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Traffic Conflicts as a Diagnostic Tool in Highway Safety

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Accident repeatability from one year to the next was found to be high at 60 intersections (r = 0.64) and 170 spot locations (r = 0.59). Nearly half of the 209 Kentucky locations designated as hazardous by accident criteria were found to have been so identified falsely because of random accident occurrences. Conflict counts were conducted at 5 intersections in central Kentucky to determine characteristics of conflict data. Good reliability was found between observers in simultaneous counts of conflicts and weaves with r values as high as 0.93. Traffic volumes accounted for only about 30 percent of the variation in numbers of conflicts. Reductions in conflicts and accidents that resulted from such safety improvements as installing left-turn signal phasing, raised pavement markers, and green-extension systems at numerous locations were determined. A revised procedure for collecting and utilizing conflict data was described.

Traffic conflicts are measures of accident potential and operational problems at a highway location. Many highway agencies are now using traffic conflict techniques to complement the limited accident data found in accident records. The Kentucky Department of Transportation has used various forms of conflict data since 1972 to assist in its efforts for highway improvement. While new procedures are currently under development for collection and use of conflict data in Kentucky, past experiences with conflicts have proved very encouraging.

The first formalized procedure for identifying and recording traffic conflicts at intersections was developed by Perkins and Harris of General Motors Corporation in 1967 (1). Major types of conflicts at intersections include rear-end, left-turn, cross-traffic, red-light violation, and weave conflicts. Conflict counts may be used to quickly evaluate changes in road design, signing, signalization, and environment. After a location is identified as hazardous, a study of conflict patterns can be used with accident diagrams to gain a more accurate understanding of operational deficiencies and accident causes.

Crude forms of traffic conflict counts to determine appropriate safety improvements have been made since traffic engineers first began making field observations. Formalized traffic conflict techniques give a more objective measure of observed traffic problems and allow for a permanent record of the comparative magnitude of such problems. The use of traffic conflict techniques has to date been primarily limited to intersections. However, conflict procedures for other types of locations are under development.

A more severe form of traffic conflict is an erratic maneuver, which is any sudden, unexpected movement by a vehicle that could cause an accident. An erratic maneuver usually involves only one vehicle's making an unsafe move independently of other vehicles. Such a maneuver may often result in a conflict if another vehicle is forced to brake or weave to avoid it. Poor signing and inadequate geometric design often cause erratic maneuvers.

While traffic conflict counts usually indicate the potential for accidents between two or more vehicles, erratic maneuver counts may also provide information about the potential for single-vehicle accidents.

A near-miss accident is a collision between two or more vehicles barely avoided by a last-second movement or stop. This type of accident is a very severe sort of conflict and is rarely observed at any location compared to other conflicts or erratic maneuvers.

Traffic events may be classified in terms of increasing severity from traffic volume to fatal accidents. The ordering of traffic events by severity is as follows:

1. Traffic volume,
2. Routine conflicts,
3. Moderate conflicts and erratic maneuvers,
4. Severe conflicts or near-miss accidents,
5. Minor collisions (usually not reported),
6. Property damage accidents,
7. Injury accidents, and
8. Fatal accidents.

While accident data provide only the last three levels of traffic events, traffic conflict counts provide the other five, since volume counts are usually made along with conflict counts.

NEED FOR CONFLICT DATA

Several limitations have been observed in the use of accident data alone in traffic safety studies. Accident files only contain records of reported accidents, which comprise only a fraction of the accidents that actually occur. The criteria for accident reporting vary considerably among states. For example, all traffic accidents in Colorado, Nevada, and the District of Columbia by law must be reported; only accidents with injury costs exceeding $400 damage to any one person must be reported in Connecticut. Reporting criteria in other states range between these extremes; the most common reporting criteria are $100 (23 states) and $200 (12 states including Kentucky) (2).

Because of such reporting criteria, estimates of traffic accidents actually reported range from 20 to 50 percent. The number of reported accidents at a site is, therefore, a function of local reporting laws, accident severity, and damage costs of each accident.

Another problem with using accident data alone for identifying and evaluating high-accident sites is the random fluctuations in accident data. Many accidents result from a vehicle malfunction (blowout or brake failure), an obvious driver error (speeding or drunk driving), or a weather-related problem (ice on road or heavy fog) that is unrelated to any geometric deficiency.

A study was completed in 1973 in Kentucky that illustrated the effects of random accidents on the identification of hazardous sites. Of the 208 spot locations identified by accident data as hazardous, 99 of them were wrongly identified because of random accident occurrences. These 99 sites were found by field inspections to need no improvements, and accidents decreased to normally low levels the following year. Nearly half the accident locations warranted no improvements (3).

To test the reliability of accident data for predicting future accidents at a location, an analysis of 60 intersections in central Kentucky was made. The number of accidents for a given year compared with the number of accidents the following year resulted in a correlation coefficient (r-value) of only 0.64. The 95 percent confidence level (twice the standard error) for this relationship was ±10.9 accidents per year, and the average number of accidents per year at the intersections was 11.1. This indicated that an error of almost 100 percent in either direction is possible when accident numbers from one year to the next are compared.

A similar analysis was also made for 170 rural, 480-m (0.3-mile) spots in Kentucky, and an r-value of only 0.59 was found. More than a 100 percent error was also found for this sample of locations (within the 95 percent confidence level), which illustrates the nonrepeatability of accident data.

Another problem with accident data is the waiting time needed to obtain a significant data base. A previous study in Kentucky suggested that up to 2 years of accident data are necessary to ensure reliability when selecting high-accident locations (4). After an improvement is made, it often takes several more years to determine the effectiveness of the improvement based on accident data. Also, without some other measure of safety, several accidents must occur at a site before improvements can be justified.

While accident data have many limitations, they can be quite useful when complemented by traffic conflict data. Accident histories can point out locations where conflict data should be collected. Conflict studies can then be made at these and other sites suspected of being hazardous. Conflict counts can be used to help select appropriate improvements and later to determine whether the improvements were effective in reducing the hazard to motorists.

