

Research Report
482

**TRAFFIC CONFLICTS AS A DIAGNOSTIC
TOOL IN HIGHWAY SAFETY**

by
Charles V. Zegeer
Research Engineer Senior

and
Robert C. Deen
Assistant Director

Division of Research
Bureau of Highways
DEPARTMENT OF TRANSPORTATION
Commonwealth of Kentucky

offered for publication to the
Transportation Research Board

November 1977

**TRAFFIC CONFLICTS AS A DIAGNOSTIC
TOOL IN HIGHWAY SAFETY**

by

C. V. Zegeer and R. C. Deen

ABSTRACT

Because of the shortcomings in accident data, such as incomplete reporting and inaccurate information on accident reports, a need was found for indicators of accident potential. Nearly half of the 209 locations identified in Kentucky as hazardous by accident criteria were found to be falsely identified due to random accident occurrences. Accident repeatability from one year to the next was found to be poor at 60 intersections ($r = 0.64$) and 170 spot locations ($r = 0.59$). Up to two years of accident data were found to be necessary to obtain a reliable base of accident data.

Conflict counts were conducted at five 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. Conflict numbers, types, and rates were found to be very repeatable at one intersection. A revised procedure for collecting data in Kentucky, which increased the sample size and reduced the required manpower, was described. Modified data sheets were also developed for signalized and unsignalized intersections.

Results from evaluations of safety improvements in Kentucky using conflicts, erratic maneuvers, and accidents were summarized. Reductions in accidents (85 percent) and conflicts (81 percent) were found at intersections where left-turn signal phasing was added. Installation of green-phase extension resulted in conflict and accident reductions of 62 and 54 percent, respectively, at several high-speed intersections. Erratic maneuvers were reduced by 27 percent after installing raised pavement markers at five freeway lane-drop locations. Procedures for intersection analysis using conflict diagrams were described. Conflict counts were recommended during routine inspections of suspected hazardous locations.

INTRODUCTION

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 accident data because of limitations found in accident records. The Kentucky Department of Transportation has utilized 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 to be 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 causation.

Crude forms of traffic conflict counts have been made since traffic engineers first began making field observations to determine appropriate safety improvements. 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. An erratic maneuver is any sudden, unexpected movement by a vehicle which could result in an accident. The usage of the term erratic maneuver differs from a conflict in that an erratic maneuver usually involves only one vehicle which commits an unsafe movement independently of other vehicles. An erratic maneuver may often result in a conflict if another vehicle is forced to brake or weave to avoid the erratic maneuver. 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 occurs when a collision between two or more vehicles is barely avoided due to a last-second movement or stop. A near-miss accident is a very severe case of a conflict or erratic maneuver, and relatively few near-miss accidents may normally be observed at any location as compared to conflicts or erratic maneuvers.

Traffic occurrences or events may be considered 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 traffic conflict counts.

THE NEED FOR CONFLICT DATA

Several limitations have been observed in the use of accident data alone in traffic safety studies. Accident files contain records of reported accidents only, which is only a fraction of accidents which occur. The criteria for accident reporting vary considerably between 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 which occur in accident data. Many accidents result from a vehicle malfunction (tire blowout or brake failure), obvious driver error (speeding or drunk driving) or a weather-related problem (ice on road or heavy fog) which is not related to any geometric deficiency. A study was completed in 1973 in Kentucky which illustrated the effect of random accidents on the identification of hazardous sites. Of 208 spot locations which were identified by accident data as hazardous, 99 of them were identified falsely 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 of the locations identified by accidents did not warrant any 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 was compared with the number of accidents the following year, resulting in a correlation coefficient (r-value) of only

0.64. The 95-percent confidence band (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 comparing accident numbers from one year to the next. A similar analysis was also made for 170 rural, 0.3-mile (480-m) spots in Kentucky, and an r of only 0.59 was found. More than a 100-percent error was also found for this sample of locations (within 95-percent confidence level), illustrating the non-repeatability 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 two years of accident data are necessary to insure reliability when selecting high-accident locations (4). After an improvement is made, several more years of waiting is often necessary 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 alone has many limitations, it 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 taken at the sites as well as 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 (1) determine consistency of conflict counts between observers, (2) evaluate volume-conflict relationships, and (3) test daily repeatability of conflicts.

