)	302	167	4	473	0.362

---

[a] All primary, multiple vehicle accidents (46 intersections, 24 hours, 1979, 1980, 1981).

[b] Probability of at least one injury (or fatality) for the given type of collision.

[c] For example, the severity factor for type 1 is 17/47 = 0.362. For type 7 it is (93 + 2)/268 = 0.354.

TABLE 13

EXPECTED ACCIDENTS AND INJURY ACCIDENTS PER MILLION CONFLICTS

Type of Collision/ Intersection Class	Accident Rate[a]	Injury Accident Rate[a]
Left Turn Same Direction		
Unsignalized Medium Volume	15.0	5.4
Same Direction		
Signalized High Volume	1.4	0.33
Signalized Medium Volume	2.7	0.64
Opposing Left Turn		
Signalized High Volume	671.0	213.0
Signalized Medium Volume	185.0	59.0
Unsignalized Medium Volume	212.0	67.0
Through Cross Traffic		
Unsignalized Medium Volume	735.0	266.0
Unsignalized Low Volume	489.0	177.0

---

[a] Accidents per million conflicts.

The sample means and variances for the above conflict per volume rates are presented in Table 14. These statistics provide typical conflict rates for signalized, high and medium volume, and unsignalized, medium and low volume intersections for these three conflict types. These conflict rates could be used in predicting conflict rates at comparable intersections where the volumes are known, and in planning similar conflict studies.

The Same Direction conflict per volume rates of the four signalization-volume classes are essentially the same, ranging from 44.71 to 49.75 conflicts per 1,000 vehicles. Thus, volume appears to be a very good predictor of Same Direction conflicts.

Except for one intersection class, the Opposing Left Turn rates were between 3 and 4 conflicts per 1,000 vehicles. Relatively more conflicts of this type were observed at the medium volume, signalized intersections. They are less likely to have separate left turn phasing than intersections in the high volume class. Also, there is greater opportunity for this type of conflict at signalized intersections than at unsignalized intersections with the same volume because the left turns are concentrated into essentially half the time period (the green phase). The variances are relatively large for all classes, indicating substantial intersection-to-intersection variation in Opposing Left Turn conflict rates.

TABLE 14

CONFLICTS PER THOUSAND VEHICLES[a]

Type of Conflict/ Signalization-Volume Class	Mean (μ)	Standard Deviation(S)	Variance	Standard Error $S/\sqrt{N}$	Coefficient of Variation (%) $100\ (S/\mu)$
Same Direction					
Signalized High (N=12)	45.16	11.14	124.12	3.22	24.7
Signalized Medium (N=14)	48.12	9.23	85.19	2.47	19.2
Unsignalized Medium (N=10)	44.71	27.42	751.97	8.67	61.3
Unsignalized Low (N=10)	49.75	16.99	288.49	5.37	34.1
Opposing Left Turn					
Signalized High	3.89	3.84	14.72	1.11	98.6
Signalized Medium	7.22	3.97	15.75	1.06	54.9
Unsignalized Medium	3.99	3.75	14.06	1.19	93.9
Unsignalized Low	3.18	3.28	10.74	1.04	103.1
Through Cross Traffic					
Signalized High	0.05	0.10	0.01	0.03	192.0
Signalized Medium	0.08	0.06	0.00	0.02	83.1
Unsignalized Medium	2.40	1.52	2.31	0.48	63.2
Unsignalized Low	3.83	1.97	3.89	0.62	51.5

---

[a] See text for volume definitions.

As noted earlier, Through Cross Traffic conflict rates are very small for signalized intersections. The unsignalized medium and low volume Through Cross Traffic conflict rates were 2.40 and 3.83 conflicts per 1,000 vehicles, respectively.

G. Correlation

Correlation and rank correlation analyses were performed on the conflict and accident data, as well as the volume and accident data, for the types of collisions used to develop accident/conflict ratios. Results of these analyses are presented in Table 15.

The results of the correlation and rank correlation tests, in general, are quite similar. Accident-conflict correlations were significant in three out of eight cases, as were the rank correlation tests (same three cases). The correlation and rank correlation tests for accident-volume relationships produced significant results in five cases.

Altogether, for seven of the eight types of collisions, the Pearson and the rank correlation coefficients were significant at the 10% level. However, only for one type (Through Cross Traffic at unsignalized low volume intersections) both the Pearson and the rank correlation coefficients were significant at the 10% level.