CHARACTERISTICS OF CONFLICT DATA

An effort was made to gain a better understanding of the nature of traffic conflicts. The immediate intent was to determine consistency of conflict counts between observers, to evaluate volume and conflict relationships, and to test daily repeatability of conflicts.

Conflict and volume data were continuously collected by the General Motors (GM) procedure at each of five sites for 11 hours from 7:30 a.m. to 6:30 p.m. on Tuesday, Wednesday, or Thursday. Two days of data were collected at one site to test for conflict repeatability. Five observers alternated duties at each site to allow for breaks when needed. Some conflict counts were made simultaneously on the same approach to test observer consistency.

Conflicts were counted on the two major approaches at four intersections and one approach at the other. One observer was stationed at each approach from 30 to 90 m (100-300 ft) back from the intersection in a state-owned car wherever possible. Chairs on sidewalks were used at urban locations that had no shoulders. Volume counts were made of every movement (through, left turns, and right turns) of all intersection approaches throughout the test period.

Conflict and volume data were recorded in 15-min periods on the GM data sheets. Several new categories of conflicts and erratic maneuvers were added from observations of the specific problems at a site. Each conflict was also classified as routine, moderate, or severe.

All five intersections were located in and around Lexington, Kentucky (population 200 000), and data were collected in the spring of 1977. A summary of volume, speed, geometric, and conflict information for each intersection approach is given in Table 1. All approaches were two lanes of four-lane arterials; minor streets were all two-lane collector streets. Each was a four-way signalized intersection, except Harrodsburg Road at Larkspur Drive, which is a T-intersection with a stop sign on the minor approach.

Observer Reliability

One of the most important aspects to consider when using conflict data is the reliability of data collected by observers. There are many factors that will account for variations in conflict counts, such as alertness, experience, and different driving attitudes of the observers; location of the observer at the site; and traffic volumes. Several hours of training are routinely given to each observer before conflict data are taken alone. Typically, an experienced observer trains an inexperienced one at a site by discussing all conflicts and weaves as they occur. Periodic checks between observers are made to help ensure consistency.

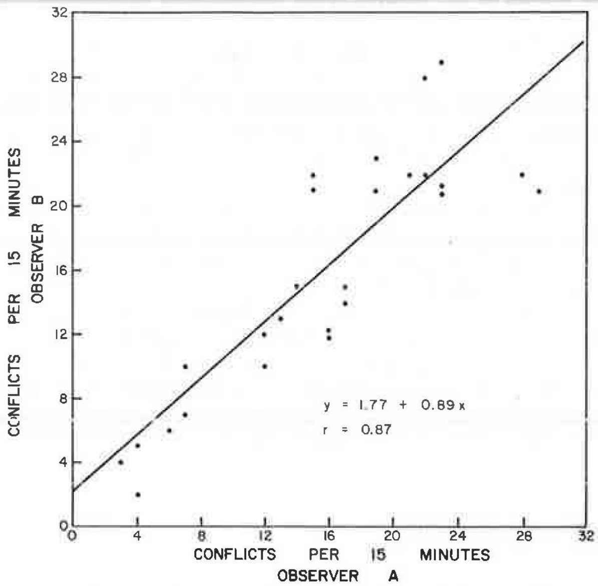
The first test was conducted in June 1977 at the signalized intersection of Limestone Street and Virginia Avenue. During data collection, four observers were used, two simultaneously counting conflicts and weaves in 15-min intervals using the GM technique. A plot was made of conflicts per 15-min period for one observer versus those of another, and the overall r-value was 0.86. Numbers of conflicts per 15-min period ranged from 5 to 36, depending primarily on traffic volume. A similar plot of weaves resulted in an r-value of 0.93, and numbers of weaves varied from 0 to 24 every 15 min. A total of 25 periods were used in this analysis.

The second site was a T-intersection of Harrodsburg Road at Larkspur Drive. Again, four observers counted conflicts and weaves on the two major approaches (in July 1977). A correlation coefficient of 0.87 was found between conflict counts by observers as shown in Figure 1 for 26 periods of 15 min each. The correlation for weaves was lower than before, at 0.77. The overall reliability of observers involved in conflict counts was considered to be very good. Reevaluation of observers is made periodically, so observer reliability is expected to improve.

Volume and Conflict Relationships

The relationship between traffic volume and conflicts was found on all intersection approaches for each day of data collection. Plots of total volume (x-axis) versus total conflicts (y-axis) were made by considering each 15-min period as one data point. A total of 44 points were plotted for each intersection approach (11 h of data with four periods per hour). The correlation coefficients varied widely from 0.24 to 0.81. Individual values of r for the approaches as ordered in Table 1 were 0.72, 0.70, 0.81, 0.35, 0.73, 0.45, 0.24, 0.51, and 0.72. Based on average r^2 of all approaches, only 37 percent of the variance in conflicts can be explained by traffic volumes.

Figure 1. Conflict counts per 15-min period for two observers.



Volume and conflict relationships were also compared on two separate days at one intersection. On the inbound approach, the r-value was 0.28 the first day and 0.35 the second day (2 weeks later). The difference was greater on the other approach where the r-values were 0.42 and 0.73 for the 2 d.

Another plot was made of conflicts per hour versus hourly volume for all approaches (11 data points), which ranged from 32 to 83; hourly volumes were between 294 and 931. The r-value was only 0.51, which indicates that only 26 percent of the conflict variation can be explained by traffic volume (r^2 = 0.26).

The previous results indicate that, while traffic volumes have some effect on number of conflicts, volume and conflict correlations vary considerably at different intersections. Also, the correlations may vary on different days at the same approach. Thus, counting conflicts is not merely another way of counting traffic volume. Most conflicts at the test sites were traced to a geometric deficiency, an inappropriate signal timing, or a capacity problem.