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

Conflicts were counted on the two major approaches at four intersections and one approach at the other using one observer for each approach stationed from 100 to 300 feet (30 to 90 m) back from the intersection. Observers were stationed in state-owned cars wherever possible. Chairs were used on sidewalks at urban locations which 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-minute periods on the GM data sheets. Several new categories of conflicts and erratic maneuvers were added, depending on the specific problems at a site. Each conflict was also classified as routine, moderate, or severe.

All five intersections are located in and around Lexington, Kentucky (population of 200,000), and data were collected in the spring of 1977. A summary of volume, speed, geometric, and conflict information of each intersection approach is given in Table 1. All approaches are two lanes of four-lane arterials, and minor streets are all two-lane collector streets. Each is 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 utilizing conflict data is the reliability of data collected by observers. There are many factors which will account for variation in conflict counts including 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 taking conflict data alone. Typically, one or more experienced observers train an inexperienced observer at a site by discussing all conflicts and weaves as they occur. Periodic checks between observers are made to help insure 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 and two observers simultaneously counted conflicts and weaves in 15-minute intervals using the General Motors technique. A plot was made of conflicts per 15-minute period for one observer versus those of another, and the overall r-value was 0.86. Numbers of conflicts per 15-minute period ranged from 5 to 36, depending primarily on traffic volume. A similar plot of weaves resulted in a r-value of 0.93, and numbers of weaves varied from 0 to 24 per 15 minutes. 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 minutes 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. Re-evaluation of observers is made periodically, so observer reliability is expected to improve.

Volume-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

considering each 15-minute period as one data point. A total of 44 points were plotted for each intersection approach (11 hours 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 the average r^2 -value of all approaches, only 37 percent of the variance in conflicts can be explained by traffic volumes.

Volume-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 (two weeks later). The difference was greater on the other approach where the r -values were 0.42 and 0.73 for the two days.

Another plot was made of conflicts per hour versus hourly volume for all approaches (11 data points). Conflicts per hour ranged from 32 to 83 and 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-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, 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 result in the need for several days of data collection at each site to insure reliable data. To obtain information concerning the day-to-day repeatability of conflicts, conflict data were collected for 11 continuous hours on each of two days 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 two weeks apart. The intersection is located adjacent to the University of Kentucky which is a high traffic generator. The first count was scheduled to take place after the spring semester ended, and the second count was conducted during the summer school 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 6,162 (Day 1) to 7,514 (Day 2). 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 1,000 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., which corresponds to 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. Traffic volume increased by 16 percent from 6,258 to 7,280. Conflicts increased only 3 percent from 586 to 604. The conflict rate was 93.6 on Day 1 and 83.0 on Day 2. The highest number of hourly conflicts was 104 (4:30 to 5:30 p.m.) and 91 (3:30 to 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 two days 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 accounted for 32 and 41 percent on the inbound approach due to 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-turning radius which caused vehicles to slow drastically to complete the right-turn maneuver. Run-red-light 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 two days. Conflicts, like accidents, are subject to human reactions as well as environmental and traffic conditions. An analysis of this moderately high-volume intersection (AADT = 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 a traffic conflicts procedure which would be both effective and practical was desired for Kentucky. After careful review of several of the conflicts procedures in use in the United States and other countries, the General Motors technique was revised for use in Kentucky. Several

modifications were made with respect to data collection procedures.

Data Collection Times

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

This procedure results in the use of about 20 man-hours of work per day, excluding the lunch break (two men for 10 hours each). A total of 2.5 hours of data is then available for each of the two major approaches. Comparing the total man-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 due to manpower limitations and the large number of locations which 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-minute conflict count to represent an hour of data also needed to be evaluated.

Using 11-hour continuous conflict counts at nine intersection approaches, the GM procedure for collecting conflict data was evaluated. First, the 15-minute count periods were picked out of the data which would have been counted by the GM technique. On an inbound approach, this would correspond to 7:30 to 7:45 a.m., 8:30 to 8:45 a.m., 9:30 to 9:45 a.m., etc. The outbound periods would be 8:00 to 8:15 a.m., 9:00 to 9:15 a.m., 10:00 to 10:15 a.m., etc. Each 15-minute conflict count was multiplied by 4 (to obtain an estimated hourly count) and compared to each actual hourly conflict count. A total of 121 hours of data were used for this analysis.