The test results for a particular type of collision also were not consistent across classes of intersections. For the Opposing Left Turn type, the signalized high volume intersections produced a significant accident-conflict correlation (0.586), but a nonsignificant accident-volume correlation (-0.247). In contrast, tests for signalized medium and unsignalized medium volume intersections produced nonsignificant accident-conflict correlation results (0.249 and -0.277, respectively), while the corresponding accident-volume correlations produced significant correlation results (0.483 and 0.698, respectively).

In summary, results of correlation and rank correlation tests produced similar results. However, except for one case, Through Cross Traffic, unsignalized low volume, which produced significant results for all tests, accident-conflict and accident-volume tests produced contrasting results.

H. Validation

As a means of validating the concept of using the computed accident/conflict ratios for each type of collision for each of the four intersection classes, we proceeded as follows. Within each class, two locations were randomly selected. Accident/conflict ratios were then computed as described earlier, but based on the data from the remaining locations only. Using the conflict rates and their variances obtained from the study, the expected accident rates and their variances were then computed for the selected intersections as described in Volume 3 and compared to the observed accident rates at these specific locations in 1982. They were also compared to the expected accident rates based on actual accident counts during the years 1979, 1980, and 1981. The randomly selected intersections were:

TABLE 15

CORRELATION RESULTS

Type of Collision/ Signalization-Volume Class	Pearson Correlation Coefficients				Spearman Rank Correlation Coefficients			
	Accident, Conflict	Significant[a]	Accident, Volume	Significant	Accident, Conflict	Significant	Accident, Volume	Significant
Left Turn Same Direction								
Unsignalized Medium Volume	0.231		0.675	Yes	0.330		0.548	Yes
Same Direction								
Signalized High Volume	0.563	Yes	-0.009		0.642	Yes	0.243	
Signalized Medium Volume	-0.171		-0.194		-0.120		-0.019	
Opposing Left Turn								
Signalized High Volume	0.586	Yes	-0.247		0.652	Yes	0.033	
Signalized Medium Volume	0.249		0.483	Yes	0.292		0.391	Yes
Unsignalized Medium Volume	-0.277		0.698	Yes	-0.200		0.691	Yes
Through Cross Traffic								
Unsignalized Medium Volume	0.011		0.475	Yes	0.191		0.445	Yes
Unsignalized Low Volume	0.577	Yes	0.717	Yes	0.636	Yes	0.727	Yes

---

[a] Significant at the 10% level.

[b] Traffic volumes are defined in text associated with Table 14, in Subsection F of Volume 2.

Signalization-Volume Class	Intersection Number and Location
Signalized, High Volume	19. Holmes - 75th 20. Troost - 75th
Signalized, Medium Volume	12. Oak - 75th 26. Blue Ridge - 107th
Unsignalized, Medium Volume	34. Holmes - 79th 46. James A. Reed - Gregory
Unsignalized, Low Volume	27. Westview/Central - Gregory 33. Main - 79th

The computations of the expected accident rates and their variances will be demonstrated on the All Same Direction type of collision at Location 19. Using the notations from Appendix D we have:

C_o = 1,386 conflicts/day from the study;

$\hat{R}$ = 1.308×10^{-6}, the average accident/conflict ratio for signalized, high volume intersections;

$\mathrm{Var}(\hat{R})$ = 2.6462×10^{-13}, the sample variance of $\hat{R}$ (=Var(R)/10); and

$\mathrm{Var}(C)$ = 65,697.8 $(\text{conflicts/day})^2$, the sample conflict variance obtained from the 10 remaining signalized, high volume locations.

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

$$\hat{A}_o = C_o \times \hat{R} = 1{,}386 \times 1.308 \times 10^{-6} = 1.813 \times 10^{-3} \text{ accidents/day.}$$

The variance of $\hat{A}_o$ is computed using equation 3 of Appendix D:

$$\mathrm{Var}(\hat{A}_o) = \mathrm{Var}(C)\ \mathrm{Var}(\hat{R}) + C_o^2\ \mathrm{Var}(\hat{R}) + \hat{R}^2\ \mathrm{Var}(C)$$

$$= 0.6381 \times 10^{-6}\ (\text{accidents/day})^2.$$

In summary, the expected daily All Same Direction accident rate at Location 19 is 0.0018 accidents/day, with a standard deviation of 0.0008 accidents/day (square root of $\mathrm{Var}(\hat{A}_o)$). In units of accidents/year on weekdays (Monday-Thursday), these results are adjusted by a multiplication factor of 4/7 x 365. Thus, the expected All Same Direction accident rate per year at Location 19 would be 0.38 accidents/yr with a standard deviation of 0.17 accidents/yr. The user is reminded here that this prediction is for that specific type of accidents on dry road only, and thus does not include, and should not be compared with, total number of accidents including night and under wet or icy road conditions accidents.

