Analysis of Traffic Conflicts and Collisions

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Parameters intrinsic to the sequence of events leading to vehicle collisions and traffic conflicts are investigated in an attempt to develop a more practical and reliable application of the traffic conflicts technique. Sequences of collisions and conflict events were videotaped and are analyzed in detail. Preliminary investigations reveal that using the common method of brake application is not adequate for describing conflict. As a result, seven methods of defining a conflict situation are introduced and evaluated. It is concluded that at least two of the proposed methods will provide a practical investigative tool that explains accident occurrence better than brake application.

Since its introduction by the General Motors Research (GMR) laboratories in 1967 (1), the traffic conflicts technique (TCT) has been employed by many traffic engineers as a method of measuring the degree of hazard at a roadway location. This permits corrective action to be taken and avoids the undesirable practice of waiting for accident information to accumulate.

The GMR procedures defined a traffic conflict in a way that included visible evasive actions taken by drivers and the occurrence of traffic violations. It was suggested that evasive actions be identified by brake lights or lane changes. Traffic violations were automatically recorded as conflicts regardless of the presence of other conflicting vehicles. This original definition of traffic conflicts was apparently well received and adopted by traffic engineers for use in numerous other studies (2, 3, 4, 5).

However, using brake application as the principal descriptor for the TCT procedure is unsatisfactory and has failed to gain global acceptance as a collision-predicting model. Alternative parameters such as time measured to collision (TMTC) and time to accident (TA) have been proposed (6, 7). These methods, too, do not appear to satisfy all the requirements of an acceptable TCT method that is capable of reliably explaining collision occurrence.

This paper briefly presents the results of a 2-year research effort conducted to develop a more reliable application of the TCT procedure (8). Fundamental weaknesses inherent in present TCT methods are identified and discussed. Since the most serious deficiencies involve the capability of properly explaining collision occurrence, a sequence of events leading to a collision is hypothesized and related to seven methods for describing a conflict situation.

The development, analysis, and evaluation are based principally on detailed investigation of actual collision and conflict events recorded by video equipment over an extended period of time. A comprehensive evaluation of the proposed TCT methods is presented, and recommendations for future development are made.

CRITIQUE OF EXISTING TCT METHODS

Using brake indications to measure traffic conflicts has several indisputable advantages. Brake applications can be easily identified and counted; subjectivity in data collection can be avoided; and brakes are applied in all categories of conflict types. This method, however, is often affected by several undesirable characteristics as well.

First, braking habits may vary from driver to driver. Some drivers are very cautious and may apply brakes on entering an intersection regardless of the hazard present, while others may not brake even when presented with a very hazardous situation. Consequently, it is possible that one could falsely identify such situations in terms of conflict.

Second, braking produces only an on-off or binary set of information that does not permit further distinction regarding the severity of a conflict situation. An abrupt brake application to avoid an imminent collision and an unnecessary precautionary application will therefore receive the same rating unless a completely subjective rating scheme is introduced.

Third, deceleration evidence by brake application is not always a wise evasive action. In some conflict cases, as witnessed in an actual collision to be discussed later, acceleration rather than deceleration might be a superior reaction to avoid a collision. Had an acceleration action taken place in such a case, it would not have been identified as a conflict by the present TCT method.

Fourth, the common procedure of observing brake application by only one of the vehicles involved in a conflict situation (by definition, the vehicle with the right-of-way), information describing the actions of the other vehicles involved is lost. Collisions are occasionally precipitated by the party with the right-of-way, such as a through vehicle that speeds toward an opposing left-turning vehicle but applies no brakes. In such cases the driver with the right-of-way may not apply his brakes, and the situation will not be considered as a conflict by the present TCT method.

There are other weaknesses. Brake lights may not be visible because of mechanical failures. The purpose of braking is also sometimes not identifiable. In some cases, application is only for the purpose of obeying traffic signal indications, while in others brakes are applied for purposes of avoiding a collision in a conflict case.

Principally because of the inability to grade the severity of a conflict situation, alternative methods have been proposed. The Transport and Road Research Laboratory (TRRL) in Great Britain introduced a modified procedure in which all conflicts were graded into five classes according to perceived severity of the event (2, 3, 4).

Hayward (6) suggested that the TMTC between two vehicles involved in a hazardous event could be employed as a reasonable scale to judge the severity of near-miss cases. The TMTC value typically varies in a dynamic mode as both drivers react to each other and reaches a minimum at the moment closest to a collision.

Hydén (7) introduced a similar term, TA, which was defined as the time that would have passed from the moment at which a driver reacts and commences a braking or turning action until the moment the collision would have occurred, if both parties had proceeded with approach speed and direction unchanged.

Although these methods can grade the severity of the conflict situation, they have critical limitations. The TRRL method would be influenced excessively by subjective decisions. The TMTC or TA are also theoretically incomplete, since the methods are based on the time measured up to the expected moment of collision. Such measurements become infinite values in the cases where collisions would have been avoided even by a fraction of a second.