The number and percent of the total hours (y-axis) were plotted against the percent 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 hours) and the GM estimated count (4 times the 15-minute counts) ranged from 0.7 percent to 13.2 percent at the 11 intersection approaches. The average difference for all approaches was 4.6 percent.

While the 15-minute counts each hour proved to be reasonably close in most cases, the manpower required for each count was still a major concern. By plotting conflicts versus time of day, the highest conflict periods occurred during peak-volume hours. During the morning peak hour (7:30 to 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 man-hours. If one observer counts conflicts on each approach and the third counts traffic volumes of all movements, only 9 man-hours of observation would be required at each intersection. This would produce a total of 3 hours 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 man-hours expended.

The collection of 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 one hour of data during very congested times when some traffic maneuvers are restricted. Times should be selected for data collection when problems are suspected. These may correspond to the noontime rush, nighttime, weekend, or even during seasonal periods at some locations. Additional data may be needed at low-volume sites to obtain adequate samples.

Conflict Categories

The GM conflict data sheet was revised for use in Kentucky. As currently used, there are ten 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 and only create confusion for the observer. The cross-traffic conflicts usually pertain only to non-signalized intersections. Abrupt stops and run-red-light violations are not included on the GM conflict form. To identify left-turn problems, it is necessary in Kentucky to classify weaves, weave conflicts, run red lights, and previous conflicts as eight left-turn or other.

The numbers and rates of each conflict type were summarized for over 5,700 conflicts observed at four signalized intersections (Table 3). Congestion and backup accounted for 3,034 conflicts (52.6 percent), and slow 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 (182), run red light (167), and brake for slow vehicle (135). Also, abrupt stops, opposing left turns, and pedestrian conflicts had 50 or more. The total conflict rate of the four intersections (all were high-accident sites) was 101.3 conflicts per 1,000 vehicles.

Based on the occurrence of conflicts at the test sites, a simplified conflicts 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, run 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 three hours of 15-minute counts. The form for nonsignalized intersections excludes run-red light and abrupt-stop 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 which are peculiar to certain locations. A listing was made of all such occurrences which were observed at the test sites or foreseen for others as shown in Table 4. This listing includes 5 causes of weaves, 13 unusual conflict types, and 26 types of erratic maneuvers. These were labeled from A to Z and AA to SS. Each observer should have this sheet during a conflict count and be familiar with the categories. If one of these events occurs, the 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-count 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 after conflict count will often identify minor adjustments, such as with 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-conflict relationships at 32 intersections, warrants 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 criteria was four left-turn accidents per year on an approach or six accidents in two 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 500 feet (152 m) in advance of high-speed signalized intersections. This supposedly eliminates the "dilemma-zone" which occurs during the amber signal phase and which causes rear-end and right-angle accidents (due to abrupt stops and running red lights). Six types of conflicts which occur during and shortly after the amber phase were counted at two intersections. Conflict data were taken for one day at US 23 and Hoods Creek Pike in Ashland and two days 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 utilizing erratic maneuvers was completed in 1974 to test the effectiveness of various types of raised pavement markers for traffic control at freeway lane drops. Counts of erratic maneuvers, brakelight applications, and lane volumes were taken 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 brakelight rates was found. The installation of raised pavement markers at other lane-drop locations was recommended based on their 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, police officer, local safety engineer, and sometimes other experts. A collision diagram also is used as well as data such as traffic volumes, speeds, and other factors.

Because of the shortcomings in accident records mentioned earlier, collision diagrams may be of limited value in determining intersection deficiencies. To supplement collision diagrams, experimentation has been made with conflict diagrams first used in Kentucky in September 1977. A conflict diagram has many similarities to 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 parenthesis. Erratic maneuvers and near misses may also be shown on a conflict diagram. As can be seen, the major conflict types (for an 11-hour period) on the northwest approach are intersection backup and congestion (354), slow for left turn (123), slow for right turn (54), slow truck (24), and

previous conflicts (16). Other types included opposing left-turn (12), run 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 due to 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 due to moderately high traffic volumes but 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 1,000 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 collection and analysis of conflict data was developed and is recommended for implementation. Since 1970, a total of 904 spots 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 upon 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.