The results for all eight validation locations are given in Table 16. Continuing with the same example, the coefficient of variation of the expectation for this accident type at this intersection, using accident/conflict ratios, is 44.1 percent. These expected values are to be compared with the expectation based on previous accidents of 0.67 accidents/yr, standard deviation of 1.15, and CV of 173.2 percent. Both expectations can then be judged against the actual result of 4 accidents in 1982. (Note that this is a "bad" example, in that the observed value of 4 accidents is a particularly unlikely result, based on the past history of the intersection. Assuming a Poisson distribution with the observed results from 1979 through 1981, the likelihood of having 4 accidents in 1982 is about one in 1,600.) Nevertheless, for this example, the expectation based on accidents is greater (and more accurate) than that based on conflicts but, having a larger variance, is less precise.

Overall, for this set of intersections and types of accidents, the total number of expected accidents based on conflicts is 18.20; based on accidents, the expected number is 19.64. Both expectations are quite close to the observed number of 20 in 1982. However, there are fairly large differences from intersection to intersection and from type to type. The expectations based on accidents were closer to the observed values in 9 cases, the expectations based on conflicts were closer in 6 cases, and there was one tie. This is too close an agreement to be attributed, statistically, to anything but chance. It is noted that for these data the conflict-based expectations were closer for unsignalized intersections, and the accident-based expectations were closer for signalized intersections. However, the data set is too small to allow convincing generalizations.

Another way of comparing the two estimation methods--one using the accident/conflict ratios, the other using the average accident rates based on 3 years of data--is to compare the pairs of deviations between expected and observed rates. Wilcoxon's signed rank test[5] was used to test whether either method produced overall closer predictions of the observed rates. The test statistic is T = 88, with N = 15 (16 - 1 tie at Location 12, Opposing Left Turn). An approximate 95 percent interval of acceptance of the null hypothesis of no difference is [25, 94]. Since T = 88 is within these limits, there is no evidence that one method produces better predictions than the other one, on the average. (With a 90 percent interval of acceptance, the accident-based predictions are marginally closer than the conflict-based predictions.)

Note that both sets of expectations are "predictions" of the <u>average</u> yearly accident rates, as opposed to predictions for any given year, which are simply samples and subject to wide variations. Therefore, a more valid way of comparing the two estimation procedures is to examine their variances. This can be done by means of comparing the coefficients of variation (standard deviation/mean) obtained in both cases. Again, Wilcoxon's signed rank test was used. The statistic is T = 42, with N = 13 (16 - 3 undetermined coefficients). An approximate 95 percent interval of acceptance of the null hypothesis of no difference is [17, 74]. Since T = 42 is well within these limits, there is 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.