Conflict Repeatability

One of the questions raised concerning use of conflict data concerns the variation in conflicts from one day to the next. A large variation in conflict numbers and patterns would require several days of collection at each site to ensure reliable data. To obtain information concerning the daily repeatability of conflicts, conflict data

Table 1. Characteristics and conflict summaries of test sites.

Intersection	Direction of Approach	Date of Count	Volume: Average Hourly	Volume: Peak Hour	Other Characteristics	Conflicts: Per Hour	Conflicts: Peak Hour	Conflicts: Per 1000 Vehicles
New Circle Road at Woodhill Drive	S	5/10/77	908	1375	Three-phase signal Left- and right-turn lanes Separate left-turn signal phase Left turns (9 percent) Right turns (10 percent)	81	127	89.5
Euclid Avenue at Woodland Avenue	NW, inbound	5/18/77	377	707	Two-phase signal No separate left-turn lanes Left turns (15 percent) Right turns (7 percent)	55	97	144.9
Euclid Avenue at Woodland Avenue	SE, outbound	5/18/77	294	530	1.2-m (4-ft) median Left turns (10 percent) Right turns (6 percent)	33	81	111.6
Limestone Street at Virginia Avenue	N, inbound	5/26/77 6/7/77	620	1046	Two-phase signal No separate left-turn lanes Left turns (10 percent) Right turns (2 percent)	57	95	92.2
Limestone Street at Virginia Avenue	S, outbound	5/26/77 6/7/77	616	1162	Inadequate right-turning radius Left turns (1 percent) Right turns (14 percent)	54	98	88.3
Main Street at Jefferson Street	SE, inbound	6/1/77	543	711	Three-phase signal Separate left-turn lanes Left turns (6 percent) Right turns (7 percent)	83	103	152.9
Main Street at Jefferson Street	NW, outbound	6/1/77	569	716	Minor approaches offset Left turns (3 percent) Right turns (14 percent)	45	65	79.3
Harrodsburg Road at Larkspur Drive	NE, inbound	7/27/77	674	871	Stop sign on side street Separate left-turn lanes Left turns (17 percent) Right turns (0 percent)	32	52	47.1
Harrodsburg Road at Larkspur Drive	SW, outbound	7/27/77	595	985	Left turns (0 percent) Right turns (13 percent)	43	119	71.8

were collected for 11 continuous hours on each of 2 d from 7:30 a.m. until 6:30 p.m. at the intersection of Limestone Street and Virginia Avenue. Traffic volumes of each movement (through, left turns, and right turns) were taken on all approaches by one observer, while observers were stationed on each of the two major approaches.

Data were collected at the site on May 26 (Thursday) and June 7 (Tuesday), 1977, approximately 2 weeks apart. The intersection is located near the University of Kentucky, which is a strong traffic generator. The first count was scheduled to take place after the spring semester ended; the second count was conducted during the summer session. Thus, slightly higher volumes were expected on the second day, and variations in conflicts were expected to be about as high as would normally be expected from day to day at most intersections.

As expected, volumes on the inbound (northbound) approach increased by about 22 percent, from 6162 (day one) to 7514 (day two). The total number of conflicts increased from 566 to 695, a 23 percent increase. The conflict rate on this approach increased very slightly from 91.9 to 92.5 (conflicts per 1000 vehicles). Numbers of conflicts were generally higher during high-volume periods, as shown in Table 2. The highest volume (728) and number of conflicts (81) were observed between 7:30 and 8:30 a.m., the morning rush hour. All values in Table 2 are actual counts and include no adjustments.

Similar results were found on the outbound (southbound) approach. While traffic volume increased 16 percent, from 6258 to 7280, conflicts increased only 3 percent, from 586 to 604. The conflict rate was 93.6 on day one and 83.0 on day two. The highest number of hourly conflicts was 104 (4:30-5:30 p.m.) and 91 (3:30-4:30 p.m.) during afternoon peak hours. The highest hourly volumes also corresponded to these hours.

An analysis was also made to determine the variations in types of conflicts from one day to the next. The percentage of each major conflict type was calculated for each approach on each day. Rear-end conflicts were 57 and 46 percent for the 2 d on the inbound approach and 64 and 58 percent on the outbound approach. Most of these rear-end conflicts were due to traffic congestion and backups throughout most of the test period. Left-turn conflicts, 32 and 41 percent on the inbound approach, were caused by the absence of a separate left-turn lane and a high left-turn demand. On the outbound approach, the percentage of right-turn conflicts (vehicles slowing for right turners) stayed nearly constant. These conflicts were due to an inadequate right-turn radius that caused vehicles to slow drastically to complete the right-turn maneuver. Running the red and other conflicts did not change significantly on the second day.

The previous analysis was not intended to prove that conflicts repeat themselves from one day to the next at all locations. However, at this intersection, conflict numbers and types were very similar for the 2 d. Conflicts, like accidents, are produced by human reactions as well as environmental and traffic conditions. An analysis of this moderately high-volume intersection (average annual daily traffic of 24 000) was made as an initial attempt to gain a better understanding of conflict data. Similar analyses will be conducted in the future, particularly at low-volume rural intersections where greater fluctuations in conflicts are expected.

DEVELOPMENT OF A CONFLICTS PROCEDURE

The development of an effective and practical traffic conflicts procedure was sought for Kentucky. After careful review of several of the conflicts procedures in use in the United States and other countries, the GM technique was revised for use in Kentucky. Several modifications were made with respect to data-collecting procedures.

Data-Collecting Times

Using the GM technique, conflict data are normally collected for 10 h each day from 7:30 a.m. to 12:00 noon and from 12:45 p.m. to 6:15 p.m. at each site on a Tuesday, Wednesday, or Thursday. For low-volume sites, more than a day of data collection may be necessary for an adequate sample size. One observer usually records conflicts while another counts traffic volumes. After each 15 min of data collection, the following 15-min period is used to record data and to move to the opposite approach (1).