REFERENCES

1. Perkins, S. R.; and Harris, J. I.; *Traffic Conflict Characteristics-Accident Potential at Intersections*, General Motors Research Publication GMR-718, December 7, 1967.
2. *Digest of Motor Laws*, American Automobile Association, 1974.
3. Agent, K. R.; *Evaluation of the High-Accident Location Spot-Improvement Program in Kentucky*,

Kentucky Bureau of Highways, Division of Research, February 1973.

4. Zegeer, C. V.; *Identification of Hazardous Locations on Rural Highways in Kentucky*, Kentucky Bureau of Highways, Division of Research, June 1974.
5. Agent, K. R.; *Development of Warrants for Left-Turn Phasing*, Kentucky Bureau of Highways, Division of Research, August 1976.
6. Zegeer, C. V.; *Effectiveness of Green-Extension Systems at High-Speed Intersections*, Kentucky Bureau of Highways, Division of Research, May 1977.
7. Pigman, J. G.; and Agent, K. R.; *Raised Pavement Markers as a Traffic Conflict Measure at Lane Drops*, Kentucky Bureau of Highways, Division of Research, February 1974.
8. Clayton, M. E.; *Evaluation of Urban Intersections Using Traffic Conflicts Measures*, Kentucky Bureau of Highways, Division of Research, August 1977.