TABLE 16

EXPECTED ACCIDENT RATES

			Conflict-Related Accidents Per Year									
			Expected						Actual			
			Based on Conflicts			Based on Accidents						
									Accidents Per Year			
Intersection-Volume Class	Intersection Number	Type of Collision	Accidents/ Year	Standard Deviation	(Standard Deviation/ Mean)x100,%	Accidents/ Year	Standard Deviation	(Standard Deviation/ Mean)x100,%	1979	1980	1981	1982
Signalized High Volume	19	All Same Direction	0.38	0.17	44.1	0.67	1.15	173.2	0	2	0	4
	20		0.26	0.13	48.8	0.33	0.58	173.3	0	0	1	0
	19	Opposing Left Turn	3.88	3.54	91.2	8.33	1.53	18.3	7	8	10	9
	20		6.51	4.52	69.4	3.33	2.08	62.5	4	5	1	2
Signalized Medium Volume	12	All Same Direction	0.39	0.19	48.6	0.0	0.0	-	0	0	0	0
	26		0.35	0.18	50.9	0.33	0.58	173.3	0	1	0	0
	12	Opposing Left Turn	0.67	0.64	95.4	1.33	0.58	43.3	2	1	1	1
	26		1.14	0.70	61.3	0.33	0.58	173.3	0	0	1	0
Unsignalized Medium Volume	34	Left Turn Same Direction	0.24	0.56	233.4	0.0	0.0	-	0	0	0	0
	46		0.26	0.56	220.7	0.0	0.0	-	0	0	0	0
	34	Opposing Left Turn	0.12	0.24	205.6	0.33	0.58	173.3	0	1	0	0
	46		0.08	0.23	299.7	0.33	0.58	173.3	0	0	1	0
	34	Through Cross Traffic	1.42	1.13	79.5	1.67	1.15	69.3	1	1	3	0
	46		0.70	0.88	126.6	0.33	0.58	173.3	0	0	1	2
Unsignalized Low Volume	27	Through Cross Traffic	0.93	0.97	104.4	1.0	1.0	100.0	1	2	0	0
	33		0.87	0.97	111.4	1.33	1.15	86.6	2	2	0	2

The two sets of expectations can be combined to yield expected values with variances less than those for either set alone. If we let $\hat{A}_a$ be the expected accident rate based on accident data, then $\hat{A}_m$, the expected accident rate with minimum variance, can be computed as

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

where

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

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 17.

I. Other "Conflicts"

The operational definitions of traffic conflicts, as given in NCHRP Report 219[1], and used in this research, precludes some vehicle interactions that could result in vehicle-vehicle accidents. Except for Same Direction conflicts, the definition is based on a vehicle with right-of-way being subjected to a conflict by another vehicle violating its right-of-way. The vehicle with right-of-way according to the definition, must always drive through the intersection to signify the occurrence of a conflict. The definition generally precludes turning vehicles with right-of-way, such as those making left turns during a protected left turn phase at signalized intersections. Conflicts resulting from interactions between two turning vehicles are also precluded in the definition. Conflicts involving turning vehicles occur as a result of a signal or stop sign violation or when vehicles are clearing the intersection at the end of a signal phase.

By definition, Same Direction conflicts can only occur while the signal phase for those vehicles is green. And, of the pair of vehicles involved in a Same Direction conflict, the following vehicle taking the evasive action must drive through the intersection to signify a conflict. If the following, evading vehicle turns at the intersection, the event was not a conflict. Likewise, no conflict occurs if a lead vehicle stops, legally, for a stop sign or red signal, even if a following vehicle brakes severely or swerves. Yet, about 10 percent of all signalized intersection accidents were of this type.

Limiting the set of operational conflict definitions to a subset of all possible vehicle interactions reduces the amount of useable conflict data that can be collected in an intersection conflict study. Recording additional types of intersection conflicts would have increased the amount of data available to develop accident/conflict relationships. The extent of the increase in the amount of useable information is unknown because data on other conflict types were not collected as part of the conflict observation procedure. It is probable that many of the accidents not used in the development of accident/conflict relationships have associated "conflicts" and thus could have been utilized to develop relationships.

TABLE 17

MINIMUM VARIANCE ACCIDENT EXPECTATIONS

Intersection-Volume Class	Validation Intersection Number	Type of Collision	Expected Values			Variances		
			Conflict-Based	Accident-Based	With Minimum Variance	Conflict-Based	Accident-Based	Minimum Variance
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
Signalized 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
Unsignalized 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

The amount of useable conflict data recorded during intersection conflict studies could be increased by revising the operational definitions of traffic conflicts to include other vehicle interactions which can result in accidents. The result would be an enlarged data base from which the operation and safety of urban intersections could be evaluated.

IV. CONCLUSIONS AND RECOMMENDATIONS

This section provides the major conclusions drawn from the research, as supported by the discussions and data in the previous section. Reference is made to detailed tables and equations presented earlier, for the convenience of the reader who wishes to apply the results of the study. This section also presents a series of recommendations about the application of the traffic conflicts technique and related matters. To make this section relatively self-contained, it begins with a capsule summary of the work on which the conclusions and recommendations are based.

