Traffic Conflicts, Erratic Maneuvers, and Near-Miss Accidents: State-of-the-Art

Charles V. Zegeer
Kentucky Department of Transportation
MEMORANDUM TO: G. F. Kemper  
State Highway Engineer  
Chairman, Research Committee

SUBJECT: Research Report 484; "Traffic Conflicts, Erratic Maneuvers, and Near-Miss Accidents: State-of-the Art;" KYP-76-81; HPR-PL-1(13); Part III B.

"Traffic conflicts and erratic maneuvers offer the best possibilities of identifying hazardous sites and in treating them in an analytical or diagnostic manner in the absence of accident histories and fatality-type statistics." This profundity served recently to introduce Report 476 ("Evaluation of Urban Intersections Using Traffic Conflicts Measures"). The concept of traffic conflicts is attributed to Perkins and Harris, in 1967 (General Motors); but emerged here from three studies which were completed in 1972. Those reports were No. 326 ("An Operational Analysis of the I 64, I 65, I 71 Route Junction in Louisville"), No. 327 ("Traffic Controls for Maintenance on High Speed Highways"), and No. 332 ("Operational Characteristics of Lane Drops"). It became necessary then to distinguish between "erratic maneuvers" and "conflicts." The first indicator of a conflict was brakelight actuation. Interest mounted, and we established a study (KYP-76-81, "Evaluation and Application of Traffic Conflicts Techniques") in 1976. Later, the Division of Traffic sponsored a special training course on "conflicts" (March 16-17, 1977) for Department personnel. In the meantime Traffic requested us to develop a procedures manual for the immediate implementation of standard techniques. We proceeded to survey the state-of-the-art -- which is the substance of the report being submitted herewith. A draft of the manual is in the Traffic Division for review, and the issuance of that volume will ensue in due time.

Respectfully submitted,

Jas. H. Havens  
Director of Research

gd
Enc.
cc's: Research Committee  
John Crossfield, Jon Clark
Traffic Conflicts, Erratic Maneuvers, and Near-Miss Accidents: State-of-the-Art

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Study Title: Evaluation and Application of Traffic Conflict Techniques

Definitions are given for the various types of traffic conflicts, erratic maneuvers, and near-miss accidents. The General Motors technique for observation of traffic conflicts is summarized. Procedures used by several highway agencies for collecting conflict data are also detailed. Criteria which have been used to identify hazardous intersections using traffic conflict data are summarized. Methods and examples of evaluating safety improvements are detailed. Relationships between conflicts and accidents found by others were given.

The procedure for observing traffic conflicts on freeway ramps is described. Definitions are given for erratic maneuvers at lane drops, gore areas, and intersections. Results from studies which utilized counts of erratic vehicle maneuvers are mentioned. The concept of near-miss accidents and the time-to-accident concept, as currently used, are explained. Advantages and limitations are given for the use of conflicts, erratic maneuvers, and near-miss accidents in identifying hazardous sites and evaluating safety improvements.
TRAFFIC CONFLICTS, ERRATIC MANEUVERS, AND NEAR-MISS ACCIDENTS: STATE-OF-THE-ART

KYP-76-81; HPR-PL-1(13), Part III B

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The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Bureau of Highways. This report does not constitute a standard, specification, or regulation.

November 1977
INTRODUCTION

Traffic conflicts are measures of accident potential and operational problems at a highway location. A conflict occurs when a driver violates a rule of the road or makes an aggressive movement. Conflict studies may be treated in terms of objective criteria. Significant data may be obtained in as little as one day of observation. Operational problems found in this way may be resolved before accidents occur.

Conflicts may also be used to quickly evaluate some changes in road design, signing, signalization, and environment. After a location is identified as hazardous, a study of conflict patterns together with accident diagrams give a better understanding of operational deficiencies and accident causation.

Many highway agencies are now using observations of traffic conflicts to complement accident data. Accident records in many cases are incomplete and inaccurate, and several years of data are needed for a reliable sample. Also, accident diagrams do not always give the whole picture of operational problems at a site; and, therefore, the most appropriate highway improvement may be overlooked.

Formalized conflict techniques give an objective measure of traffic problems and a permanent record of their comparative magnitudes. The use of traffic conflict techniques has, to date, been primarily limited to intersections. However, conflict-type analyses for other locations are under development.

The most serious type of conflict is an erratic maneuver, which is any sudden, unexpected movement that may result in an accident. Erratic maneuvers have been used in the evaluation of gore areas and in locating accident-prone locations.

A near-miss accident occurs when a collision between two or more vehicles is avoided due to a last-second evasive movement or stop. A very severe conflict or erratic maneuver is considered to be a near-miss accident. Near-miss accidents occur infrequently in comparison to other conflicts. Great reliance on the subjectivity of observers is essential in classifying near-miss accidents.

The ordering of traffic descriptors at a site in terms of intensity is as follows:
1. traffic volume,
2. minor conflicts,
3. moderate conflicts and erratic maneuvers,
4. severe conflicts or near-misses,
5. minor collisions (usually not reported),
6. property damage accidents,
7. injury accidents, and
8. fatal accidents.

Accident data provide the last three levels; conflict counts provide four; volume counts are usually made along with most conflict counts. Conflicts, erratic maneuvers, and near-miss accidents provide an important base of information for use in traffic engineering decisions.

Techniques for counting conflicts, erratic maneuvers, and near-miss accidents are described herein. Applications of conflict counts by other agencies are summarized. Other information in this report will be useful in developing a routine, systematic procedure for collection and analysis of conflict data in Kentucky.

THE NEED FOR ANALYSES OF TRAFFIC CONFLICTS

Several limitations have been observed in the use of accident data in traffic safety studies. Accident files contain records of reported accidents only, which are only a fraction of the accidents that actually occur. Also, the criteria for reporting vary considerably between states. For example, all traffic accidents in Colorado, Nevada, and the District of Columbia must be reported, while only accidents involving injury costs exceeding $400 to any one person must be reported in Connecticut. The most common limits for reporting are $100 (23 states) and $200 (12 states) in damages (1). The number of accidents reported at a site is, therefore, a function of local reporting laws, accident severity, and damage costs.

Another problem with using accident data alone for identifying and evaluating high-accident sites is the spurious fluctuations in occurrences. Many accidents result from a vehicle malfunction (blowout or brake failure), obvious driver error (speeding or drunk driving), or a weather-related problem (ice on road or heavy fog), which are not related to any geometric deficiency. A study completed in 1973 illustrated the effect of random (spurious) occurrences on the identification of hazardous sites in Kentucky. Of the 208 spot locations identified from accident data as being hazardous, 99 of them were identified falsely because of random occurrences. The 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 in the roadway (2).
The use of number of accidents for predicting future accidents at a location (accident repeatability) has also been found to be somewhat unreliable. An analysis of 60 intersections in Central Kentucky showed that the correlation coefficient ($r$) was only 0.64 when correlating the number of accidents for a given year with the successive year. The 95-percent confidence band (twice the standard error) for this relationship was ±10.9 accidents per year for an average of 11.1 accidents per year. 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 a $r$-value of only 0.59 was found. More than a 100-percent error was also found for this sample of locations (95-percent confidence), illustrating the non-repeatability of accident data (3). Similar findings were noted in the state of Washington where the year-to-year reliability of accident data ranged from $r$-values of 0.60 to 0.65 (4).

Another problem with accident data is the time needed to obtain a significant data base. In connection with a previous study in Kentucky, it was suggested that between 1 and 2 years of accident data were necessary to insure reliability when selecting high-accident locations (5). Another study of 433 intersections over a 13-year period indicated that 3 years of data should be used (6). Years of waiting are often necessary to determine the effectiveness of highway improvements if accident data alone is used. Also, several accidents must occur before improvements normally can be justified.