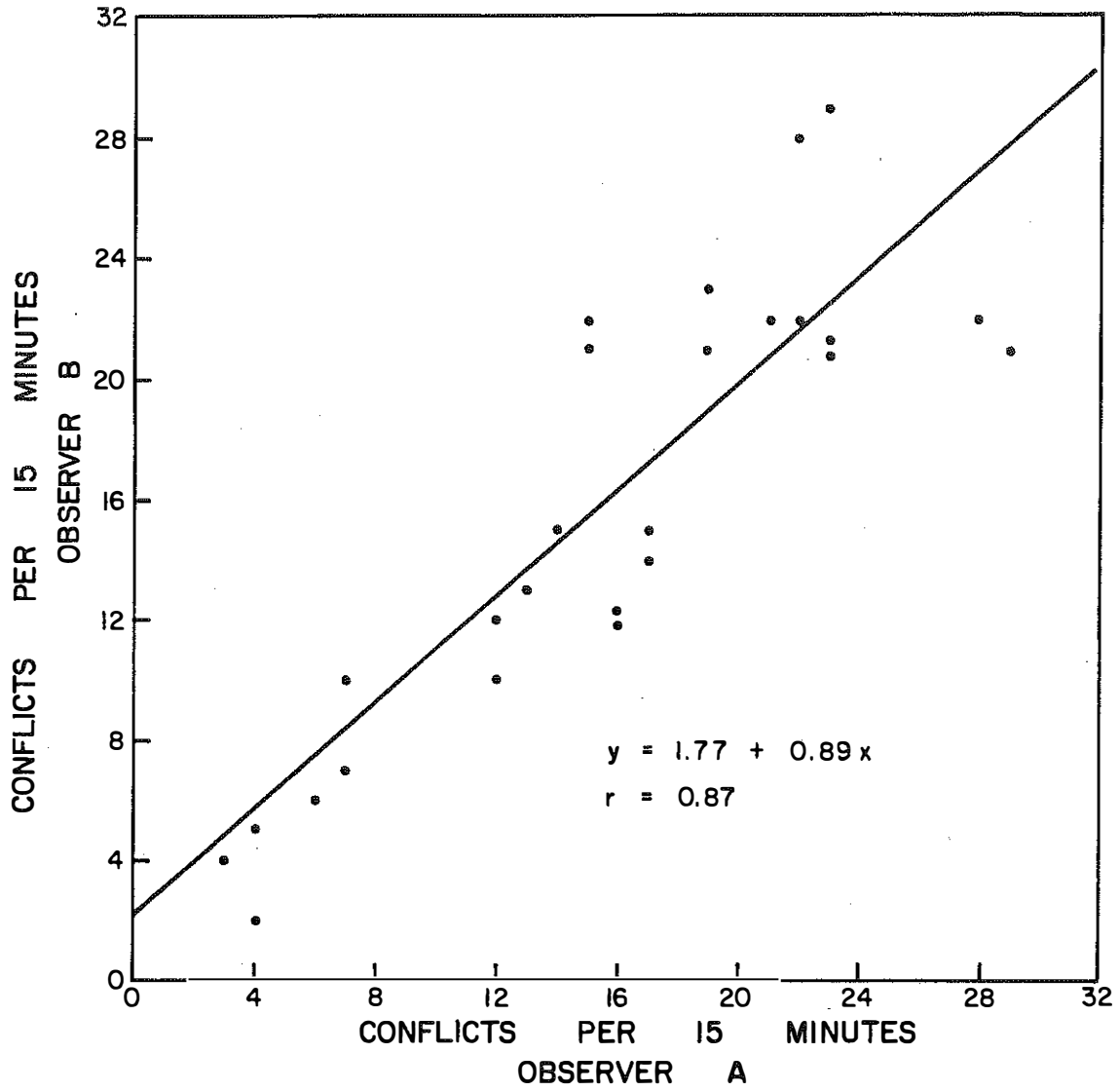


Figure 1. Conflict Counts per 15-Minute Period for Two Observers.

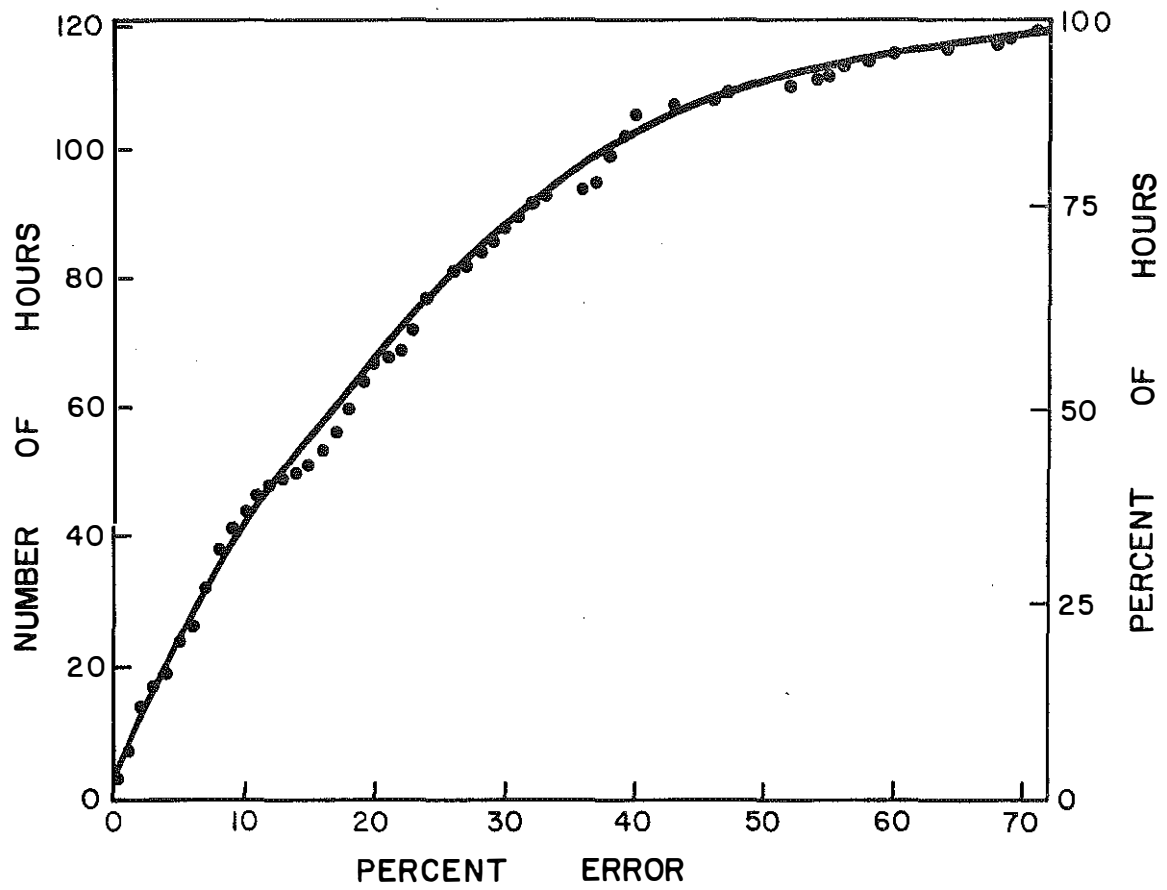


Figure 2. Differences between Hourly and 15-Minute Conflict Counts.