A. The Research Scope

The traffic conflicts technique (TCT) has been studied and applied in this country and abroad for years, although not universally or even widely among traffic engineers. Prior to this study the major piece of TCT research was NCHRP project 17-3, which resulted in NCHRP Report 219.[1] That study developed definitions and procedures with acceptable repeatability and reliability that can be easily learned and applied. Those procedures were used in this study.

The purpose of the present research, briefly, was to establish relationships between traffic conflicts and accidents, and to identify expected and abnormal conflict rates given various circumstances. (It is also sometimes noted that the TCT might have application as an operational measure, as contrasted to a safety measure, but that aspect was not investigated here.)

The TCT data upon which the conclusions and recommendations are based, were collected during the summer of 1982 at 46 intersections in the Greater Kansas City area. The conclusions are limited to daytime (0700 to 1800) and weekday (Monday-Thursday) traffic, and to dry pavement conditions. The extent to which the findings can be extended to other situations is not known, but it is expected (based on general accident and safety research) that accident/conflict ratios may be higher at night, and when the pavement is wet or icy.

The 46 intersections studied were placed into four strata or classes based on the presence or absence of signalization and the total volume in vehicles per day (vpd) through the intersection. The resulting strata were as follows:

1. Signalized, high volume (over 25,000 vpd)--14 intersections
2. Signalized, medium volume (10,000-25,000 vpd)--12 intersections
3. Unsignalized, medium volume (10,000-25,000 vpd)--10 intersections
4. Unsignalized, low volume (2,500-10,000 vpd)--10 intersections.

Each intersection was observed for four days, giving four replicate conflict data sets. Twelve types of primary conflicts were noted and recorded, following NCHRP Report 219, as well as secondary conflicts (those resulting from an earlier conflict).

Accident data were obtained in hard copy form for each of these intersections for a three-year period. Data for an additional year was acquired for eight randomly selected intersections for use in validation studies. All accidents were classified according to whether or not they were conflict-related and met the TCT data collection time, day, and pavement condition requirements; only those that met these criteria were used in the subsequent analyses.

B. Conclusions

1. A fundamental difficulty with a study of this kind is the rarity of accidents, the very fact that leads one to search for "accident surrogates" in the first place. The 1,292 total accidents in the 3-year, 46-intersection data base yields an average of only about 28 accidents per intersection. After deleting those accidents that involve single vehicles, nighttime, adverse pavement conditions, etc., only 319 accidents (about 7 per intersection in 3 years) remained which could be considered conflict-related. Further subdivision into the 12 conflict types yields a sparse data set, indeed.

2. Annual accident frequencies varied greatly from intersection to intersection. For signalized intersections they ranged from 1 to 31 per year (total); for unsignalized intersections the range was 0 to 12. Thus, a surrogate such as TCT, if it were effective, would be useful indeed to discriminate high from low accident rate locations.

3. It is often enticingly suggested that conflicts deemed to be "serious" (by whatever of various alternative definitions) should be more closely related to serious accidents (injury producing, say) than total conflicts are related to total accidents. The NCHRP study showed the extreme rarity of these severe conflicts in the U.S. This study reemphasized another frequent observation, that injury accidents are a small fraction (in the order of 1/3 to 1/4) of all reported accidents in the U.S. Thus, the problem of insufficient data noted earlier is accentuated even further for serious accidents and conflicts, and makes the chances of determining reliable relationships between them quite bleak.

4. It would be helpful if wet- and dry-pavement accidents and conflicts could be pooled or related in an easy way. Such appears not to be the case, however, as wet- and dry-pavement conflicts are not distributed across types in the same fashion as wet- and dry-pavement accidents. Nevertheless, the work done here, applicable to dry pavements, covers the majority (80 percent) of the conflict-related accidents.

5. Earlier work[1] noted that accidents, conflicts, and volumes vary according to time of day, but not in precisely the same way. Data obtained here substantiated this. The three measures each exhibit morning and afternoon peaks, but the volume and conflict peaks are higher in the morning and lower in the afternoon, relative to accident peaks.

6. Accident and conflict data were collected by approach leg and time of day for each intersection. However, because of the paucity of accidents and, to a lesser extent conflicts, it was necessary to combine data from all approaches of the studied intersections and all time periods before attempting statistical analyses. This pooling is probably going to be necessary in operational applications of the TCT, even though theoretical reasoning would recommend more disaggregation.