For example, if two vehicles are in a situation where a collision could be avoided by only 0.1 s if no evasive action were taken, TMTC or TA would be identified as infinite simply because the expected collision time is interpreted to be nonexistent. Also, these methods require accurate speed information for interacting vehicles, which is usually difficult to obtain.

COLLISION ANALYSIS

Based on the above reasoning, exploring alternative means of defining traffic conflict situations appeared warranted. This was attempted by examining actual collision and conflict scenes monitored by video equipment. Observation was concentrated on events in which left-turning vehicles conflict with opposing through vehicles. A video camera, installed permanently at a busy intersection in Toronto, recorded traffic movements continuously by time-lapse photography and collected collision scenes. The observation period extended from October 1975 to December 1976. A total of 25 collision scenes, including 9 left-turn collisions, were recorded in this way.

A typical left-turn collision is described below and is depicted in the time-space diagram in Figure 1 and in the simulation in Figure 2. In this event, the left-turning vehicle on the eastbound approach collided with a westbound through vehicle approaching at a speed of 82 km/h (51 mph). The left-turning vehicle had waited for a gap since the beginning of green and approached slowly to the middle lane of the three through lanes (lane 2). The vehicle then moved rapidly into the outer through lane (lane 1), hitting the side of the through vehicle. The through vehicle was pushed aside more than one lane width by the impact. The sight line of the left-turning driver was blocked briefly by a van in the opposite left-turn lane approximately 5 s before the collision. It was also observed that, if the through vehicle had proceeded with its original speed of 82 km/h without any deceleration, the collision might have been avoided.

Other left-turn collisions recorded by the video camera were also analyzed. Of the nine collisions recorded, five occurred during the red signal and one occurred in the third second of an amber clearance interval. One occurred as a result of the second left-turning vehicle attempting a so-called "rabbit jump" at the commencement of the green, and the last one seemed to result from an improper left turn that began from the outer third lane from the center line of the approach.

It became apparent from the above that left-turn collisions often occur (or the process begins) during the clearance interval. Drivers apparently panic and attempt to clear themselves quickly from the intersection. As seen above, six out of nine left-turn collisions occurred in an amber or a red period.

COLLISION GENERATION PROCESS

After the recorded collision scenes were analyzed, conflict situations monitored by the same equipment at the same location were examined in a similar manner.

A traffic conflict has generally been described as a situation in which the driver perceives that evasive ac-

Figure 1. Time-space diagram of the left-turn collision on November 24, 1975.

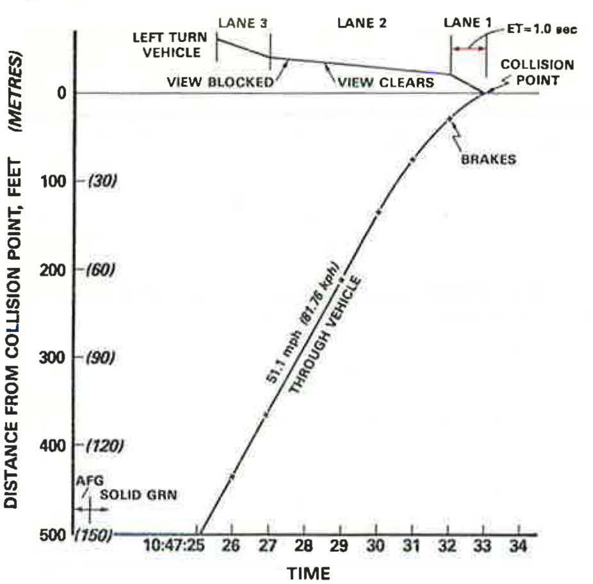
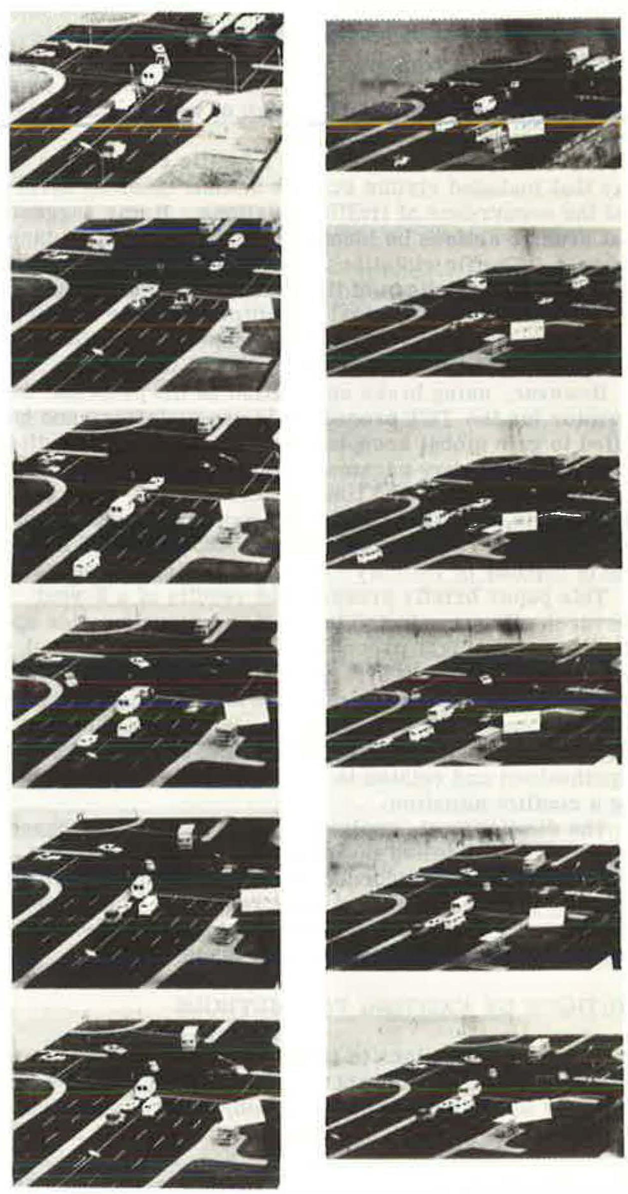