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 CONGESTION	SLOW-MOVING VEHICLE	PEDESTRIAN CONFLICT	
	AROUND LEFT TURNER	OTHER	AROUND LEFT TURNER	OTHER		TURNING LEFT	STRAIGHT OR RIGHT									

Figure 3. Conflict Data Sheet for Signalized Intersections.

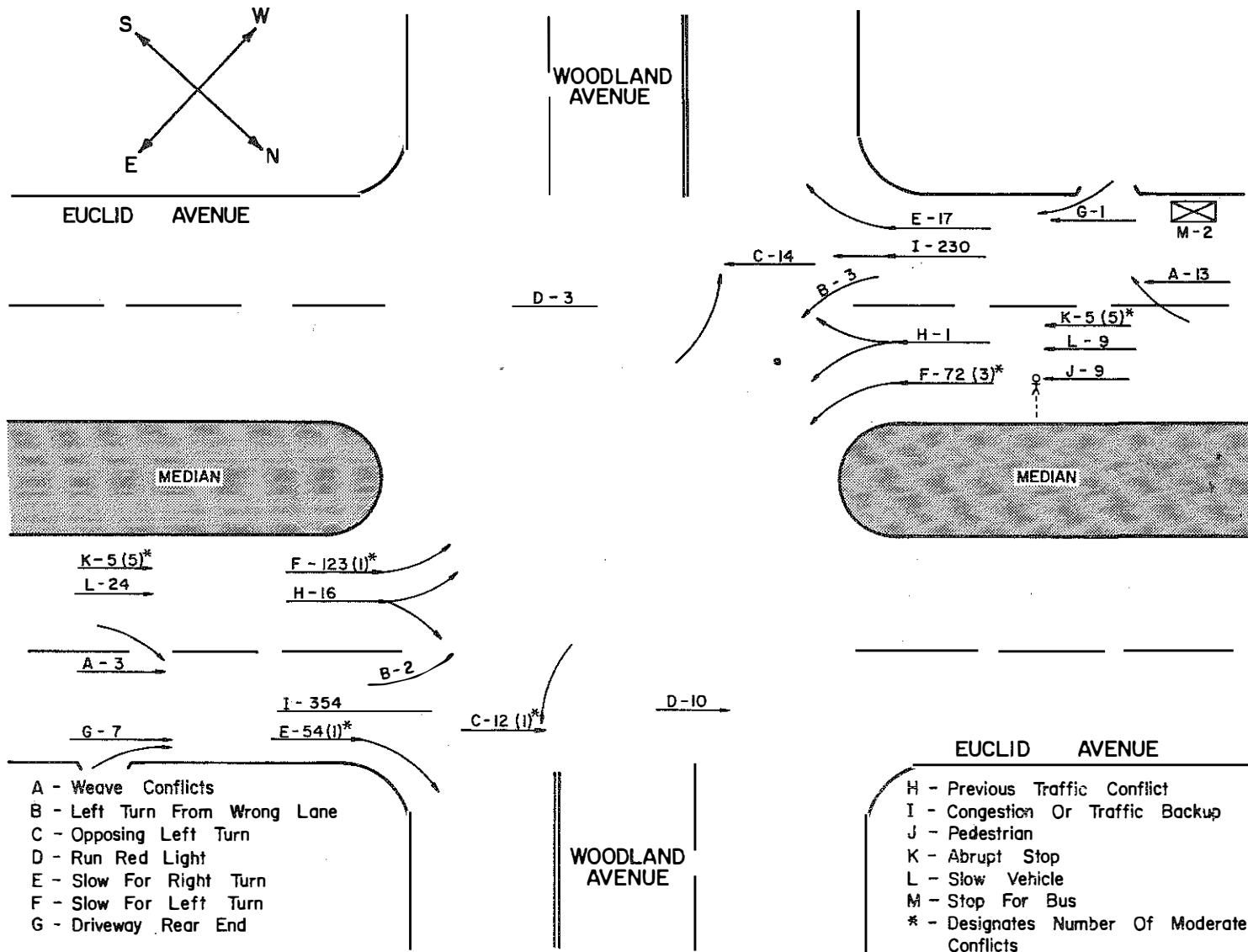


Figure 4. A Typical Conflict Diagram.