7. There are 12 basic conflict types that are possible, according to NCHRP Report 219.[1] Of these, some are fairly common, but others are so rare that they can be discounted as being impractical for operational applications. At signalized intersections the Same Direction conflicts are common, as are Opposing Left Turn conflicts. The 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 is a violation of the usual right-turn-on-red ordinances.) At unsignalized intersections, Same Direction conflicts are also common (except for those resulting from lane changes). Cross Traffic conflicts are much more prevalent at such intersections (compared to signalized intersections), except for the unusual Right Turn From Left conflict.

8. 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 seems to be little incentive to collect data on conflict types for which corresponding accidents hardly ever occur. Thus, the practical, useable conflict types are the following:

Signalized intersections:
- Same Direction (pooled types 1, 2, 3 and 4)
- Opposing Left Turn (type 5)

Unsignalized intersections
- Through Cross Traffic from Left and Right (pooled types 7 and 10)

Unsignalized intersections, medium volume only
- Opposing Left Turn (type 5)
- Left Turn Same Direction (type 1)

9. 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_o, the expected accident rate, $\hat{A}_o$, is

$$\hat{A}_o = C_o\hat{R} .$$

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 7, along with their variances. The latter can be used to estimate the variance in the expected accident rate using Equation (2) in the text.

10. Accident/conflict ratios, $\hat{R}$, differ substantially from type to type, ranging from as low as 1 or 2 accidents per million conflicts for Same Direction conflicts at signalized intersections to as high as about 700 accidents per million conflicts of the Opposing Left Turn and Through Cross Traffic types. (The latter are for unsignalized intersections only; at signalized intersections these are on the order of 10,000 accidents per million Through Cross Traffic conflicts, but the rarity of this type of conflict precludes a very accurate estimate.)

11. The variation in accident/conflict ratios is generally quite large (coefficients of variation (CV) up to about 200 percent), indicating a substantial difference among intersections of nominally 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.

12. 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 above, as well as the substantial number of intersections having no accidents of a specified type. Despite the lack of proof of such differences between intersection classes, it is probably unwise to combine the data to obtain "universal" ratios.

13. 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 a definition of abnormal, rates that exceeded the 90th percentile (alternatively, the 95th percentile). The values obtained are given in Tables 8 through 11.

14. If a potential TCT user determines that his conflict rates and variances differ substantially from those obtained in the midwest U.S.A. during this study, he will have to adjust the values given in Tables 8 through 11. The procedure is described in the text, and involves the use of a few simple equations and interpolating from an available statistical table.

15. The accident/conflict ratios, $\hat{R}$, are applicable to estimating total reported accidents of a specified type, as opposed to accidents of some particular severity. Table 12 gives severity factors for each conflict type which, when multiplied by $\hat{R}$, enable one to estimate the expected number of injury accidents based on the TCT data. The appropriate rates are given in Table 13.

16. Volume data were obtained at the intersections along with the conflict data, and procedures were adapted from the literature to obtain the usual intersection volume measures of exposure (which differ by conflict type). Conflict/volume rates are presented in Table 14, and range from as low as 0.05 conflicts per thousand vehicles for Through Cross Traffic conflicts at signalized intersections to about 50 conflicts per thousand vehicles for Same Direction conflicts.

17. The volume, conflict, and accident data can be combined and looked at from a motorist's point of view. The numbers below are "order of magnitude" values that arise upon making simplifying assumptions and combining some data categories for simplicity. (The purpose here is to illustrate a point--not to produce hard figures, which would be of little research use.)

Conflict	Intersections per Conflict	Accidents Per Million Conflicts	Million Intersections per Accident
Same Direction	20	10	2
Opposing Left Turn	750	350	2
Through Cross Traffic (Unsignalized)	600	600	1
Through Cross Traffic (Signalized)	10,000	10,000	1

The numbers suggest, for example, that a motorist would be exposed to a conflicting vehicle going in the same direction about once every 20 intersections. (Also, he would cause a Same Direction conflict every 20 intersections.) At the other extreme, he would be exposed to a Through Cross Traffic conflict only once in 10,000 signalized intersections. However, accidents are 1,000 times as likely with Through Cross Traffic conflicts at signalized intersections (10,000 per million) than with Same Direction conflicts (10 per million). As a result, a motorist's chances of being in an accident of any specific type are about 1 or 2 per million intersections, almost independent of the type.