This procedure results in the use of about 20 work hours per day, excluding the lunch break (two people for 10 h each). A total of 2.5 h of data is then available for each of the two major approaches. Comparing the total work-hour requirements with the resulting quantity of data obtained from the GM technique, questions were raised as to the efficiency of this procedure. Such large allotments of time were thought to be impractical in Kentucky because of personnel limitations and the large number of locations that warrant conflict counts. Also, little or no useful information was generated from conflict counts during off-peak hours at the test sites. The adequacy of using only one 15-min conflict count to represent an hour of data also needed to be evaluated.

The GM procedure was evaluated from 11-h continuous conflict counts at nine intersection approaches. First, the 15-min count periods were removed from the data that would have been counted by the GM technique.

Table 2. Conflict reliability study.

	Inbound Approach				Outbound Approach			
	Day One		Day Two		Day One		Day Two	
Time Period	Conflicts	Volume	Conflicts	Volume	Conflicts	Volume	Conflicts	Volume
7:30-8:30 a.m.	81	728	94	1046	31	617	45	572
8:30-9:30 a.m.	49	437	38	643	48	352	46	441
9:30-10:30 a.m.	46	485	52	578	37	418	23	497
10:30-11:30 a.m.	33	577	39	566	43	519	38	480
11:30 a.m.-12:30 p.m.	26	652	77	697	71	653	63	857
12:30-1:30 p.m.	77	610	109	681	48	536	56	565
1:30-2:30 p.m.	53	475	75	661	45	444	42	607
2:30-3:30 p.m.	39	582	55	663	55	591	61	716
3:30-4:30 p.m.	60	586	63	757	91	766	91	801
4:30-5:30 p.m.	58	588	57	716	74	895	104	1162
5:30-6:30 p.m.	44	442	36	506	43	467	35	582
Total	566	6162	695	7514	586	6258	604	7280

On an inbound approach, this would correspond to 7:30-7:45 a.m., 8:30-8:45 a.m., 9:30-9:45 a.m., and so on. The outbound periods would be 8:00-8:15 a.m., 9:00-9:15 a.m., 10:00-10:15 a.m., and so on. Each 15-min conflict count was multiplied by four (to obtain an estimated hourly count) and compared to each actual hourly conflict count. A total of 121 h of data were used for this analysis.

The number and percentage of the total hours (y-axis) were plotted against the percentage of error (x-axis) in Figure 2 to summarize the results. The plot shows that an error of 10 percent or less was found in about one-third of the sample. The error is within 17 percent about half the time, and about 75 percent of the sample had an error of 32 percent or less. The difference between the total daily count (11 h) and the GM estimated count (four times the 15-min counts) ranged from 0.7 to 13.2 percent at the 11 intersection approaches. The average difference for all approaches was 4.6 percent.

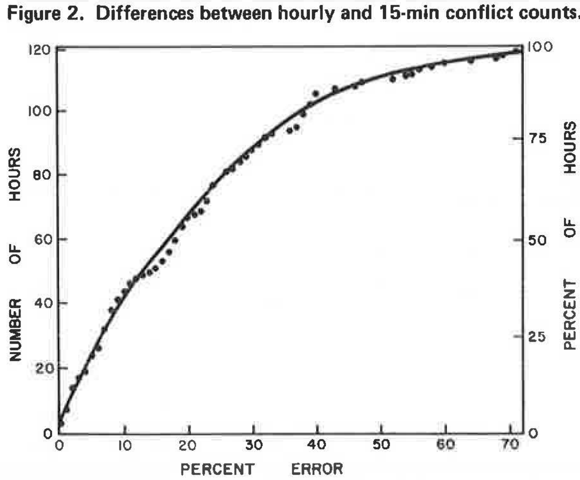
While the 15-min counts each hour proved to be reasonably close in most cases, the personnel required for each count was still a major concern. By plotting conflicts versus time of day, the highest conflict periods occurred during peak hours.

During the morning peak hour (7:30-8:30 a.m.), inbound approaches had their highest conflict numbers, while few conflicts occurred on outbound approaches. The opposite was true in the afternoon, when peak periods generally lasted from 3:30 to 5:30 p.m.

A comparison was made between the GM time periods and the three peak hours in terms of required work hours. If one observer counts conflicts on each approach and the third counts traffic volumes of all movements, only 9 work hours of observation would be required at each intersection. This would produce a total of 3 h of data. Data would represent one high-conflict hour, one low-conflict hour, and one intermediate hour for each approach. About 20 percent more minutes of data would be collected with less than half the work hours expended.

Collecting conflict data only during peak hours was found to be desirable, because off-peak hours were generally uneventful. Problems with left-turning vehicles, for example, are not usually detected until certain left-turn and opposing volumes exist. Care should be taken to avoid collecting more than 1 h of data during very congested times, when some traffic maneuvers are restricted. Data-collecting times should be when problems are suspected. These may correspond to the noon, evening, or weekend rush, or even during seasonal periods at some locations. Additional data may be needed at low-volume sites to obtain adequate samples.

Figure 2. Differences between hourly and 15-min conflict counts.



Conflict Categories

The GM conflict data sheet was revised for use in Kentucky. As currently used, there are 10 columns for counts of vehicle movements and 24 columns for counts of traffic conflicts (a total of 34 categories). Many of these columns were found to be unnecessary; they only create confusion for the observer. The cross-traffic conflicts usually pertain only to unsignalized intersections. Abrupt stops and running-the-red violations are not included on the GM conflict form. To identify left-turn problems, it is necessary in Kentucky to classify weaves, weave conflicts, running red lights, and previous conflicts.

The numbers and rates of each conflict type were summarized for 5700 conflicts observed at four signalized intersections (in the table below, conflicts per 1000 vehicles out of a total flow of 56 897).