TABLE 1. CHARACTERISTICS AND CONFLICT SUMMARIES OF TEST SITES

INTERSECTION	DIRECTION OF APPROACH	DATE OF COUNT	VOLUME		OTHER CHARACTERISTICS	CONFLICTS PER HOUR	PEAK-HOUR CONFLICTS	CONFLICT RATE**
			AVERAGE HOURLY	PEAK HOUR				
New Circle Road at Woodhill Drive	S	5-10-77	908	1,375	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 (IB)*	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 (OB)	5-18-77	294	530	4-foot (1.2-m) Median Left Turns - 10 Percent Right Turns - 6 Percent	33	81	111.6
Limestone Street at Virginia Avenue	N (IB)	5-26-77 6-7-77	620	1,046	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 (OB)	5-26-77 6-7-77	616	1,162	Inadequate Right-turning Radius Left Turns - 1 Percent Right Turns - 14 Percent	54	98	88.3
Main Street at Jefferson Street	SE (IB)	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 (OB)	6-1-77	569	716	Minor Approaches are Offset Left Turns - 3 Percent Right Turns - 14 Percent	45	65	79.3
Harrodsburg Road at Larkspur Drive	NE (IB)	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 (OB)	7-27-77	595	985	Left Turns - 0 Percent Right Turns - 13 Percent	43	119	71.8

*Signifies Inbound or Outbound

**Conflicts per 1,000 Vehicles

TABLE 2. CONFLICT RELIABILITY STUDY

TIME PERIOD	INBOUND APPROACH				OUTBOUND APPROACH			
	DAY 1		DAY 2		DAY 1		DAY 2	
	CONFLICTS	VOLUME	CONFLICTS	VOLUME	CONFLICTS	VOLUME	CONFLICTS	VOLUME
7:30 to 8:30 a.m.	81	728	94	1,046	31	617	45	572
8:30 to 9:30 a.m.	49	437	38	643	48	352	46	441
9:30 to 10:30 a.m.	46	485	52	578	37	418	23	497
10:30 to 11:30 a.m.	33	577	39	566	43	519	38	480
11:30 a.m. to 12:30 p.m.	26	652	77	697	71	653	63	857
12:30 to 1:30 p.m.	77	610	109	681	48	536	56	565
1:30 to 2:30 p.m.	53	475	75	661	45	444	42	607
2:30 to 3:30 p.m.	39	582	55	663	55	591	61	716
3:30 to 4:30 p.m.	60	586	63	757	91	766	91	801
4:30 to 5:30 p.m.	58	588	57	716	74	895	104	1,162
5:30 to 6:30 p.m.	44	442	36	506	43	467	35	582
TOTALS	566	6,162	695	7,514	586	6,258	604	7,280

TABLE 3. CONFLICT TYPES AT SIGNALIZED INTERSECTIONS

TYPE OF CONFLICT	NUMBER OF CONFLICTS	CONFLICT RATE*
Congestion and Traffic Backup	3,034	53.3
Slow for Left Turn	885	15.6
Slow for Right Turn	654	11.5
Brakelight due to Previous Conflict	203	3.6
Other Rear-end Conflict	182	3.3
Weave Conflict	172	3.0
Run 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
Totals	5,761	101.3

*Conflicts per 1,000 vehicles (based on a total volume of 56,897 during test periods on major approaches).

TABLE 4. OTHER TRAFFIC EVENTS

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 due to 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 due to 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 non-use of turn lane)
FF	Late-entry left turn (or non-use of turn lane)
GG	Vehicle unexpectedly stopped in road
HH	Vehicle swerve 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