Figure 2. Simulation of the left-turn collision on November 24, 1975.



tion is required to avoid a collision or to secure a safe maneuver. Evasive action may be decelerating or weaving or any other move that the driver considers useful and expedient. In some cases such actions may not be directly or easily observable, and in others collisions may occur without evasive action being taken.

Therefore, the currently accepted concept of traffic conflicts, which is based on observable evasive actions, may fail to include all cases that could lead to a collision. This is obviously a very undesirable situation, since conflicts should comprise a population of events within which collisions reside. Thus definitions that allow for the occurrence of a collision not preceded by a conflict are not desirable. The flow diagram in Figure 3 illustrates this point. It should be noted particularly that the logic depicted in the diagram identifies potential for a collision even when evasive action is not taken.

In an attempt to further qualify and quantify a conflict event, consider the time-space diagram of a left-turning and a through vehicle in Figure 4. The through driver would perceive the potential for a collision, take evasive action usually by reducing speed (the deceleration rate being in accordance with the perceived severity of the potential), succeed in avoiding a collision, and thus terminate the conflict situation. The driver will then attempt to recover his previous driving condition by accelerating (if he previously decelerated as an evasive action).

Figure 3. Collision generation process.

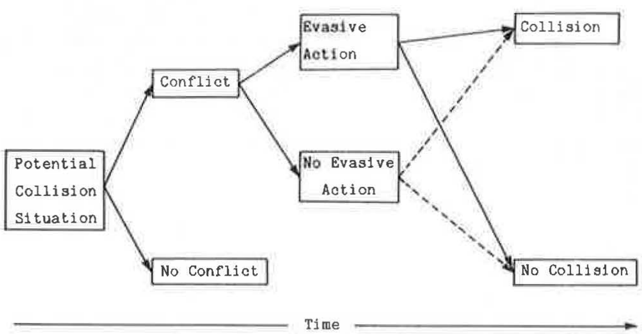


Figure 4. Time-space diagram of a typical left-turn conflict.

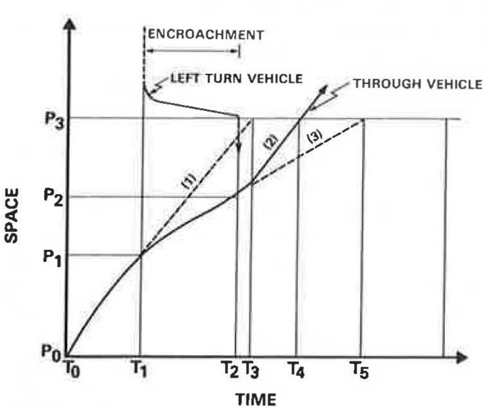
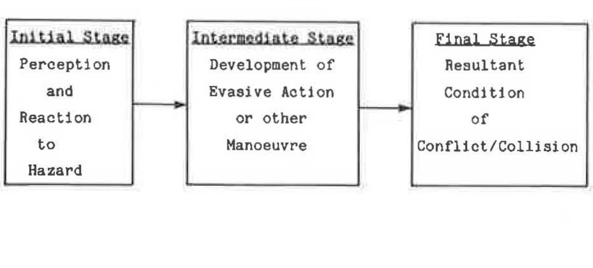


Figure 5. Sequential development of a conflict-collision event.



More specifically, the through vehicle in this example perceives a potential conflict at location P_1 at time T_1 as the left-turning vehicle encroaches on the occupied through lane. If the through vehicle were to maintain the approach speed V, it would arrive at the potential collision point at time T_3 as depicted by the dashed line 1. Assuming that the left-turning vehicle had cleared the through lane by time T_2, the through vehicle would have missed the collision by a gap time $(T_3 - T_2)$.