The information contained on individual accident reports may also be incomplete or biased. The investigating police officer has primary responsibility of aiding injured persons, maintaining traffic, and determining fault of the accident (for insurance purposes). He may not be aware of specific contributing causes of the accident. While accident data alone has many limitations, it can be quite useful when complemented by traffic conflict data. Accident histories may indicate locations where conflict data might indicate appropriate improvements and later to determine whether or not the improvements were effective.

**THE GENERAL MOTORS TECHNIQUE**

In 1967, the first formalized, systematic procedure for identifying and recording traffic conflicts at intersections was published. The technique was developed by Perkins and Harris of General Motors Corporation and is commonly referred to as the GM technique. It has gained widespread acceptance and, with minor modifications, is the basis used by several highway agencies (7). In 1969, a procedures manual was written by Perkins to give additional information for collection of conflict data (8).

The GM technique identifies five major classes of traffic conflicts: left-turn, weave, cross-traffic, red-light violation, and rear-end. There are 24 specific conflict categories which are classified under the basic conflict groups. Definitions (7) of these basic groups are as follows:

- **Left-turn Conflict** occurs when a vehicle turns left in front of an oncoming, through vehicle, and causes the through vehicle to brake or swerve. This conflict would be observed on the approach of the through vehicle from a brakelight or a lane change.

- **Weave Conflict** is a situation where a vehicle changes lanes into the path of another vehicle causing the offended driver to brake or swerve to avoid a collision. This conflict is viewed from the rear where brakelight applications can be observed. Weave conflicts can result from lane changes, improper turns from lanes, or turns into wrong lanes.

- **Cross-traffic Conflict** results when a vehicle crosses or turns into the path of a through vehicle having right of way, causing it to brake or swerve. Cross-traffic conflicts usually occur at non-signalized intersections where the minor approach is controlled by stop signs. Cross-traffic conflicts may be through-, left-turn-, or right-turn-type movements by the offending vehicle. The right-turn, cross-traffic conflict may occur at a signalized intersection where a vehicle turns right on red in front of an oncoming vehicle.

- **Red-light Violation** occurs when a vehicle crosses the stop line (bar) on a red phase. Vehicles which enter the intersection on green and complete their movement on red are not considered violators. The three categories of red-light violations are left-turn, right-turn, and through vehicles.

- **Rear-end Conflict** is a situation in which a vehicle stops or slows unexpectedly and causes a following vehicle to take evasive action to avoid a rear-end collision. Twelve specific rear-end conflicts are
  1. stop on amber,
  2. slow for left turn,
  3. slow for right turn,
  4. previous traffic conflict,
  5. shopping entrance beyond intersection,
  6. slow truck,
  7. congestion in intersection,
  8. clear intersection,
  9. stalled vehicle,
  10. traffic back-up,
  11. pedestrian, and
  12. merging beyond intersection.
All rear-end conflicts are observed on the approach where brakelight applications can be observed (8).

In addition to the five major categories of conflicts, pedestrian-vehicle conflicts are also counted and classified as single vehicle-pedestrian or weave-pedestrian conflicts. When counting conflicts, each event is considered only one conflict. For example, if a vehicle stops suddenly and causes five following vehicles to apply brakelights, only one rear-end conflict is counted. Diagrams of specific types of conflicts are shown in Figure 1 (7).

The data sheet used in the GM technique is shown in the APPENDIX (Figure A1). The starting time of the count (military time) is entered in the columns at the far left. There are 24 categories. The first 10 groups are considered maneuver conflicts; the next 12 are rear-end conflicts; and the last two involve pedestrians. The maneuver conflicts include counts of the number of vehicles making the movement and the number of conflicts resulting. Categories 5 through 10 are usually associated with non-signalized intersections (8).

The GM survey is usually a one-day surveillance of the two major approaches of an intersection. This corresponds to approximately 2.5 hours of data for each leg. If data collection is required for all four approach legs, two days of data collection are recommended. The survey team consists of two observers on one approach leg at the same time. Usually, one observer counts and records conflict data and the other observer records volume data (Figure A2) (8). Recommended days are Tuesday, Wednesday, and Thursday. The survey day is a 10-hour period from 7:30 a.m. to 12:00 noon and 12:45 p.m. to 6:15 p.m. Survey times are sometimes extended to include both morning and afternoon peaks.

After each 15-minute period of counting, the next 15-minute period is used for recording data and for moving to the next approach leg. For most T- and four-way intersections, data are collected only on the two major approach legs. Where two major arterials cross, data should be taken alternately on all approach legs.

Data should be collected from a vehicle parked on the roadway shoulder about 100 to 300 feet (30 to 90 m) back from the intersection. The vehicle should face the direction of travel and not interfere with normal movements of traffic. In urban areas where sidewalks are adjacent to the road, observers should stand or sit at appropriate distances from the intersection. Police vehicles should not be used for data collection.

Other information needed is given in the APPENDIX. It includes an inventory of existing highway features (Figure A3), an inventory of past safety improvements (Figure A4), accident data (Figure A5), and photographs of the intersection (Figure A6). Data formats on all sheets were designed for punching on computer card. Details of coding instructions can be found in the GM procedures manual (8).

METHODS USED BY OTHER AGENCIES

While the GM technique is the basis for conflict counts by several highway agencies, many modifications have been made to fit local needs and preferences. Various severity categories of conflicts are used in Great Britain and in the state of Washington. In Washington, conflicts are classified as a routine conflict, a moderate hazard, or a near miss (4). Five levels of severity were used by Spicer in Great Britain to rate conflicts as follows (9, 10, 11):

1. precautionary braking or lane change where a collision is very unlikely,
2. controlled braking or lane change to avoid collision but with ample maneuver time,
3. rapid deceleration, lane change, or stopping to avoid collision (a near-miss situation),
4. emergency braking or violent swerve to avoid collision resulting in a very near miss or minor collision, and
5. emergency action followed by a collision.

The first two groups were termed slight, and the last three were termed serious. For some uses, only the serious conflicts were considered.

Washington collects data on any day of the week, including Saturdays and Sundays, if the problem at a particular site is most acute at that time. Conflict counts are made during the most critical time periods at a given intersection, and the necessary information is collected within a 4- to 6-hour period. Washington uses one observer in a vehicle to count conflicts and another observer in a second vehicle to count traffic volumes (4, 12).

In Ohio (13), only one trained observer collects all the data. The observation point is about 330 feet (100 m) back from the intersection. At unsignalized intersections, counts are made on the two uncontrolled approach legs on a given day. At signalized intersections, the two opposing legs are observed on one day, and a second day is needed for the other two legs. Counts are made only on Tuesday, Wednesday, and Thursday but not on the day of or the day before a holiday. Days of inclement weather are also avoided. About 100 intersections are counted by each trained observer annually.
Figure 1. Conflict Criteria from GM Technique (7).
In Canada, because of very low traffic volumes on many rural roads, counting times are from 7:00 a.m. to 9:00 p.m. and may be completed in two, 7-hour days. Data are collected on Mondays, Tuesdays, Wednesdays, and Thursdays. Three or four observers may be used, depending on the type of intersection (T- or four-way intersection); and volume and conflict counts are recorded at hourly intervals (14).

The Transport and Road Research Laboratory studies in Great Britain are based on an average of a 10-hour day (8:00 a.m. to 6:00 p.m.). Direct, on-site collection of data requires two to six observers, depending on site conditions. A second procedure consists of filming a location with time-lapse, color photography (at two frames per second using a 16-mm camera). An elevated vantage point is necessary for camera placement. Analysis of the film is made by trained analysts. An average of about one man-hour of analysis is required for each hour of filming. Speed measurements of vehicles are also taken using radar meters (9, 10, 11).