Type of Conflict	No. of Conflicts	Conflict Rate
Congestion and traffic backup	3034	53.3
Slow for left turn	885	15.6
Slow for right turn	654	11.5
Brake for previous conflict	203	3.6
Other rear-end conflict	182	3.3
Weave conflict	172	3.0
Running red light	167	2.9
Brake for slow-moving vehicle	135	2.3
Abrupt stop	81	1.4
Opposing left turn	73	1.3
Pedestrian	50	0.9
Other conflicts and erratic maneuvers	125	2.2
Total	5761	101.3

Congestion and backup accounted for 3034 conflicts (52.6 percent), and slowing for left and right turns accounted for another 885 and 654 conflicts respectively (26 percent total). Other conflict numbers over 100 included previous conflicts (203), other rear ends (182), weave conflicts (172), running red lights (167), and braking for slow vehicles (135). Also, abrupt stops, opposing left turns, and pedestrian conflicts were 50 or more. The total conflict rate of the four intersections (all were high-accident sites) was 101.3 conflicts per 1000 vehicles.

Based on the occurrence of conflicts at the test sites, a simplified conflict data sheet was developed for signalized intersections (Figure 3). To aid in the evaluation of the left-turn problems, separate left-turn categories were included for weaves, weave conflicts, running red lights, and previous left turns. All observed conflicts should be classified as either routine, moderate, or severe. Twelve horizontal rows are provided to accommodate 3 h of 15-min counts. The form for unsignalized intersections excludes the running red lights and abrupt stopping categories. Additional categories include five types of cross-traffic conflicts as used in the GM method.

Although the conflict categories on the data sheets will account for about 98 percent of all events, there are various types of weaves, conflicts, and erratic maneuvers peculiar to certain locations. The list below was made up of all such occurrences observed at the test sites or foreseen for others.

Figure 3. Conflict data sheet for signalized intersections.

LOCATION__________ DIRECTION__________ DATE __________

STARTING TIME	WEAVES		WEAVE CONFLICTS		OPPOSING LEFT TURN	RUN RED LIGHT		ABRUPT STOP	SLOW FOR RIGHT TURN	SLOW FOR LEFT TURN	PREVIOUS LEFT TURN	OTHER PREVIOUS CONFLICT	TRAFFIC BACKUP OR CON-GESTION	SLOW-MOVING VEHICLE	PEDESTRIAN CONFLICT
	AROUND LEFT TURNER	OTHER	AROUND LEFT TURNER	OTHER		TURNING LEFT	STRAIGHT OR RIGHT								

Weaves

- A Weave for stopped truck
- B Weave for stalled vehicle
- C Weave for stopped bus
- D Weave for road maintenance or construction
- E Weave to avoid pedestrian
- F Weave into turn lane and back into major traffic flow

Conflicts

- G Conflict from erratic maneuver
- H Slow for turn out of driveway or shopping entrance
- I Slow for turn into driveway or shopping entrance
- J Driveway cross traffic from left
- K Driveway cross traffic from right
- L Slow for stopped bus
- M Slow for road maintenance or construction
- N Slow for stopped truck
- O Weave pedestrian conflict
- P Previous conflict from pedestrian (following car)
- Q Right turn on red without stop
- R Left-lane vehicle slow for right turner
- S Slow or stop for stalled vehicle

Erratic Maneuvers

- T Left turn from wrong lane
- U Right turn from wrong lane
- V U turn in road
- W Use of shoulder for turns
- X Right turner hitting curb
- Y Vehicles overrunning stop bar and backing up
- Z Vehicle backing from driveway across traffic lanes
- AA Turn into wrong lane (opposing lane)
- BB Stop in median
- CC Run off road
- DD Right turn on red without stopping
- EE Late-entry right turn (or nonuse of turn lane)
- FF Late-entry left turn (or nonuse of turn lane)
- GG Vehicle unexpectedly stopping in road
- HH Vehicle swerving across traffic lanes
- II Vehicle backing in road
- JJ Turn into turn lane and back into traffic flow
- KK Vehicle on wrong side of road
- LL Wide turn (encroaching into adjacent lane)
- MM Multiple vehicle erratic maneuver
- NN Multiple bicycle erratic maneuver
- OO Bicycle on wrong side of road
- PP Bicycle riding in median
- QQ Illegal pedestrian crossings

This list includes 6 causes of weaves, 13 unusual conflict types, and 24 types of erratic maneuvers. Each observer should have this sheet during a conflict count and be familiar with the categories. If one of these events occurs, a corresponding letter should be put on the data sheet. If the event is repeated several times, one of the extra columns can be designated to count such events.

Volume data should be collected by an observer during all conflict-counting periods if possible. Space is provided for counting left-turning, straight, and right-turning vehicles on all intersection approaches. Most counts will take three observers: one observer per approach and one volume counter.

EVALUATION OF SAFETY IMPROVEMENTS

Shortly after completion of safety improvements at an intersection, another traffic conflict count should be made to determine the effectiveness of the improvement. The second conflict count will often identify minor adjustments, such as signal timing, which would further add to the safety of the intersection. Several evaluations of safety improvements have been completed in Kentucky in recent years in terms of both accidents and conflicts.

In one study, conflict and accident evaluations were conducted at locations where left-turn signal phasing was added. There was an 81 percent reduction in left-turn conflicts (peak hours) at three intersections. An accident study of 24 intersections with similar improvements showed an 85 percent reduction in left-turn accidents after adding exclusive left-turn phases. Based on accident and conflict relationships at 32 intersections, criteria were developed for installation of left-turn phasing. An average of ten or more left-turn conflicts in the peak hour was the conflict criterion. The recommended accident criterion was four left-turn accidents per year on an approach or six accidents in 2 years (5).

Traffic conflicts were used to evaluate the effectiveness of a green-phase extension system (GES) in another Kentucky study in 1976 (6). GES merely extends green time for through vehicles up to about 152 m (500 ft) in advance of high-speed signalized intersections. This supposedly eliminates the "dilemma-zone," which occurs during the amber phase and causes rear-end and right-angle accidents (abrupt stops and running red lights). Six types of conflicts that occur during and shortly after the amber phase were counted at two intersections. Conflict data were taken for 1 d at US-23 and Hoods Creek Pike in Ashland and 2 d at US-27 and US-150 in Stanford for each of the before-and-after periods. These conflicts were reduced by 62 percent at the two intersections after installation of the GES. Total accidents were reduced by 54 percent at three locations with similar improvements (6).