Obviously, if the through vehicle had traced line 1 with an insufficient gap time, a collision would have occurred as in the situation presented in Figure 1. However, in the case shown, the driver of the through vehicle considered such a gap time too short and accordingly decelerated. Upon observing that the left-turning vehicle had cleared his path and was no longer encroaching, or at least confidently predicting the end of encroachment, the driver accelerated to recover his desired speed. This behavior is traced by the solid line 2. If the vehicle had not accelerated after the encroachment, the time-distance trace would be the dashed line 3.

Observing this relatively typical example, one can easily perceive that a conflict situation should be described as a series or sequence of identifiable events, as suggested in Figure 4, rather than as the occurrence of a single event.

In the initial stage of a conflict, a specific situation is perceived by the drivers involved. This generally results from an unexpected action by one party offending the other. Encroachment on a through lane by a left-turning vehicle is a typical offending action against the through vehicle on the same lane. The degree of hazard perceived by the drivers in this initial stage will of course contribute to subsequent developments throughout the conflict situation, but it will not wholly dictate the outcome of the event sequence.

Given the circumstances that evolved during the initial stage, the drivers involved would subsequently react in an intermediate stage by attempting to further correct the remaining hazardous situation. The success of this attempt would depend on their degree of driving skill, the degree of hazard remaining from the initial stage, and the impact of any new circumstances surrounding the event.

The sequence of events that occurred during the initial and intermediate stages will result in a condition in the final stage (Figure 5). If a very hazardous situation had been faced in the first stage and the drivers did not react effectively, then a near-miss or a collision would have occurred as a result.

According to this notion of events sequentially leading to a final conflict situation, one can imagine the usefulness of measurement parameters capable of describing one or more of these stages. For example, brake application is perhaps indicative of events in the intermediate stage but does little to describe events in the final stage.

In order to specify traffic conflict parameters that adequately describe the events in various stages of the development of a collision or conflict, several measurements were proposed and investigated. A discussion of these measurements is presented in the following section.

PROPOSED TCT MEASUREMENTS

When a hazardous situation is perceived in the initial stage of conflict development, the vehicles involved will try to stop or decelerate to avoid a collision. The capability of stopping is a function of the available stopping distance, which is determined by the approach speed, the attained deceleration rate, and the distance remaining to the collision point.

Specifically, the ratio of the distance available for a driver to maneuver to the distance remaining to the projected location of collision should describe the seriousness of the given situation. This ratio is defined as the proportion of stopping distance (PSD) and is given by

$$PSD = RD/MSD \quad (1)$$

where

PSD = proportion of stopping distance, or the ratio of RD to MSD,
RD = remaining distance to the potential point of collision,
MSD = acceptable minimum stopping distance = $V^2/2D$, and
D = acceptable maximum deceleration rate.

As an example, a PSD value of 0.50 would mean that the driver would have only half the acceptable minimum stopping distance at a chosen maximum deceleration rate, whereas one needs a PSD value of 1.0 or more to stop safely before the expected collision point. The PSD values were measured at time T_1 in Figure 4, the moment when the left-turning vehicle starts to infringe upon the right-of-way of the through vehicle.

A measure of the gap time (GT) as illustrated by the vector T_3-T_2 in Figure 4 could also describe a conflict event in the initial stage of development. (The term "gap time" should be distinguished from the term commonly used in gap acceptance.) Time T_3 denotes the time at which the through vehicle was expected to arrive at the potential point of collision provided the vehicle had maintained the original approach speed and direction. Time T_2 is identified as the time at which encroachment by the left-turning vehicle on the through lane ended. By virtue of this definition, GT could assume a positive or a negative value.

It seems intuitively obvious that GT would adequately describe the potential for a collision. For example, a large positive gap time would indicate that a long time duration exists between the end of encroachment and arrival of the through vehicle at the potential point of collision, and vice versa. Therefore one could assume that the severity of the conflict or the potential for a collision was indicated by the magnitude of the GT value.

Encroachment time (ET) is defined simply as the time during which the left-turning vehicle infringes upon the right-of-way of the through vehicle. In Figure 4 this can be identified as the time T_2-T_1. Presumably, ET would be an accurate reflection of conflict severity only if all through approach speeds were uniform and the position at the commencement of each conflict identical for all vehicles. If such were the case, a relatively long ET would indicate a relatively severe conflict, since this would cause the through driver to decelerate substantially. Although such speed uniformity assumptions are not expected to hold true in reality, ET would describe driver actions in the intermediate stage of the conflict development depicted in Figure 5.

A method identified as the "zonal braking technique" was employed in an attempt to grade conflicts according to severity based on the location where the evasive action (brake application) took place. Assuming that the approach speeds of through vehicles do not vary widely, one would intuitively think that an evasive action taken farther away from the point of potential collision would constitute a less severe conflict situation than one taken closer to the collision point. Using this logic, one could conceive of zones within which a brake application would represent a conflict of specified severity.