CRITERIA FOR IDENTIFYING HAZARDOUS SITES

Washington's criteria for rating intersections by priority is based on numbers of conflicts per hour and type of intersection. Conflict counts are taken only at intersections with operational deficiencies, so conflict counts represent the most hazardous intersections. All intersections are classified as (1) signalized and channelized, (2) signalized only, (3) channelized only, or (4) non-channelized (12). Five priority levels are used for rating intersections in each of the four classifications. Priority 1 is the top 15 percent of intersections, Priority 2 is the next 15 percent, Priority 3 is the next 20 percent, and Priorities 4 and 5 constitute 25 percent each. Intersections in Priority 1 require corrective action as soon as possible. Locations in Priority 2 should be corrected as soon as funds are available, and Priority 3 intersections are worthy of consideration for future improvements. Priority 4 and 5 sites are not seriously considered for improvements at present. Their conflict criteria are given in Table 1 for each classification and priority group. For example, intersections which are signalized only are placed in Priority 1 if they have 65 or more conflicts per hour. Other conflict criteria are 46 to 64 for Priority 2, 24 to 45 for Priority 3, 9 to 23 for Priority 4, and 8 and under for Priority 5.

Another use of conflict counts for rating intersections was in a study in Pennsylvania by Taylor and Thompson in 1976 (15). There, nine highway and traffic indicators were used to compute a hazard index for each intersection. They included number of accidents, accident rate, accident severity, volume-capacity ratio, sight distance, traffic conflicts, erratic maneuvers, driver expectancy, and deficiencies in signing, etc. The rating was based on data from Washington state and was expressed as a second-degree curve (number of conflicts per hour versus indicator value) as shown in Figure 2. Based on the conflicts per hour at an intersection, the hazard index from 0 to 100 can be found.

In a Kentucky study completed in 1976, Agent developed warrants for left-turn phasing based on left-turn conflicts during peak hours (16). Correlations were made between left-turn conflicts and histories of left-turn accidents at 32 intersections. Based on these relationships, warrants were developed for consideration of left-turn phasing. An average of 10 or more left-turn conflicts in the peak hour was the qualifying criterion. Warrants were also developed based on left-turn accidents.

Conflict rates (conflicts per 1,000 opportunities) incorporates traffic volumes and allow comparison between locations having different volumes. Average conflict rates could be determined for various categories of intersections. As this base of data becomes very large and statewide conflict rates are approximated for various types of locations, the Rate-Quality Control technique could be applied in a manner similar to that applied to accidents; this assumes that conflicts approximate a Poisson distribution.

EVALUATION OF SAFETY IMPROVEMENTS

After a highway location is identified as hazardous using accident data and/or conflict data, field inspections should be made by an investigative team to find specific deficiencies and recommend safety improvements. Shortly after completion of the improvements, another set of counts should be made to determine the effectiveness of the improvement. The conflicts afterward will often identify minor adjustments, such as signal timing, which might further improve the intersection.
<table>
<thead>
<tr>
<th>PRIORITY GROUP</th>
<th>NUMBER OF CONFLICTS PER HOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGNALIZED AND CHANNELIZED, N = 47</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>39 and over</td>
</tr>
<tr>
<td>Group 2</td>
<td>28 to 38</td>
</tr>
<tr>
<td>Group 3</td>
<td>17 to 27</td>
</tr>
<tr>
<td>Group 4</td>
<td>11 to 16</td>
</tr>
<tr>
<td>Group 5</td>
<td>10 and under</td>
</tr>
<tr>
<td>SIGNALIZED, N = 36</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>65 and over</td>
</tr>
<tr>
<td>Group 2</td>
<td>46 to 64</td>
</tr>
<tr>
<td>Group 3</td>
<td>24 to 45</td>
</tr>
<tr>
<td>Group 4</td>
<td>9 to 23</td>
</tr>
<tr>
<td>Group 5</td>
<td>8 and under</td>
</tr>
<tr>
<td>CHANNELIZED, N = 43</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>38 and over</td>
</tr>
<tr>
<td>Group 2</td>
<td>29 to 37</td>
</tr>
<tr>
<td>Group 3</td>
<td>15 to 28</td>
</tr>
<tr>
<td>Group 4</td>
<td>8 to 14</td>
</tr>
<tr>
<td>Group 5</td>
<td>7 and under</td>
</tr>
<tr>
<td>NON-CHANNELIZED, N = 146</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>39 and over</td>
</tr>
<tr>
<td>Group 2</td>
<td>26 to 38</td>
</tr>
<tr>
<td>Group 3</td>
<td>17 to 25</td>
</tr>
<tr>
<td>Group 4</td>
<td>9 to 16</td>
</tr>
<tr>
<td>Group 5</td>
<td>8 and under</td>
</tr>
<tr>
<td>ALL INTERSECTIONS, N = 272</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>40 and over</td>
</tr>
<tr>
<td>Group 2</td>
<td>27 to 39</td>
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<tr>
<td>Group 3</td>
<td>19 to 26</td>
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<tr>
<td>Group 4</td>
<td>10 to 18</td>
</tr>
<tr>
<td>Group 5</td>
<td>9 and under</td>
</tr>
</tbody>
</table>
An analysis of safety improvements at 32 locations in Virginia was made in 1971 using before-and-after conflict data (17) and resulted in a definite reduction of conflicts at 24 of the 32 locations. Highlights from that analysis are as follows:

1. Weave and rear-end conflicts were virtually eliminated at 16 of 17 intersections where turn lanes were constructed.

2. Installation of traffic signals resulted in the elimination of cross-traffic conflicts at four locations.

3. Left-turn conflicts were eliminated at one intersection after adding a separate left-turn phase to the signal.

4. Prohibition of left-turns from a shopping center resulted in elimination of cross-traffic conflicts.

5. A 38-percent reduction in total conflicts and the elimination of left-turn conflicts resulted at one location after trimming trees to improve sight distance.

6. A 50-percent reduction in total conflicts was found after construction of a concrete median, but there was some question as to the influence of the improvement on the conflicts.

7. At six locations, there were no significant changes in conflicts after improvements.

8. An increase in traffic conflicts occurred after improvements at two locations; the increases were attributed to increases in traffic volumes during the after period.

A before and after study of left-turn conflicts was made at three intersections in Kentucky, where left-turn phasing was installed. At one T-intersection in Louisville (Dixie Highway and Deering Road), the number of left-turn conflicts decreased by 76 percent; the rate of left-turn conflicts (conflicts per 1,000 left-turning vehicles) decreased from 104 to 24. At another T-intersection in Hopkinsville (US 41A and Skyline Drive), there was a 69-percent reduction in left-turn conflicts and a decrease in conflict rate from 64 to 20. At a four-way intersection in Louisville (Dixie Highway and Pages Lane), the number of conflicts per hour decreased by 94 percent; and the conflict rate dropped from 146 to 8 after installation of left-turn phasing (16).
Traffic conflicts were used to evaluate the effectiveness of a Green-phase Extension System (GES) in another Kentucky study in 1976 [18]. GES merely extends green time for vehicles detected in an approach zone as much as 500 feet (152 m) in advance of high-speed intersections. A GES system, when properly used, will theoretically reduce the number of rear-end and right-angle accidents which occur because of abrupt stops and running red lights. The six types of conflicts which occur during and shortly after the amber phase were counted at two locations. These conflicts were reduced by 40 percent at one intersection and 85 percent at the other.

In Grand Rapids, Michigan, in 1976 [19], adding left-turn phasing, replacing 8-inch (200-mm) lenses with 12-inch (300-mm) lenses marking signal heads for each lane, and adjusting timing reduced conflicts 11 to 14 percent for ten major approach legs at five intersections. The reduction in accidents was 17 percent.

A study in Indiana [20] to evaluate the use of stop signs, yield signs, and no control at 18 low-volume, rural intersections in the ranges of 0 to 25, 26 to 50, and 51 to 100 vehicles per hour on the minor approaches produced conflict probabilities ranging from 0.035 to 0.137, depending on volume and type of signing. Probabilities were higher for stop signs than for yield signs or no control. Higher volumes on the minor approaches contributed to the higher probability of conflict.