18. Previous research has indicated that attempting to establish useful statistical relationships between observed accidents and conflicts using regression analysis, correlation coefficients, etc., lead to mixed, and generally rather poor results. That finding was substantiated here. Such procedures are not the appropriate way to judge a proposed accident surrogate.

19. 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 accurately and precisely estimate the average (expected) value.

20. 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 previous accident history. Overall for the eight intersections, both methods produced about the same estimates--18.20 accidents based on conflicts; 19.64 based on previous accidents. There were actually 20 conflict-related accidents in 1982 at the eight intersections. Breaking these down to the 16 possible combinations of validation intersections and conflict types indicated that both procedures produced estimates, some higher and some lower than actually occurred. In this respect, the accident-based procedure produced closer estimates more often than the conflict-based procedure, but only marginally so.

21. Although the accident estimates based on conflicts may not have been quite as accurate as those based on previous accidents, they were close. But, it is also important to examine the precision of the estimates. Other things being equal, the estimation procedure with the smallest variance is the better. 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; one cannot reject the null hypothesis that the conflicts procedure produces estimates equally as precise as do prior accident histories.

22. 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 using either one separately. Equations (8) and (9) in the text give the combinational procedure.

23. The amount of useable conflict data recorded during intersection conflict studies could be increased by revising the operational definitions of traffic conflicts to include other vehicle interactions which can result in accidents. The result would be an enlarged data base from which the operation and safety of urban intersections could be evaluated.

24. 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 just as 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.

C. Recommendations

1. The TCT approach should be used to provide measures of safety effectiveness only for the specific conflict types and intersection classes identified above.

2. Expected accident rates and their variances should be determined by conducting a TCT study using the procedures detailed in NCHRP Report 219,[1] and using equations (1) and (2) in the text together with the parameters in Table 7.

3. Accident estimates based on conflicts should be used if reliable accident data are insufficient or unavailable.

4. Accident estimates based on conflicts can be combined with estimates based on accident history to improve the reliability of the estimate.

5. If daily conflict rates at an intersection exceed the 90th (or 95th) percentile values given in Tables 8 through 11, one should suspect either that the TCT study was faulty or that the intersection has an unusual safety (or operational) problem.

6. If one consistently obtains conflict rates different from those given here, one should suspect that there are important regional differences, and should use the statistical approach given in this report to adjust the values in Tables 8 through 11.

7. There are many multiple vehicle intersection accidents that either are not conflict-related or are associated with very rare (and therefore not useful) conflicts. One should consider using as an accident surrogate some measure of severe braking behind vehicles stopped or stopping at a red traffic signal--an event not treated here as a conflict but which results in numerous accidents. Likewise, because conflicts resulting from red light violations are so rare, one should consider using red light violations, themselves, as an accident surrogate (as some do[7]).

8. Further work can be done to refine the variance estimation procedure used in this report. Basically, we used the sample variance. A better (i.e., with smaller variance) estimate can be obtained through analysis of the underlying distribution.

9. If additional work of this type is done to validate the TCT, considerably more effort should be placed on obtaining a greater accident data base, and less could be spent on collecting conflict data. One or two days of conflict data should suffice, but there should be more intersections (hence, more accidents) and more years of accident data.

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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH, DEVELOPMENT, AND TECHNOLOGY

The Offices of Research, Development, and Technology (RD&T) of the Federal Highway Administration (FHWA) are responsible for a broad research, development, and technology transfer program. This program is accomplished using numerous methods of funding and management. The efforts include work done in-house by RD&T staff, contracts using administrative funds, and a Federal-aid program conducted by or through State highway or transportation agencies, which include the Highway Planning and Research (HP&R) program, the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board, and the one-half of one percent training program conducted by the National Highway Institute.

The FCP is a carefully selected group of projects, separated into broad categories, formulated to use research, development, and technology transfer resources to obtain solutions to urgent national highway problems.

The diagonal double stripe on the cover of this report represents a highway. It is color-coded to identify the FCP category to which the report's subject pertains. A red stripe indicates category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, and green for category 9.

FCP Category Descriptions

1. **Highway Design and Operation for Safety**
   Safety RD&T addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act. It includes investigation of appropriate design standards, roadside hardware, traffic control devices, and collection or analysis of physical and scientific data for the formulation of improved safety regulations to better protect all motorists, bicycles, and pedestrians.

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