The deceleration rate (DR) is an event that occurs during the intermediate stage of a traffic conflict and can be interpreted as indicative of the severity of the situation. Although it may vary from driver to driver, rapid deceleration will generally occur in a severe situation, whereas moderate deceleration normally implies a minor occurrence.

Post encroachment time (PET) for a conflict is identified as the time from the end of encroachment to the time that the through vehicle actually arrives at the potential point of collision (T_4-T_2 in Figure 4). This is an obvious measurement of how nearly a collision has been avoided. PET is also a suitable measurement for identifying the resulting events in the final stage of a traffic conflict. Although it directly describes neither the situation defined in the initial stage nor the action taken by the drivers in the intermediate stage, it does represent the result of the combined effects of the two earlier stages. For example, a PET value approaching zero demonstrates that a collision was avoided by only the very smallest of margins. This could result from a very severe situation perceived in the initial stage, a very poor driving maneuver during the intermediate stage, or a combination of the two.

Although PET does give a reasonable indication of the severity of a conflict, the value could be affected by the common driving habit of accelerating during the termination of a conflict. Therefore, it could become a better measurement by eliminating such early acceleration effects. This could be accomplished if one were to use the initial deceleration rate as a forecast of the initially attempted post encroachment time (IAPE) as identified by T_5-T_2 in Figure 4. Using this notion one can identify IAPE as

$$IAPE = T_5 - T_2 \quad (2)$$

$$T_5 = T_1 + (P_1P_3/V_2) \quad (3)$$

where

T_1 = time of commencement of encroachment,
P_1P_3 = distance from the location of the through vehicle at the beginning of encroachment to the potential point of collision, and
V_2 = average speed of the through vehicle during the period of encroachment.

Each of the preceding conflict measures incorporates a degree of weakness by its very definition. However, it was felt that each had the potential to more adequately explain collision occurrence than the conventional brake application procedure. In particular, one would expect that those measurements that identified events in or near the final stage of the conflict-generation sequences would possess the greatest explanatory power.

To evaluate the suitability of each candidate measure, several hundred conflict events were thoroughly analyzed, measures compared, and relationship to collision history examined. A detailed discussion of that evaluation is contained in the following section.

EVALUATION OF CONFLICT MEASUREMENTS

The significance and applicability of the measures discussed above were examined by selecting a total of 347 left-turn conflict events from 2 weeks of video records. For each event all values of the parameters were obtained. Several statistical analyses were applied to

Table 1. Summary of criteria evaluation.

Criterion	Ranking 1	2	3	4	5	6
Relation to collision history	PET	GT	DR	IAPE	ET	PSD
Relations among other measurements	ET	GT	IAPE	PSD	PET	DR
Consistency over time	GT	PET	DR	IAPE	PSD	ET
Relation to brake application	GT	ET	PET	DR	IAPE	PSD
Ease of measurement	PET	ET	DR	GT	IAPE	PSD
Applicability to other conflict types	DR	PSD	GT	PET	ET	IAPE
Final rating	GT	PET	DR	ET	IAPE	PSD

evaluate the conflict measures according to the following criteria: (a) relation to collision history, (b) relations among candidate conflict measures, (c) consistency among different days' observations, and (d) relation to brake application technique.

In addition, the measures were evaluated in terms of ease of field observation and applicability as a measure of conflict types other than left turns. A summary of the evaluation according to all criteria is given in Table 1.

Collision history for westbound through vehicles and opposing left-turning vehicles at the study site was compiled for the previous 4 years. The compiled collisions and conflict measurements were ranked by time of day (three periods) and by lane position (three lanes) into a nine-cell matrix. Correlation of conflict measurements with collision history was computed by using the corresponding nine elements. The highest correlation coefficient, 0.495, went to PET and the lowest, 0.413, to PSD. Neither the overall correlations among collision and conflict measurements nor the differences among the measurements were sufficiently significant to allow any strong conclusions.

If we assume that the conflict measures introduced in this paper are all reasonable and independent, the correlation between the parameter values should give an indication of their suitability. To investigate this relationship, the same analysis technique used above was applied to the different conflict measures. On an average, ET had the highest correlation coefficient value, 0.53, to all other measurements. The lowest was DR with 0.28. However, taking the results from other analyses into account, we considered that PSD and GT were among the most highly evaluated methods, based on the relation to other measurements.

Since the TCT procedure normally utilizes 1 or 2 days' observations, consistency among different days of data collection is a desirable trait for an ideal measurement. Hourly and daily variations in observations were computed for each measurement, and the variance expressed as a percentage of the mean was computed. GT rendered the lowest variation, while ET produced the poorest result.

The average values of all measurements, classified by whether the brakes were applied or not, were compared. One intuitively thinks that the population with brake application should yield more severe parameter values than that without brake application. All measurement values agreed with this intuitive notion, with GT and PSD being respectively the most and least closely conforming measures.