In Virginia and Indiana, new right-turn-on-red (RTOR) laws were evaluated using before-and-after counts of conflicts [21, 22]. In the Virginia study [21], counts were made of RTOR conflicts at 20 intersections. Specific conflict types counted were
1. opposing left turn,
2. through cross-traffic left to right,
3. left-turn cross-traffic from left,
4. right-turn cross-traffic,
5. rear end, and
6. pedestrian.

In both studies, the adoption of permissive RTOR was found to cause no significant increase in accident potential.

Counts of driver violations and other conflict types were made at seven locations in Canada to determine the safety benefits from increased police enforcement of traffic laws. Specific violations were categorized as improper or prohibited turns, failure to use "turn" indicators, and infractions at the traffic signal. Visible presence of police at an urban intersection was found to significantly reduce the number of traffic violations. However, this effect disappeared almost immediately after the police left. No significant change in other conflicts was noted [23].

ACCIDENT-CONFLICT RELATIONSHIPS

After developing the GM technique, Perkins and Harris stated that a high degree of correlation existed between conflicts and accidents [7]. However, a later analysis of their published data by Heany [24] in 1969 found the correlation (r-value) to be about 0.48. The conflict counts used in the correlation were not classified as to severity. A study by Baker [25] of the Federal Highway Administration was completed in 1972 in cooperation with state highway agencies in Virginia, Ohio, and Washington. Conflict data were collected in all three states at a total of 886 approach legs at 392 intersections using the GM technique. Correlation coefficients for T- and four-legged intersections were computed for accident-conflict situations as shown in Table 2. Statistical significance at the five-percent level was found for all types of intersections except for signalized, T-intersections. Similar correlations were also found to be significant for most of the specific conflict types for various classes of intersections. The overall correlation coefficient (r-value), however, was only about 0.46.

Conflict rates were also determined in the FHWA study in terms of conflicts per 1,000 opportunities for signalized and non-signalized, four-legged intersections as shown in Table 3. Accidents per 100,000 conflicts were also found for four conflict types. The data in this study were determined to support the theory that conflicts and accidents are associated. The conflict technique was found to be especially applicable to low-volume, rural intersections where the accident reporting level is unusually low [25].
TABLE 2. FHWA CORRELATION COEFFICIENTS (r) FOR T AND FOUR-LEGGED RIGHT-ANGLE INTERSECTIONS (25)

<table>
<thead>
<tr>
<th>INTERSECTION</th>
<th>CONFLICT-ACCIDENT SITUATION</th>
<th>WEAVE</th>
<th>LEFT-TURN</th>
<th>CROSS-TRAFFIC</th>
<th>REAR-END</th>
<th>ALL MANEUVERS</th>
<th>CRITICAL r</th>
<th>SAMPLE SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HEAD-ON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signalized</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td></td>
<td>0.207</td>
<td>-0.128</td>
<td>-0.170</td>
<td>0.075</td>
<td>-0.172</td>
<td>± 0.532</td>
<td>14</td>
</tr>
<tr>
<td>Four-legged right-angle</td>
<td></td>
<td>0.360</td>
<td>0.661</td>
<td>0.209</td>
<td>-0.018</td>
<td>0.410</td>
<td>± 0.179</td>
<td>122</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td>0.402</td>
<td>0.615</td>
<td>0.136</td>
<td>-0.017</td>
<td>0.326</td>
<td>± 0.160</td>
<td>157</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-signalized</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td></td>
<td>0.294</td>
<td>0.432</td>
<td>0.830</td>
<td>0.410</td>
<td>0.837</td>
<td>± 0.205</td>
<td>94</td>
</tr>
<tr>
<td>Four-legged right-angle</td>
<td></td>
<td>0.159</td>
<td>0.459</td>
<td>0.602</td>
<td>0.213</td>
<td>0.653</td>
<td>± 0.192</td>
<td>106</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td>0.276</td>
<td>0.453</td>
<td>0.655</td>
<td>0.295</td>
<td>0.671</td>
<td>± 0.130</td>
<td>235</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All combined</td>
<td></td>
<td>0.356</td>
<td>0.546</td>
<td>0.429</td>
<td>0.154</td>
<td>0.458</td>
<td>± 0.100</td>
<td>392</td>
</tr>
</tbody>
</table>

*aIndicates statistical significance at the five-percent level.

*bIncludes other intersection types such as skewed and multileg as well as T and four-legged, right-angle intersections.

*cComposed of all signalized and non-signalized intersections.

---

TABLE 3. FHWA CONFLICT/OPPORTUNITY AND ACCIDENT/CONFLICT RATIOS (25)

<table>
<thead>
<tr>
<th>INTERSECTION</th>
<th>CONFLICT-ACCIDENT SITUATION</th>
<th>WEAVE</th>
<th>LEFT-TURN</th>
<th>CROSS-TRAFFIC</th>
<th>REAR-END</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conflicts per 1,000 opportunities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signalized, four-legged, right-angle</td>
<td></td>
<td>51</td>
<td>28</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>Non-signalized, four-legged, right-angle</td>
<td></td>
<td>64</td>
<td>28</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>All combined</td>
<td></td>
<td>65</td>
<td>28</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Accidents per 100,000 conflicts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Signalized, four-legged, right-angle</td>
<td></td>
<td>7</td>
<td>20</td>
<td>56</td>
<td>3</td>
</tr>
<tr>
<td>Non-signalized, four-legged, right-angle</td>
<td></td>
<td>7</td>
<td>9</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>All combined</td>
<td></td>
<td>6</td>
<td>15</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>

*aIncludes other intersection types such as skewed, multileg, and T as well as signalized and non-signalized four-legged, right-angle intersections.
After the FHWA study, which utilized conflict data from Ohio, the Ohio DOT expanded their own conflict data using the GM technique to include 611 approach legs. A series of regression models was generated to predict 2-year accident occurrence for signalized intersections from the formula which was later expressed in the following form (26, 27):

\[
AP2Y = 1.16153 + 11.6345 \times (ADT) - 0.0503 \times (CPT) - 0.0321 \times (RROPP) + 0.0387 \times (OCP02) + 0.0285 \times (TTOPP) - 0.02255 \times (OPOPP)
\]

where
- \(AP2Y\) = accident prediction value per 2 years,
- \(ADT\) = average daily traffic (in ten thousands) calculated from conflict counts,
- \(CPT\) = opposing conflicts,
- \(RROPP\) = rear-end conflict opportunities,
- \(TTOPP\) = total observed conflict opportunities,
- \(OCP02\) = opposing conflict opportunities per 10 opportunities,
- \(OPOPP\) = opposing conflict opportunities per 10,000 ADT.

The prediction equation for unsignalized approaches is

\[
AP2Y = 0.36 + \text{RATE} (ADT) = 0.36 + ADT [22.3568 + 17.773 \times (SPLIT) - 36.7045 \times (ADT^{1/2}) + 1.6785 \times (SPLIT^2) + 18.2544 \times (ADT) - 0.0264 \times (OPOPP) + 0.8385 \times (OPCON)].
\]

Prediction errors using the above equations were relatively low, as is shown in Table 4.

**TABLE 4. PREDICTION ERRORS USING EQUATIONS DEVELOPED BY OHIO DOT (26)**

<table>
<thead>
<tr>
<th>DATA CLASS</th>
<th>NUMBER OF POINTS</th>
<th>50%</th>
<th>75%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Data</td>
<td>611</td>
<td>± 1.2</td>
<td>± 2.0</td>
<td>± 4.2</td>
</tr>
<tr>
<td>Signalized</td>
<td>220</td>
<td>± 1.5</td>
<td>± 2.4</td>
<td>± 4.6</td>
</tr>
<tr>
<td>Unsignalized</td>
<td>391</td>
<td>± 1.1</td>
<td>± 1.8</td>
<td>± 3.8</td>
</tr>
</tbody>
</table>

The Washington Department of Highways also developed its own accident-conflict relationships. Based on a study mentioned previously, the average conflicts per hour were compared to the average number of accidents over a 3-year period for each of the five priority groups as shown in Table 5. As conflicts increased from less than 9 to over 40 per hour, accidents increased from 6.3 to 23.4. Data used for this analysis were taken from 240 intersections. An equation was developed to predict accidents from conflict data, which resulted in an error of 2.6 accidents per year for an average of 4 accidents per year. This error is less than the error which was found in Kentucky using accident data in 1 year to predict accident data the following year (3, 4).