A Kentucky study of erratic maneuvers completed in 1974 tested the effectiveness of various types of raised pavement markers for traffic control at freeway lane drops. Erratic maneuvers, brake applications, and lane volumes were counted at five lane-drop locations. After installation of raised pavement markers, a statistically significant decrease in the total erratic-maneuver rate occurred in nearly all cases, particularly at night. The total reduction in erratic-maneuver rate was 27 percent. No significant change in braking rates was found. The installation of raised pavement markers at other lane-drop locations was recommended based on cost effectiveness (7).

INTERSECTION ANALYSIS

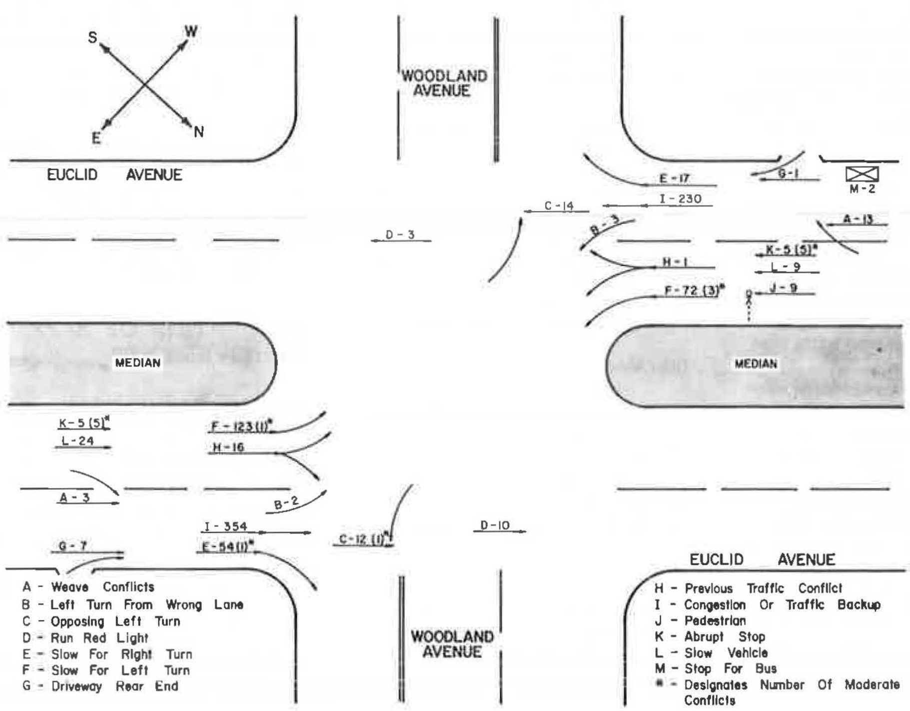
After a highway location is identified as hazardous in Kentucky, a careful analysis is made of the site. This consists of a thorough field investigation by a traffic engineer, a police officer, a local safety engineer, and sometimes other experts. A collision diagram also is used, as are data such as traffic volumes and speeds.

Because of the shortcomings in accident records mentioned earlier, collision diagrams may be of limited value in determining intersection deficiencies. To supplement collision diagrams, experiments have been done with conflict diagrams first used in Kentucky in September 1977. A conflict diagram shares many similarities with a collision diagram, and arrows are used to represent vehicle movements on each major approach. With a conflict diagram, only one set of arrows is used for each conflict type per approach, and the number of conflicts in a specified period is given.

An example of one such conflict diagram for Euclid Avenue at Woodland Avenue in Lexington, Kentucky, is given in Figure 4. The total number of conflicts is given with the number of moderate conflicts in parentheses. Erratic maneuvers and near misses may also be shown on a conflict diagram. As can be seen, the major conflict types (for an 11-h period) on the northwest approach are intersection backup and congestion (354), slowing for left turn (123), slowing for right turn (54), slow truck (24), and previous conflicts (16). Other types included opposing left-turn (12), running red light (10), driveway conflicts (7), abrupt stops (5), weave conflicts (3), and turns from wrong lane (2). The southeast approach had similar problems and also had several pedestrian conflicts and stop-for-bus conflicts (8).

Based on this conflict diagram, recommendations were made to add dual left-turn lanes on Euclid Avenue to reduce conflicts from vehicles slowing or weaving for left turners. Adjustments in signal timing were also recommended. The high incidence of backup and congestion conflicts was found to be unavoidable because of

Figure 4. Typical conflict diagram.



moderately high traffic volumes, but it was not abnormally high compared to other signalized intersections.

Another aid to intersection analysis is the use of conflict rates. The hourly conflicts, peak-hour conflicts, and conflict rates are given in Table 1 for all approaches. The highest hourly conflicts (83) and conflict rate (152.9 conflicts per 1000 vehicles) were found on the southeast approach of Main Street at Jefferson Street. Based on all available conflict data, specific problems were found on this approach, and appropriate safety improvements were recommended.

RECOMMENDATIONS

Based on the successful use of conflict and erratic maneuver data in Kentucky since 1972, increased use should be made of such data on a routine basis. A procedure for collecting and analyzing conflict data was developed and is recommended. Since 1970, a total of 904 locations have been investigated under Kentucky's spot-improvement program (about 130 per year). By routinely conducting conflict counts during such investigations, a large sample of conflict data would be available within a few years. This would provide the engineer with a systematic procedure for observing the location, and a permanent record of driver confusion and error could be generated and compared with problems at other locations. Valuable information on which to base appropriate safety improvements at the site would be obtained, and an after study of conflicts would allow for an evaluation of the improvements.