While all proposed measurements could be most precisely obtained by using sophisticated observation techniques such as video recording or other time-lapse photographic methods, it appears to be completely feasible to measure at least PET, ET, and DR with simpler devices. At the simplest level, values of PET and ET can obviously be obtained by manual observation with a stopwatch. A device composed of a multichannel event recorder and specially adapted dual tape switches has been used in other research projects to obtain DR, among other data. The other measurements are not so easily obtained and would create considerable difficulties in collecting vast amounts of data.

With respect to the applicability to other conflict types, it should be noted that the development of conflict measures in this study was based on the notion of a fixed potential collision point and the time periods from beginning to end of encroachment upon the through lane. Therefore, for a conflict type for which such baseline information is not readily observable, such as a moving rear-end conflict situation, all proposed measurements are not applicable. However, it is easy to conceive of a slightly different definition of the encroachment period for right-turn and crossing conflicts. By doing so, the proposed methods could be readily adopted.

An evaluation summary of the different measurements is shown in Table 1, which lists the measurements in order of perceived performance. When the ranking was not obvious from the more quantitative information available, subjective judgments were applied to establish the ranks. The resulting rating for each measurement was determined by comparing the total numerical values of ranking obtained for each evaluation criterion. No differential weighting to either the ranks or the evaluation criterion was applied in the sum. In this way, the lowest sum of the scores was assumed the best. Although this is obviously a very crude comparative tool, it does give an overall indication of relative merit.

It can be seen that GT and PET are the most highly evaluated measurements, while PSD and IAPE are the lowest. By considering that deceleration results from brake application and by accounting for the relative ease of measurement and applicability to other conflict types, one could say that the conventional brake application technique would be in a slightly higher than average rank.

CONCLUSION

Although substantial efforts were made to objectively identify the precise sequence of events surrounding traffic conflict and collision situations in quantitative terms, many conclusions were based, in part, upon more qualitative assessments. Although this immediately implies that a degree of caution in interpretation be invoked, we feel confident that experience gained from this project has properly guided the statements that follow.

Perhaps the most controversial aspect of this study has been rejection of conventional brake application methods for the TCT. It is apparent that the assessment of alternate conflict measurements presented in the preceding section did little to firmly convince anyone that the "new" techniques should perform more satisfactorily as predictive methods.

The lack of confidence likely to be generated about this point can be attributed in large measure to the absolute size of the available collision record. Since the intersection site chosen was in a city of very large size and the collision history was the most active of all possible locations in that city, one can quickly become convinced that attempts to confidently correlate conflict measures with collision experience will never be successful. It would logically follow, then, that low correlations can always be expected and that brake-light counts are just as acceptable a technique as any other. This view is likely to be particularly appealing, since a ponderous momentum of approximately 10 years of TCT experience with brake application methods is currently in force.

However, one cannot ignore the completely sound conceptual notions presented earlier. Those notions clearly negate all arguments for continued use of conventional TCT brake application counts and will not be repeated here. It is sufficient to summarize by stating that the proposed techniques by definition can explain collision and conflict mechanisms in a more rational manner. In this regard, PET seems to hold the greatest potential as a conceptually sound descriptor while retaining considerable ease of field measurement.

As a result of this and extensive discussions presented by Allen and Shin (8), we concluded: Enumeration of brake applications is not an acceptable traffic conflict measurement technique for the TCT.

This conclusion is particularly pertinent when one considers the definition requirement that all collisions must be preceded by a conflict. A collision is in fact the most severe category of conflict possible. Clearly, brake application does not precede all collisions and is therefore an inadmissible measure.

RECOMMENDATIONS

The major task facing researchers and practitioners in the immediate future is to apply the proposed TCT under a wide variety of environmental conditions at several intersections so that acceptable estimates of the probability of collision occurrence can be derived. It is obvious that the range should include a variety of locations representing a variety of traffic, geometric, and control characteristics for a variety of conflict types.

This implies the need to standardize the measurement technique and method as quickly as possible so that several agencies may undertake the studies and still retain complete data compatibility. As noted earlier, collection of PET measurements is a relatively simple task, and it is anticipated that relatively little effort will be required to collect the vast amounts of data necessary for establishing relationships.

Finally, the applicability of PET measurements to other conflict types should be investigated in more detail. Although earlier suggestions were made in this report regarding transferability, firm procedures must be established and tested.

As a result of experience and insight gained by the study team during the project, we recommend that

1. Post encroachment time (PET) as defined in this report be thoroughly investigated as the principal traffic conflict measure for the TCT (DR is also worthy of investigation if one assumes that suitably portable tapeswitch mechanisms can be used),
2. Modest research efforts be undertaken to develop, test, recommend, and apply PET to conflict types other than left turns, and
3. Relatively major efforts be undertaken to collect large amounts of PET conflict data for a variety of conditions to establish a data base on which derivation of collision probabilities can be confidently estimated.