Coefficients of correlation were also computed in Washington state between accidents and conflicts by categories of conflicts (Table 6). The strongest correlation existed between weave conflicts and accidents (\(r = 0.53\)). An \(r\)-value of 0.42 was found between conflicts and accidents for all categories combined. The lack of better correlations was attributed to the poor year-to-year reliability of accident data in Washington (\(r\)-values between 0.60 and 0.65) (12).
### Table 5. Relationships between Accident and Conflict Levels in Washington State (12)

<table>
<thead>
<tr>
<th>Priority Group</th>
<th>Conflicts Per Hour</th>
<th>Number of Intersections</th>
<th>Average Number of Unweighted Accidents (3-Year Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40 and over</td>
<td>39</td>
<td>23.4</td>
</tr>
<tr>
<td>2</td>
<td>27 to 39</td>
<td>38</td>
<td>15.8</td>
</tr>
<tr>
<td>3</td>
<td>19 to 26</td>
<td>34</td>
<td>14.0</td>
</tr>
<tr>
<td>4</td>
<td>10 to 18</td>
<td>55</td>
<td>9.2</td>
</tr>
<tr>
<td>5</td>
<td>9 and under</td>
<td>74</td>
<td>6.3</td>
</tr>
</tbody>
</table>

### Table 6. Correlations between Specific Types of Conflicts and Accidents in Washington State (12)

<table>
<thead>
<tr>
<th>Conflict Type</th>
<th>Intersection Types 1, 2, 3&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Intersection Type 4&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 108</td>
<td>N = 132</td>
<td>N = 240</td>
</tr>
<tr>
<td>Opposing left-turn</td>
<td>.06</td>
<td>.25</td>
<td>.13</td>
</tr>
<tr>
<td>Weave</td>
<td>.54</td>
<td>.36</td>
<td>.53</td>
</tr>
<tr>
<td>Rear-end</td>
<td>.38</td>
<td>.43</td>
<td>.39</td>
</tr>
<tr>
<td>Cross traffic</td>
<td>.16</td>
<td>.39</td>
<td>.23</td>
</tr>
<tr>
<td>All conflicts</td>
<td>.38</td>
<td>.49</td>
<td>.42</td>
</tr>
</tbody>
</table>

<sup>a</sup>Intersection Type 1 - Signalized and Channelized
Intersection Type 2 - Signalized
Intersection Type 3 - Channelized

<sup>b</sup>Intersection Type 4 - Non-signalized and Non-channelized
The best correlations between accidents and conflicts were found in a study by Spicer in Great Britain in 1973 (9). Serious conflicts were plotted against the number of injury accidents in 3 years as shown in Figure 3. The correlation between serious conflicts and injury accidents for six intersections was 0.97, which is statistically significant at the 0.1-percent level. This correlation is extremely high, possibly because severe conflicts are more closely related to accidents than moderate conflicts (such as brakelight applications). Also, using 3-year totals of injury accidents, the effects of yearly fluctuations in accidents and of non-reporting of minor (non-injury) accidents were minimized.

A study was made in Canada by Hauer in 1975 concerning accident-conflict relationships. A conclusion was that the traffic conflict technique is more accurate than accident records in predicting the expected annual accident rate at locations with less than three or four accidents per year and when the accident history is very short. This conclusion was based on estimates of variance in accident data at 1,800 intersections and variance in traffic conflicts based on the variability of the accident-to-conflict ratio (28).

Another Canadian study was conducted in 1971 and 1972 using 59 unsignalized intersections to determine what traffic parameters are most efficient for predicting accidents. Accidents and conflicts were significantly related at the 0.01 level, and the linear correlation was 0.45. Conflicts were also found to be closely related to traffic volumes. After correlation with traffic volume, conflicts could not account for differences in numbers of accidents. Summary data from that study is given in Table 7, which shows accident rates, conflict rates, and conflict-accident ratios for various situations (29).

An Australian study in 1976 investigated the occurrences of conflicts and accident exposure. A series of studies was conducted in the Sydney metropolitan area, generally in rush hours, and conflict criteria used were similar to the GM technique. Correlations between conflicts and volumes at two intersections were 0.54 and 0.56. It was suggested that conflicts should be classified by severity to more accurately estimate accident potential. Data were not sufficient for correlating conflicts and accidents (30).
TABLE 7. ACCIDENT/OCCUPORTUNITY, CONFLICT/OCCUPORTUNITY, AND CONFLICT/ACCIDENT RATIOS FROM CANADIAN CONFLICT STUDY (29)

<table>
<thead>
<tr>
<th>CONFLICT OR ACCIDENT SITUATION</th>
<th>ACCIDENTS/MILLION OPPORTUNITIES</th>
<th>CONFLICTS/MILLION OPPORTUNITIES</th>
<th>CONFLICTS/ACCIDENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weave</td>
<td>3.50</td>
<td>8,737</td>
<td>2,496</td>
</tr>
<tr>
<td>Right-turn</td>
<td>0.43</td>
<td>3,400</td>
<td>7,907</td>
</tr>
<tr>
<td>Cross-traffic</td>
<td>6.32</td>
<td>15,700</td>
<td>2,484</td>
</tr>
<tr>
<td>Left-turn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main legs</td>
<td>1.47</td>
<td>9,560</td>
<td>6,503</td>
</tr>
<tr>
<td>Minor legs</td>
<td>0.04</td>
<td>825</td>
<td>20,625</td>
</tr>
<tr>
<td>All legs</td>
<td>0.82</td>
<td>5,450</td>
<td>6,646</td>
</tr>
<tr>
<td>Rear-end</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main legs</td>
<td>0.20</td>
<td>1,210</td>
<td>6,050</td>
</tr>
<tr>
<td>Minor legs</td>
<td>1.30</td>
<td>4,160</td>
<td>3,200</td>
</tr>
<tr>
<td>All legs</td>
<td>0.25</td>
<td>1,340</td>
<td>5,360</td>
</tr>
<tr>
<td>Total</td>
<td>11.32</td>
<td>34,627</td>
<td>3,059</td>
</tr>
</tbody>
</table>

Close correlation between accident types and related conflicts has also been found. A study of left-turn accidents and conflicts at intersections in Kentucky in 1976 developed warrants for left-turn phasing. Five-year histories of left-turn accidents were collected at 32 signalized intersections in Central Kentucky and correlated with average left-turn conflicts during peak hours. Correlations were found to be as high as 0.78 and were greatest using the highest 2-year accident period at each site (16).

In 1975, Thorson and Glennon of Midwest Research Institute did an evaluation of the traffic conflicts technique (27). Most of the major conflict studies to date were critically examined. The authors were critical of the studies where positive correlations were found between conflicts and accidents. The studies evaluated by Thorson and Glennon include works by Baker (FHWA), Paddock (Ohio), Pugh (Washington), Spicer (Great Britain), Cooper (Canada), and Hauer (Canada) (25, 26, 4, 9, 29, 28). Examples of criticisms made of the studies included insufficient data samples, inadequate correlation coefficients, and unsupported conclusions. Thorson and Glennon also suggested that accidents and conflicts are related because of their high interrelationships with traffic volumes. The assumption used in their evaluations is that "... accidents are the ideal measure of safety for a highway location" (27). It follows then that, if conflicts do not correlate highly with accident data, something must be inherently wrong with conflict data.

As discussed previously, accidents are considered by most experts to be anything but ideal measures of safety because of biased and incomplete reporting, random accident fluctuations, inconsistent reporting criteria for local jurisdictions, and the large accident history needed. Several studies have found that correlations between accidents and conflicts depend mainly on the reliability of accident reporting.