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Discussion

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Traffic conflict studies were performed in an attempt to determine the extent of accidents caused by the "dilemma zone" problem at high-speed, isolated, signalized intersections. The studies were made during the summer of 1977 as part of a master's degree research project.

The conflict studies were based on similar studies performed in Kentucky in 1976 that evaluated the effectiveness of green-extension systems in reducing the dilemma-zone problem. The seven categories of conflicts used were identical to those used by Kentucky except for the division of running red light into two categories based on the offending vehicle's relation to the stop line.

Five high-speed, isolated, signalized intersections having potential dilemma-zone problems were chosen for study on the recommendation of the Fulton County, Georgia, traffic engineer. All five intersections had similar approach characteristics. One intersection was operated in the semiactuated mode, with no detectors on the high-speed approaches; the other four intersections were fully actuated, but with detector setbacks far below those recommended for high-speed approaches.

Traffic conflicts for each approach were tabulated for two full hours of high traffic volume. Offending vehicles were classed by type. Volumes taken during the conflict studies were also divided into the three vehicle classes. Only non-turning vehicles were observed in the study.

Seventeen months of accident data, for the period just prior to the study, were obtained from police accident files. An attempt was made to identify the accidents caused by the dilemma-zone problem. In general, rear-end accidents, right-angle accidents caused by a high-speed vehicle running the red light, and sideswipe accidents caused by improper lane changes were classed as dilemma-zone accidents. Additional information concerning accident cause was usually not available. In addition, it is probable that not all accidents were reported, as noted in the Zegeer and Deen paper.

A comparison of the dilemma-zone accident and conflict rates showed no correlation ($r = 0.16$) (see Figure 5). Similar results were obtained when the total accident rate was compared to the conflict rate. This can point to two different conclusions, either that the accident data are unreliable or that conflict studies cannot be used to predict high dilemma-zone accident locations.

However, the usefulness of the dilemma-zone conflict study performed may be shown by two additional comparisons.

The clearance intervals required for each of the 10 approaches were calculated with the method described in the Traffic and Transportation Engineering Handbook. A deceleration rate of 2.7 m/s^2 (9 ft/s^2) was used instead of the suggested 4.6 m/s^2 (15 ft/s^2), the latter being obtainable only as a panic stop on dry pavement. The ratio of actual clearance-period timing (yellow plus all red) to required timing was compared to the dilemma zone conflict rate, and resulted in a good correlation ($r = 0.83$). The running-red-light conflict rate did not appear to be related to clearance timing. Figure 6 shows the "scattergram" and least squares analysis line for the first comparison.

By classifying the seven conflict categories into two types, in which the offending vehicle either stopped or continued on through the intersection, another comparison can be made. A regression analysis, resulting in an r-value of 0.74, shows that the ratio of nonstopping conflicts to total conflicts increases with an increase in approach volume. This agrees with the expectation that drivers are hesitant to stop quickly in heavy traffic. Figure 7 shows the results of this regression analysis.

Therefore, the conflict data taken during this study tend to agree with expected occurrences within the di-

Figure 5. Dilemma-zone accident rate versus conflict rate.

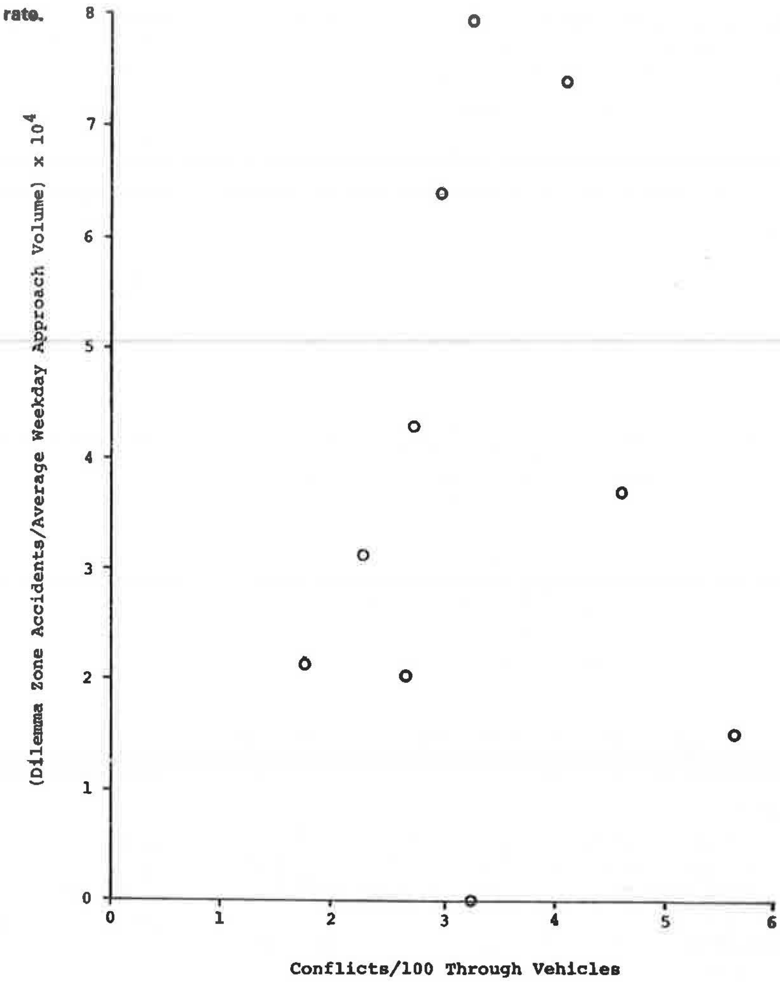


Figure 6. Conflict rate versus percentage of required clearance time.