There is no doubt that several of the statements presented in this report will be subjected to severe criticism. However, we feel that the results of an intensive research effort conducted over the past 2 years have justified those statements. In particular, we feel that the traffic conflicts technique does indeed hold promise as a reliable predictive and evaluative tool for traffic engineers, provided that the appropriate measure of traffic conflicts be used. To this end, we suggest that post encroachment time as defined here is the appropriate measure and is capable of explaining more about collision occurrence than brake application alone can. All that remains is to use this very practical procedure expeditiously and comprehensively.

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Mr. Said M. Easa receives our sincere thanks for the many tireless hours he devoted during the often frustrating development work on conflict concepts in late 1975 and early 1976. His assistance was indeed valuable, timely, and very much appreciated.

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Discussion

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Because of the unreliability of accident records and other problems associated with using accident data to estimate the relative safety of highways, other, more inexpensive, but reliable measures to describe events that may lead to traffic collisions have long been needed for the effective management of highway safety. The authors are to be congratulated for their efforts in deriving seven new descriptors for measuring safety at intersections. Their presentation of the collision generation process (Figure 3) and their sequential development of a conflict-collision event (Figure 4) are especially appealing concepts. However, their conclusions appear not to be warranted by the data presented.

In their concluding remarks, they reject the use of brake applications as an acceptable technique for measuring traffic conflicts. The study data do not adequately support this conclusion for the three reasons given below.

First, one of the authors' reasons for rejecting the brake application technique is based on data and experience gained by observing conflict-collision events on one approach at one Toronto intersection. In fact, their evaluation of the new safety measures, as well as the brake applications, was limited to only the left-turn conflict situation at that approach. The problems associated with using such an extremely limited data base to develop general conclusions are obvious. Results obtained by observing a single condition at any given site may be related to inherent characteristics of the driver-vehicle-environment system that exist at that site. If the authors had used all conflict events—cross traffic, rear end, left-turn, etc.—or the left-turn conflict at several intersections with a variety of traffic and geometrical configurations, the resulting rating (Table 1) of the measures might have led to other conclusions. Because of the limited data base, it is doubtful that any general conclusions are justified.

Second, in describing the collision generation process, the authors point out that the current method of observing evasive maneuvers may fail to include all cases that could lead to a collision. Because of this deficiency, they conclude, the conventional definitions are undesirable. Conceptually, this deficiency may be a good reason for rejecting the brake criterion. However, the authors do not test the hypothesis with data collected during their observations. For example, if their data indicated that some of their conflict-collision observations were not preceded by the application of brakes, this information would have been useful in supporting their conclusion. Without these data, one can only speculate that the deficiency is serious enough to cause rejection of the brake application technique.

Third, evaluation of the data for the study site does not provide sufficient evidence to warrant rejection of the brake application technique. Correlation coefficients computed for the new measures and accidents were low; for example, PET had an r value of 0.495. Other researchers have reported correlation values of similar magnitude between the brake-light counts and accidents (2, 3, 4, 5). Thus, as the authors mention, the new measures are not superior to brake-light indicators as accident predictors. The authors also point out that, considering the ease of measuring and applying the technique to other types of conflicts, brake applications could be interpreted as having a slightly higher than average rank when compared to the new measures.

The authors' recommendation that PET is an appropriate conflict technique capable of explaining more about collision occurrence than brake applications is also questionable. The recommendation is based on the analysis of only the left-turn maneuver and was not applied to include other major conflict types commonly found at intersections. The authors admit that the new measures are not applicable for the moving rear-end conflict situation. This discrepancy may prove to be a major fallacy in the proposed measures, because rear-end conflicts and accidents are, on the average, major events at intersections.

The study is based on the premise that the traffic conflicts technique can be used as a practical and reliable predictor of collisions. The low correlations between the new measures and accidents indicate that either the measures are not closely associated with accidents or the accident-reporting procedures are unreliable. Although 25 collisions were recorded, the authors did not give the number of accidents reported as a result of the collisions. A record of the discrepancy between observed and reported collisions would be useful in estimating the unreliability of accident records.

This discussion is not intended to discourage development of new safety measures or to support continued use of brake applications as the appropriate traffic conflicts descriptor. The authors have correctly identified problems associated with brake applications. However, it should be noted that the new measures also contain deficiencies.

Because highway accidents are often the result of complex events, no single measure can adequately explain the occurrence of collisions. Ultimately, the integration of several measures may provide a better accident descriptor. It is also possible that a more practical and reliable use of traffic conflicts measures would be evaluating highway operating and safety improvements instead of predicting accidents. These hypotheses must be thoroughly investigated before researchers and practitioners can either accept or abandon the traffic conflicts technique.

Authors' Closure

While there is no denying that collisions and the number of brake applications at a location are positively associated, it has been shown by a number of researchers that the correlation is not independent of the influence of traffic volumes. In fact, the degree of dependence is very great. This, coupled with another known phenomenon, that in a significant proportion of accidents no evidence of prior braking on the part of one or both vehicles can be found, leads logically to our decision to explore the chain of events leading up to collisions for clues as to which parameters can be employed for predictive purposes.