Based on the studies available, correlations between conflicts and accidents can be quite high, particularly if only severe conflicts are compared to accident occurrences (9). While counts of all conflict types are useful to the traffic engineer, severe conflicts appear to more closely indicate accident probability. Some form of severity weighting formula for conflicts should be evaluated.
Studies by Cooper and Paddock have shown that conflict counts using the GM technique are highly related to traffic volumes. However, correlations between severe conflicts and traffic volumes were found to be quite low. Spicer found the correlation between severe conflicts and traffic volumes to be 0.20, and the correlation between volume and severe accidents was 0.15. However, accident-conflict correlations of the same sample were 0.97 (9). Russam and Sabey found correlations between accident severity and volume and conflict severity and volume to be 0.10 and 0.08, respectively. Accidents and severe conflicts were found to be closely related (31).

Current thinking among many experts is that finding high correlations between accidents and conflicts is not important. Since conflict data provide information about current conditions at a site, it is extremely informative, particularly at sites having low volumes or insufficient accident histories. However, the use of both accident and conflict data whenever possible provides the best data base for identifying and evaluating hazardous sites.

CONFLICTS ON Freeway RAMPS

The application of the traffic conflict technique to freeway ramps was recently developed by Bart Cima of the Illinois Department of Transportation (32). Eleven specific driver maneuvers were defined as conflicts at entrance ramps onto freeways. These conflicts have been classified as acceleration-lane or merge-lane conflicts. Acceleration-lane conflicts occur on the entrance ramp forward of the first opportunity for merger. Merge-lane conflicts occur on the mainline lane adjacent to the entrance. Conflicts were also classified as routine, moderate, or severe. The six acceleration-lane conflicts are as follows:

1. A braking-on-the-accleration-lane-or-ramp conflict occurs when a merging vehicle is braked because no acceptable gap appears in the freeway traffic stream. A brakelight indication is considered a routine conflict; a vehicle forced to stop would be either a moderate or severe conflict, depending on the deceleration rate (Figure 4).

2. A brake-for-lead-vehicle conflict occurs when the lead vehicle in a platoon of vehicles entering the freeway causes one or more of the following vehicles to brake or stop (Figure 5). Severity is assigned based on whether a brakelight indication or vehicle stopping results.
3. A weaving-around-the-lead-vehicle conflict occurs when a following vehicle weaves around the lead vehicle and enters the mainstream of the freeway (Figure 6). The effect of the weaving vehicle on the lead vehicle determines the conflict severity.

![Figure 6. Weaving-around-Lead-Vehicle Conflict (32).](image)

4. A lane-two-entrance conflict is where an entering vehicle enters the freeway and immediately crosses into an inner lane of the freeway. The conflict severity is determined by its smoothness and the speed and angle of entry (Figure 7).

![Figure 7. Lane-Two-Entrance Conflict (32).](image)

5. A double-entry conflict occurs when two vehicles in the acceleration lane are competing for gaps and(or) merging opportunities. The mutual danger created by the vehicles determines severity (Figure 8).

![Figure 8. Double-Entry Conflict (32).](image)

6. A late-entry conflict occurs when a vehicle waits until reaching the end of the acceleration lane before merging and encroaches the shoulder (Figure 9). Severity is determined by the driver's control during the maneuver and the nearness of collision with other freeway vehicles.

![Figure 9. Late-Entry Conflict (32).](image)
The five traffic conflicts related to the merge lane are as follows:

1. A weave conflict occurs when an entering vehicle causes a mainline vehicle to change lanes, as shown in Figure 10. The severity is determined based on the smoothness of the weave and the danger of collision.

![Figure 10. Weave Conflict (32).](image)

2. A rear-end conflict occurs when an entering vehicle causes a mainline vehicle to brake (Figure 11). Severity is based on the degree of deceleration by the mainline vehicle and the closeness of a collision.

![Figure 11. Rear-End Conflict (32).](image)

3. A secondary-weave conflict arises when a mainline vehicle slows for an entering vehicle and causes a following, mainline vehicle to change lanes. The lead vehicle need not be involved in a rear-end conflict, but an entering vehicle is required (Figure 12). Severity is determined by smoothness of the lane change and the closeness of the two mainline vehicles.

![Figure 12. Secondary-Weave Conflict (32).](image)

4. A secondary-rear-end conflict occurs when a mainline vehicle slows down for an entering vehicle and causes a following, mainline vehicle to brake. Severity is determined by the degree of deceleration of the following vehicle and the danger of collision between the two mainline vehicles (Figure 13).

![Figure 13. Secondary-Rear-End Conflict (32).](image)
5. An encroachment conflict occurs when a mainline vehicle crosses the line of the inner lane to avoid an entering vehicle. The offended vehicle does not change lanes in this case, as shown in Figure 14. The degree of swerving determines the severity.

Figure 14. Encroachment Conflict (32).

Background data are required for each location under study. Required geometric data for the freeway includes number of lanes, pavement type, shoulder width and surface type, alignment, and grade. Ramp data includes ramp type, length of acceleration lane, ramp width at nose, merging angle, grade, and ramp controls (if any). A minimum of 2 years of accident data is desirable. Traffic volumes classified as cars or commercial vehicles are also needed for each freeway lane and the entrance ramp. Weather conditions and lighting are also recorded as they vary during the survey day.

Observers should classify conflicts at the site or from video recordings. A minimum of 4 to 6 hours of training is required for each observer. Observers should position themselves about 200 feet (60 m) upstream from the ramp junction. Conflicts should be classified as to type and severity using Figures 15 and 16. Data are recorded in 5-minute intervals. Designations should be made by defining the type(s) of vehicles involved in each conflict situation. Starting times and duration of counts depend upon the objectives of the study. The number of survey days needed depends on the amount of data collected at a site. Usually a minimum of two observers is required at a time to collect volume and conflict data.

ERRATIC MANEUVERS

An erratic maneuver is any movement that involves a sudden disruption of direction and/or the speed. An erratic maneuver is usually equivalent to a moderate or severe conflict. 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 result in a conflict if another vehicle is forced to brake or weave. 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 provide information about the potential for single-vehicle accidents. Erratic maneuver counts can be used in much the same way as conflict counts.

One of the primary uses of erratic movement counts to date has been for evaluating problems at gore areas and lane drops on interstates and freeways. In a study in 1973 to determine causes of erratic maneuvers at exit gores, Taylor and McGee (33) defined eight types of erratic maneuvers as follows:

1. Cross-gore-paint occurs when a vehicle crosses the lane-delineation line in the gore area while exiting or continuing through.
2. Cross-gore-area is where a vehicle traverses the unpaved area beyond the pavement markings while exiting or continuing through.
3. Stop-in-gore occurs when a vehicle comes to a complete stop in any part of the gore area before exiting or continuing through.
4. Back-up is where a vehicle passes the gore area, stops, and backs to change direction.
5. Sudden-slowing occurs when a vehicle follows the proper path but brakes abruptly.
6. A lane-change, in this instance, is a delayed weave into the outer lane; the vehicle traverses one or more lanes within the deceleration lane area in order to exit.
7. A swerve is where a vehicle changes lateral position suddenly within the deceleration lane area while exiting or continuing through.
8. Stop-on-shoulder occurs when a vehicle stops on the shoulder within the interchange area and then continues through or exits.
Figure 15.  Acceleration-Lane Conflict Data Form (32).