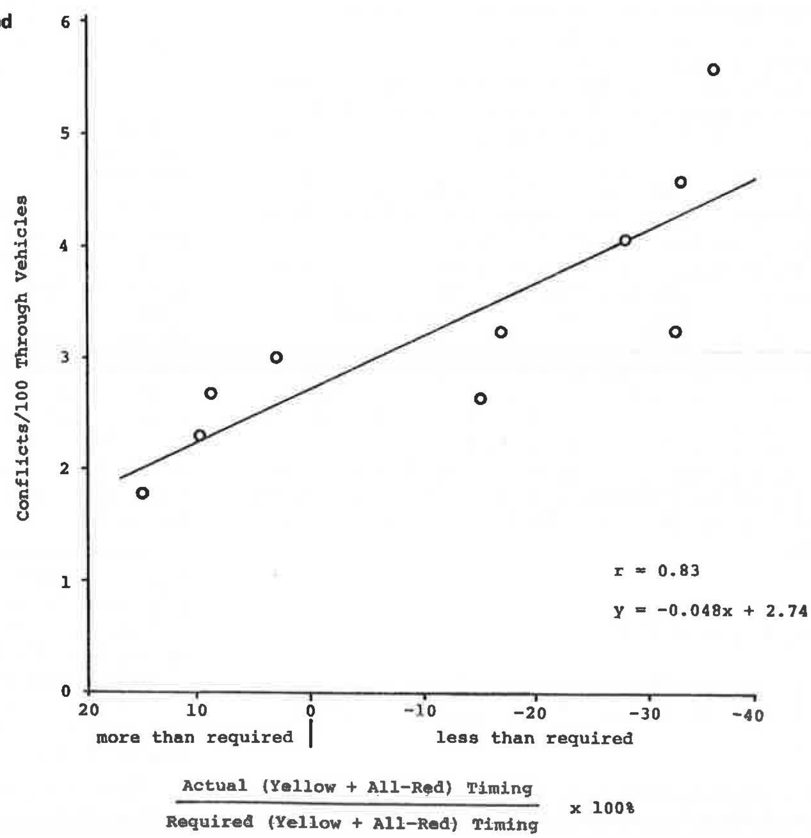
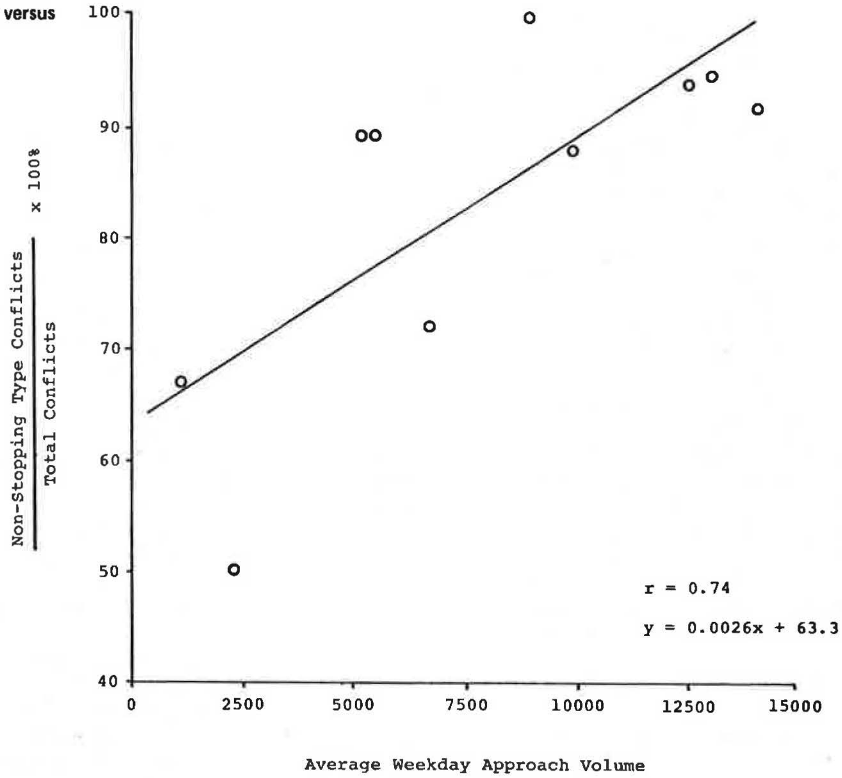


Figure 7. Percentage of nonstopping conflicts versus approach volume.



lemma zone and reinforce the usefulness of the study method.

Since no studies were made at a location where the dilemma zone was known not to be a contributor to the accident history, a comparison was not available. However, it appears that the traffic conflict study is of value in evaluating the timing of clearance intervals and stopping behavior in heavy traffic.

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Design Considerations of Traffic Conflict Surveys

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The traffic conflicts technique is a device for measuring safety indirectly. It requires, at present, a field count of conflict occurrences, which gives the basis on which the rate at which conflicts occur is estimated. This report deals with the accuracy of such estimating and its dependence on the design of the field survey. Current practices in conflict-count duration are reviewed, and the relationship between count duration and estimation accuracy is examined. Using data from several sources, the daily variability of conflict counts is described. It is concluded that the expected conflict rate varies from day to day. Use of negative binomial distribution is suggested as appropriate for representing the distribution of sample means obtained from conflict studies. On this basis, confidence limits and probabilities of type I and type II errors in hypothesis testing are obtained and tabulated. Their use in study design is illustrated by numerical examples. The marginal increase in estimation accuracy diminishes rapidly as conflict-counting time increases. Thus, there is little to be gained by counting longer than 3 d. This establishes a practical limit to the accuracy with which expected daily conflict rates can be estimated.

The traffic conflicts technique is a device for indirectly measuring safety. Its early history may be traced (1, 2, 3, 4), and its recent applications have been described (5, 6, 7, 8, 9). There are also state-of-the-art surveys now available (9, 10, 11).

The traffic conflicts technique is applicable to a variety of situations. It can be used to assess changes in safety through before-and-after studies and by comparison with control sites; to investigate effectiveness of devices, layouts, design, and procedures; and to identify and diagnose hazards.

All such uses require a field study to observe and count the occurrences of conflicts and thus estimate their occurrence rate. The purpose of this paper is to