As such, this study was never intended to produce a definitive statistical assessment. Rather, the project was to serve as a pilot investigation into identifying suitable traffic conflicts concepts worthy of further, more detailed investigation. We anticipate that such additional work will commence this year. The standard against which success of any new technique will be judged is of course defined by the performance of established methods, such as the counting of brake applications that GMR developed.

We thank Martin Parker for his thoughtful discussion, which virtually amplifies several important issues already identified by the study team and referred to in the paper. It is particularly interesting to note that Mr. Parker has expanded upon precisely those issues of greatest concern to the authors, concerns that will be explictly accounted for in the continuing research effort mentioned previously.

However, despite the stated preliminary nature of the study, we did look in detail (8) at the specific relationships questioned by Parker. For example, less than 30 percent of the conflicts studied exhibited observable brake applications. Although this statistic surely lends itself to the premise that brake application alone is at least conceptually inadequate, it should be noted that the percentage increased as conflict severity increased, indicating a degree of positive correspondence.

Parker also raised an extremely important point concerning the adequacy and availability of police collision reports. In our study, all police reports of collisions occurring during the data collection phase were obtained. Of some 20 police reports, only eight collisions were identified by scanning the video records. This was caused by a combination of equipment failure, night recording conditions, and the fact that our records covered only one approach at the intersection. Perhaps more significantly, the police records did not contain information on 17 (68 percent) of the collisions identified by the video records. The implications of such a weak correspondence for correlation between conflict and collision occurrence are obvious.

Finally, we agree completely with Mr. Parker when he states that important hypotheses on use of the traffic conflicts technique "must be thoroughly investigated before researchers and practitioners can either accept or abandon" the procedure. Emphasis on the words "either" and "or" is extremely important, and we hope that this approach will guide future research into this very interesting and important traffic safety topic.

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Abridgment

Evaluating Highway Guide Signing

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Wallace G. Berger, U.S. Senate Appropriations Committee

An operational method for the field evaluation of highway guide signs that is readily applicable by traffic engineers or researchers was developed on the basis of valid measures of effectiveness (MOEs) and sensitive, off-the-shelf data-collecting techniques.

The need for this method arises from the diversity of approaches in previous guide sign evaluations and the lack of an established, uniform, valid method for appraising results. A recent NCHRP effort (1) addressed this problem through a literature synthesis, the field development of guide-sign MOEs, and a sensitivity assessment of applicable data-collecting techniques. The product of this effort is the evaluation method reported here.

MOEs OF GUIDE SIGNS

The field development of measures established four types of vehicle behavior at interchanges as guide-sign MOEs. Each is listed and operationally defined in Figure 1, which summarizes the evaluation procedures. An analysis of over 1100 interviews that compares responses of drivers behaving in these ways with those of drivers not behaving in any of these ways revealed group differences linking driver guide-sign responses with each type as follows:

1. Gore weave and high-risk gore weave: (a) greater information-processing difficulty with all guide signs on interchange approach, (b) less certainty of action response to all guide signs on approach, (c) less time available to read and respond to intermediate exit direction guide signs, (d) lower preference rating for intermediate exit direction guide sign, and (e) less likelihood of detecting at least one guide sign.
2. Late lane change: (a) greater information-processing difficulty with at least two guide signs and (b) less certainty of action to be taken to gore-located exit direction guide sign and one advance sign.
3. Driving slowly: (a) greater information-processing difficulty with at least one guide sign and (b) lower preference rating of gore-located exit direction sign.

FIELD STUDY APPROACH

There are currently two approaches for examining the effects of a traffic control device: a study and an experiment. A study is an examination of effects only at the site where the device is installed. Generally, before-and-after observation at the site would form the basis for a judgment regarding the effectiveness of the new guide sign. An experiment, on the other hand, involves simultaneous before-and-after observation at another location (control site) not receiving the treatment. The advantage of the experiment is to permit insight into other changes in traffic behavior that are not caused by the new sign.

Data-collecting methods and guide-sign MOEs suggested here are equally applicable to a study and an experiment. Although the experiment is favored in view of the increased sensitivity of the MOEs to a signing change, a study may apply in situations where control of spurious effects is not considered necessary. The before data-collecting period must closely follow the signing change, and the after period should allow for a minimum adjustment period of 30 d. Before-and-after data-collecting periods must be matched by time of day and day of week. Sound experimental procedure dictates that these periods occur exactly 52 weeks apart. It is important that all data be gathered concurrently at the test and control sites to maintain the experimental integrity of the design.

DATA COLLECTION TECHNIQUES

Statistical reliability of off-the-shelf techniques was obtained by comparing the data with those of the traffic evaluator system (TES), a highly reliable collection method involving electronic road switch sensors. Recommendations for applicable techniques took into account the cost and general suitability of each method for use by a practicing traffic engineer. For the four guide-sign MOEs, the following reliable method factors were found.