<table>
<thead>
<tr>
<th>TIME</th>
<th>TRUCK VOLUME</th>
<th>BRAKING ON RAMP</th>
<th>BRAKE FOR LEAD VEHICLE</th>
<th>WEAVING AROUND LEAD VEHICLE</th>
<th>LANE 2 ENTRANCE</th>
<th>DOUBLE ENTRY</th>
<th>LATE ENTRY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ROU-TINE</td>
<td>MOD-ERATE</td>
<td>SERIOUS</td>
<td>ROU-TINE</td>
<td>MOD-ERATE</td>
<td>SERIOUS</td>
<td>ROU-TINE</td>
</tr>
<tr>
<td></td>
<td>MOD-ERATE</td>
<td></td>
<td></td>
<td>MOD-ERATE</td>
<td></td>
<td>SERIOUS</td>
<td>MOD-ERATE</td>
</tr>
<tr>
<td></td>
<td>SERIOUS</td>
<td></td>
<td></td>
<td>SERIOUS</td>
<td></td>
<td></td>
<td>MOD-ERATE</td>
</tr>
</tbody>
</table>

FREeway: Location
Observer: Comments:

DATE: WEATHER: PAVEMENT
Figure 16. Merge-Lane Conflict Data Form (32).

<table>
<thead>
<tr>
<th>TIME</th>
<th>FREEWAY TRUCK VOLUME</th>
<th>WEAVE</th>
<th>SECONDARY WEAVE</th>
<th>REAR END</th>
<th>SECONDARY REAR END</th>
<th>ENCROACHMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ROUTINE</td>
<td>MODERATE</td>
<td>SERIOUS</td>
<td>ROUTINE</td>
<td>MODERATE</td>
</tr>
<tr>
<td>LANE 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANE 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANE 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FREeway:  
LOCATION:  
OBSERVER:  
COMMENTS:  
DATE:  
WEATHER:  
Pavement:
A vehicle was not counted if it was forced into an erratic maneuver by another vehicle. If a trailing vehicle committed a similar erratic maneuver as the lead vehicle, such as a sudden slowing, only one erratic maneuver was counted. Also, if a vehicle stopped in the vicinity of the exit for an obvious, unrelated purpose (such as to change drivers or for vehicle repairs), no erratic maneuver was assigned.

The counting day consisted of observations during 14 hours of daylight and 4 hours of darkness at each of the nine exit sites. The sites incorporated various geometric features. Erratic maneuver rates were found in terms of exiting and through traffic. The factors found to cause erratic maneuvers at freeway exits were classified as driver related (a breakdown in the driver's decision-making process), information deficiencies, or geometric deficiencies. Remedial improvements were made at eight of the nine sites and evaluated using driver interviews and counts of erratic maneuvers. The frequency of hazardous vehicle maneuvers was reduced due to the improvement of signing and delineation.

A 1972 study was conducted in Kentucky to determine traffic behavior at seven lane-drop locations as influenced by various types of signs, pavement markings, and lane delineations (34). Erratic movements, brakelight applications, vehicle speeds, and lane volumes were counted at each site. The types of erratic movements counted were cut-across-gore-area, crowded-weave, stopped, stopped and backed, slowed-drastically, swerved, and multiple error. Data for the Kentucky study were initially collected during a 12-hour duration: 9 hours in daytime and 3 hours at night. Observations were scheduled to correspond to high-volume times. Due to no correlations between traffic volumes and erratic maneuver rates, samples were later limited to six daytime hours having high volumes of traffic. Three checks of observer reliability showed no significant differences between observers.

At the seven lane drops, three configurations of devices were tested. These included various combinations of yellow striping, pavement reflectors, and modifications of exit signing. Different traffic control devices were found to be more effective in reducing erratic excursions, depending on geometric differences. No significant reductions in brakelight rates were attributable to the improvements.

A study utilizing counts of erratic maneuvers was completed in 1972, and its objective was to determine the most effective traffic controls for maintenance on high-speed highways (35). Various types of signing were used at lane closures on interstate facilities. Data collection included spot speeds, erratic maneuvers (termed "traffic conflicts" in the report), merging maneuvers, and turn-signal indications. Erratic maneuvers counted were abnormal brake application, forced merge, and complete stop. The locations of merging maneuvers with respect to the lane closures were also recorded and expressed as percentages within various distances from the lane closure. Driver interviews were also conducted with respect to the maintenance signing. Orange signs were found to be slightly better than yellow signs in reducing erratic maneuvers and merges near the barricade. Significant improvements were also noted using newer, clearer signing. Driver attitudes about lane-closure signs were found to have compounded the problem of effective signing.

Another Kentucky study utilizing erratic maneuvers was completed in 1974 by Pigman and Agent, and its purpose was to test the effectiveness of various types of raised, pavement markers for traffic control at lane drops (36). Counts of erratic movements, brakelight applications, and lane volumes were taken at five lane-drop locations. Data were recorded for six daylight hours and three nighttime hours at each site. Erratic movements were grouped as cut-across-gore-area, crowded-weave, stopped, slowed-drastically, swerved, stopped-and-backed, and multiple-error. After installation of raised, pavement markers, a statistically significant decrease in the total erratic movement rate occurred in nearly all cases, particularly at night. The total reduction in erratic movement rate was 27 percent. No significant change in brakelight rates was noted. The installation of raised, pavement markers at other lane-drop locations was recommended based on their cost effectiveness.

A study was made of traffic maneuvers at the interchange of I 81 and Route 33 near Harrisonburg, Virginia, by Parker in 1976 to determine if remedial measures, including construction of acceleration lanes, were warranted (37). Specifically, the maneuvers counted were weaves, near-or-full-stop-on-shoulder, near-or-full-stop-on-ramp, right-turn-cross-traffic, and rear-end conflicts (brakelight applications). Volume counts, color photographs, and super-8 movies were taken. Observation periods consisted of eleven 15-minute counts at each ramp during the morning and evening peak-traffic periods. It was concluded that the high occurrence of adverse maneuvers and conflicts could be reduced or eliminated by constructing acceleration lanes at the ramps.

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A study of erratic maneuvers was made at the interchange of I 10 and I 110 near Baton Rouge, Louisiana, to determine the need to replace conventional signing with a diagrammatic sign. Problems were believed to be occurring with motorists westbound on I 10, which must keep to the left and take what appears to be a left exit to remain on I 10. Measures selected to determine sign effectiveness were abnormal weaves, stopping and/or backing, and other unusual maneuvers such as hesitations, partial weaves, or abnormal braking. The original intent was to compare erratic movements under conventional signing with counts after installation of the diagrammatic sign. However, because of the relatively low incidence of these erratic maneuvers, the use of diagrammatic signing was not warranted. Thus, no signing changes were made at the site (38).

Diagrammatic signing was evaluated using erratic maneuvers at an exit to the Capitol Beltway near Washington, D.C., in a 1971 study by Hanscom (39). A significant decrease in weaving maneuvers in the gore area was found after installation of the diagrammatic sign. Also, fewer vehicles stopped and backed during the after period. However, an increase in partial weaves and vehicle hesitations was attributed to more tourists during the after period. Overall, a safer condition resulted from use of the diagrammatic sign, and statistical tests showed more consistent patterns of driver behavior. A considerable reduction in accident rate also resulted during the after period.

The evaluation of a color delineation and marking scheme for highway interchanges was made in a 1967 study in Michigan (40). Data included erratic movements, driver interviews, and accident data at the interchanges in the northbound direction of a 40-mile (64-km) section of US 23 between Ann Arbor and Flint, Michigan. Conclusive evidence was not found, but there was a significant reduction in erratic movements and accident experience at locations where the marking scheme was used.

Counts of vehicle encroachments on a 40-foot (12-m) median of I 74 in Illinois were used by Hutchinson to determine minimum, desirable median widths (41). Encroachments into the median were noted from direct observation, police accident records, and repair records of barrier medians. Encroachment rates were determined for various volume ranges. A minimum, clear median of 30 feet (9 m) was recommended with mild cross slopes for safe stopping or control of encroaching vehicles at rural highway speeds. A 30-foot (9-m) clear zone on the right of the road was also recommended.

In a 1974 study by Vaswani in Virginia (42), wrong-way entries at interchanges on four-lane, divided highways were evaluated in a 2-year survey. Incidences of wrong-way driving were used along with accident reports which involved wrong-way vehicles. Several sites were identified as having high occurrences of wrong-way incidents and accidents, and on-site investigations were made at five sites. Case studies were made of those sites, and specific recommendations were made for improvements.

Little, if any, information is available concerning types and numbers of erratic maneuvers which occur at intersections; this is so because accident analyses and conflict data have primarily been used. When observing operational problems at an intersection, various types of erratic maneuvers may occur, depending on the geometric and traffic conditions of the intersection. Some of the erratic maneuvers recurring with some regularity may include

1. U-turn,
2. use of the shoulder for turns (short turn lane),
3. right-turners hitting curb (inadequate room for right turn),
4. vehicles overrunning stop bar and backing,
5. vehicles backing from driveways near intersection, and
6. weaves into turn lanes and then back into major stream of traffic.

NEAR-MISS ACCIDENTS

A near-miss accident occurs when a collision is avoided due to a last-second movement or stop by one or more vehicles. A near-miss accident is a very severe type of conflict or erratic maneuver, and relatively few near-miss accidents may normally be observed at any location as compared to conflicts or erratic maneuvers.

One of the problems with using near-miss accidents for safety monitoring or accident prediction is the great dependence on judgment by the observers. A conservative observer may consider an event as dangerous; it may appear to be commonplace to an observer who drives aggressively. Therefore, counts of near-miss accidents will vary substantially depending on the personalities, driving experiences, and state-of-mind of the observers.

One of the first studies of near-miss accidents was by Forbes in 1957 (43). A total of 179 near-accident reports were filed by people interested or working with traffic. Information in greater detail was expected as compared to accident information since no liability would be involved with a near-accident. Questions concerned accident description, causative factors, environmental conditions, and state-of-mind of the drivers. In most near-accidents, from two to seven causal factors were involved. "Drivers-in-a-hurry" was an
important factor. Only limited success was found using such questionnaire data for engineering purposes. More research was suggested to determine the various combinations of behavior and conditions which may get drivers into accident situations.

To reduce the subjectivity of defining a near-miss accident, a frame of reference was developed for distinguishing degree of danger of traffic events. A parameter termed time-measured-to-collision or time-to-accident (TA) was developed by Hayward in 1972 (44). The TA is the time required for two vehicles to collide if they continue at their present speeds and on the same path. Calculation of the TA may be performed at any instant within the excursion. A high TA represents a small amount of danger since ample time is available to react and avoid a collision. A low TA indicates that extreme evasive reaction is necessary to avoid a collision.

Events of near-misses were filmed in the Hayward study using two television cameras positioned on opposite corners of the intersection of 14th and F Streets in Washington, D.C. Continuous monitoring was used, and near-miss accidents were transferred onto 16-mm motion picture film for further analysis. Observation periods were from 9:30 a.m. to 1:00 p.m. and 2:00 p.m. to 4:00 p.m. on two test days; a total of 90 suspected near-misses were recorded, and 43 were later analyzed. The parameters determined for each vehicle for every point in the near-miss sequence were velocity, acceleration, coordinate positions, spacing, and time-to-accident.

A numerical minimum time-to-accident was considered to be approximately 1/2 second, which corresponds to the time required for one driver to apply his brakes. Minimum TA's were found to be as low as 0.20 seconds for the near-misses, and 15 of 43 events had TA's at or below 1 second. The average of the TA minimums was 1.46 seconds and the median TA value was 1.25 seconds. The near-miss types were classified in one of the following categories:

1. Rear-end occurs when a following vehicle is forced to stop suddenly to avoid an accident.
2. Lane-change, in this instance, is where a slow vehicle changes lanes into the path of a faster vehicle, causing it to either slow or swerve to avoid a collision.
3. Cutoff occurs when a vehicle turns in front of another vehicle, causing it to alter its motion.
4. Broadside is when a vehicle passes into the intersection on the amber phase and blocks the cross street.
5. Right-of-way occurs when two drivers proceed to the same point and refuse to grant a clear path to the other.

The suggested criterion for designating a near-miss accident was 1 second. At the test intersection, the number of near-miss accidents meeting this criteria per hour was 3.5, which corresponded closely with the number of accidents per year, which was 4. Near-misses were determined to be valid indicators of the danger of two-vehicle interactions. Recommendations were made for establishing an ongoing program to routinely count near-miss accidents.

Another study using the concept of time-to-accident to determine the seriousness of traffic events was by Hyden in Sweden in 1975 (45). There, events were defined as conflicts and serious conflicts, and a serious conflict corresponded to definitions by others of a near-miss accident. Serious conflicts were graded by two criteria: TA less than 1 second, and TA between 1 and 1.5 seconds. Attempts were also made to classify conflicts for the two TA criteria by speeds below 22 mph (34 km/hr) or above 22 mph (35 km/hr). In the Hyden study, data were recorded by trained observers at 50 intersections. Observations were made between 9:00 a.m. and 6:30 p.m. with one or two observers at each site. Intersections were classified by signal control, traffic speed, and sight conditions. Because of the poor reporting of non-injury accidents (estimated at 25 to 50 percent), only injury accidents were used for comparisons with conflicts. All accidents and conflicts were classified by means of transport (car-pedestrian, car-car, car-bicycle, etc.), time of day, and vehicle movement (straight or turning). A total of 247 accidents and 765 conflicts were analyzed. Correlations were made between accident data (injury accidents only) and severe conflicts (near-miss accidents) for the 50 intersections in Sweden. Using regression analyses, r-values were quite low. However, after redefining the variables with respect to speed and means of transport, r-values of around 0.73 were found. The major problem with correlating accidents and near-miss accidents was the inadequacy of the available accident data.

ADVANTAGES AND LIMITATIONS

Since the number of conflicts at a site is related to traffic volumes, the use of conflict rates may be more desirable for analysis purposes. However, a large sample of conflict data is necessary to determine what conflict rates are unusually high for various types of locations. Thus, the use of conflict and accident data together may be most beneficial for identifying hazardous locations. Careful training of observers is also essential for accurate counts of traffic conflicts.
As mentioned previously, there are several advantages to using conflict, erratic maneuver, and near-miss accident data in traffic engineering studies. These data provide up-to-date information in as little as one day of observation. The techniques allow determination of specific traffic problems which may not be discernible from accident data. Some studies have shown conflict counts to be better predictors of future accidents than past accident records, particularly at low-volume and rural intersections. The most promising uses of conflict data appear to be in identifying specific geometric deficiencies at a site and for evaluating safety improvements shortly after they are installed. When used along with accident data, counts of conflicts, erratic maneuvers, and near-miss accidents provide a better understanding of safety needs so that money for safety improvements can be expended in a more cost-effective manner.

REFERENCES

3. Zegeer, C. V.; and Deen, R. C.; Traffic Conflicts as a Diagnostic Tool in Highway Safety, submitted for publication to the Transportation Research Board, November 1977.
22. Mamlouk, M. S.; Right Turn on Red: Utilization and Impact, Purdue University, June 1976.
23. Cooper, P. J.; Effects of Increased Enforcement at Urban Intersections on Driver Behavior and Safety, Record 540, Transportation Research Board, 1975.
34. Cornette, D.; Operational Characteristics of Lane Drops, Kentucky Department of Highways, Division of Research, August 1972.
APPENDIX

DATA SHEETS FOR SUPPLEMENTAL INFORMATION AT INTERSECTIONS (FROM THE GM TECHNIQUE)
Figure A1. Traffic Conflicts Data Sheet from GM Technique (8).
Figure A2. Volume Data Sheet from GM Technique (8).
| Figure A3. Data Sheet for Inventory of Existing Highway Features from GM Technique (8). |
Figure A4. Data Sheet for Inventory of Intersection Improvements from GM Technique (8).
Figure A5. Accident Data Sheet from GM Technique (8).
Figure A6. Photograph Sheet from GM Technique (8).