TRAFFIC CONFLICT ANALYSIS, A ROAD SAFETY RESEARCH TECHNIQUE

R-77-9
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Voorburg, August 1977
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Summary

Based on research results, it is ascertained to what extent traffic conflict analysis can be applied as a method of traffic safety research. It appears from the literature that there is no substantial relation between conflicts and accidents. Traffic volumes probably play an important role with regard to this relation. Better results are gained if only serious conflicts are considered. However, research in this field has been made only on a limited scale. In this connection the problem of the reliability and validity of the measurements is of some momentum. It is concluded that a great deal of evaluating research still has to be done before conflict analysis can be applied on a large scale. In specific cases, particularly those in which only very few accidents have been recoded or no accident history is available, the application of the technique may be useful. A strategy is proposed to decide between both techniques. It is suggested applying traffic encounters instead of traffic volumes to measure exposure and using the results of conflicts in combination with other data such as those derived from observations of road-users' behaviour.

1. Introduction

Road safety research puts the emphasis on traffic accidents. Usually, the number of accidents, with various modifications according to type and severity, adjusted or not for traffic or transportation performance, is used as the criterion of road safety or danger.

Analysis of road traffic accidents, however, produces a number of difficult problems. The main reason is the comparative infrequency of accidents. Although the total number of road traffic accidents in any country, province or city is often considered unacceptably high, the number on practically any individual road section is too small a basis for research. Consequently, other methods have been sought for detecting dangerous traffic situations and for tracing their causes; vide, inter alia, Pahl (20) and Van Minnen (15). The most promising method so far is that of traffic conflict analysis. Although various causes of accidents can be distinguished, most accidents are due to two or more road users coming into conflict.

Even in ostensibly one-sided accidents there may be a conflict, for instance when a vehicle runs off the road to avoid a head-to-tail collision.

2. Traffic conflicts versus accidents

Traffic conflicts are very frequent. But seldom do they lead to road accidents. Especially at intersections an accident can almost invariably be described as uncorrectible conflict. The fact that traffic conflicts are so numerous and also have a presumed relationship with accidents has led to their being researched to trace the cause of road accidents. The principal advantages of using traffic conflicts instead of accidents are:

1. The comparatively large number of traffic conflicts that can be established at a given traffic location. Even if accidents are recorded for a number of years the number occurring at specific locations is often still too small, for instance for black-spot research. Research might still be possible with traffic conflict analysis. Hayward (12) has estimated that the number of conflicts on any one day is equal to the number of accidents per year. Harris & Perkins (10) think there are as many traffic conflicts per hour as there are accidents per year. The discrepancy between these estimates is related both to the definition of an accident (for instance fatal accidents only, accidents involving injury, etc.) and the definition of a conflict.

2. Since traffic conflicts are so numerous, very detailed information about them can be gathered quickly; sufficient data can be collected in several days or even hours.

3. Since data can be collected so quickly, a homogeneous situation can be studied. Road accident data are often collected for a period of several years. During that time, the traffic flow or the road features have often changed.

4. Pahl also mentions the ethical aspect: there is no need to wait for accidents to happen before the hazards are pointed out.

This impressive list of advantages might suggest a quick change-over to traffic conflict analysis instead of accident analysis.

But before taking this step, it will have to be properly ascertained whether the naive notion on which the technique is based is substantiated by reasearch results. It will have to be demonstrated that measures based on traffic conflict analysis do in fact lead to greater safety and not merely to an imagined improvement of road safety.

It is, of course, possible to start by using the conflict analysis technique and afterwards to evaluate the consequent measures against a recorded or unrecorded reduction in the accident rate. But a better way might be to examine the relationship between traffic conflicts and road accidents before switching to the conflict analysis technique. This applies to the conflict observation technique used for recording conflicts and also to a more comprehensive conflict analysis technique aimed at tracing the causes of traffic hazards. If this is dropped and an effort is made for instance, simply to improve road safety by reducing the number of conflicts, this implies that use is in fact being made of a wider definition of road safety. An approach in which the widening of this definition is made explicit by including convenience aspects, such as the road user's sense of safety, are found in Oving (18).

Another problem is that of putting acquired knowledge into general terms in order to make measures applicable on a larger scale. It is often very difficult to express knowledge of accidents in specific situations into more general terms. It is even more difficult to try and reach general conclusions from a knowledge of conflicts without adequate knowledge of the correlation between road accidents and traffic conflicts.

3. Definitions of conflict

The basic idea behind the use of traffic conflict analysis instead of road accidents is the attempt to expand the range of research: from accidents to potential accidents, with the view that conflicts are potential accidents. The domain of the potential accidents is determined by the definition of a traffic conflict. Depending on this, the range of research is extended to a greater or a less extent. The widest definition is obtained by referring to a potential accident if two or more road users are in such close proximity as might influence their movements. The choice of this definition practically changes road accident research to traffic density research. And little of the original purpose is left. Limiting the range will give a definition closer and closer to that of an actual road accident. The point of departure for most conflict studies is the wide definition given in research by Harris and Perkins (10, 21,22): "A traffic conflict occurs whenever one driver takes evasive action - brakes/weaves - to avoid a collision" (10, pa 27).

The terms given in the literature on conflict analysis can be arranged as follows, in a scale from accidents to densities: accident - near-miss - serious conflict - conflict - encounter - proximity - presence. Many cases scored by Harris and Perkins as conflicts can thus be described better as encounters (a term introduced by Kraay), or even as proximity, such as precautionary braking at an intersection. Their investigations therefore show that there is not only a correlation between the number of road accidents and the number of traffic conflicts, but also between the number of conflicts and the traffic density. The immediate question therefore is whether density would not suffice. The momentum of traffic density in the relation between conflicts and accidents is mentioned in hardly any research. No data on the degree of this correlation are given by Harris and Perkins. Heany (12), after analysing their data arrives at the rather low correlation of r = .48[1] between all traffic conflicts and road accidents. This means in fact that only $(.48)^2$ x 100% = 23% of the variance in accidents can be explained with the help of conflicts. Baker (3), using this same definition of a conflict and collecting data on 392 intersections, does not reach a higher correlation: r = .458. At specific locations, such as non-signal controlled intersections and especially at T-junctions, he finds higher values: mostly in conflicts between intersecting traffic flows.

Cooper (5) also finds a correlation between traffic conflicts and road accidents of r = .45. In his research the correlation between conflicts and densities is substantial too.

Campbell & King (4) used the same definition as Harris and Perkins, but at first they found no correlation between conflicts and accidents. After eliminating head-to-tail collissions, the conflicts regarded as least serious, they did find a significant correlation (r_{sp} = .80), but for only six pairs of numbers. Paddock (19) also based his results on the same wide definition of a traffic conflict. This research used not only various types of conflicts but

1) The following notations are used:
r = Pearson Product-Moment correlation
r_{sp} = Spearman rank correlation
R^2 = Squared Multiple Correlation.

also various density characteristics for accident prediction. Data were collected for 922 traffic points, with disappointing results. The multiple correlation was less than $R^2 = .30$ and for some subgroups did not exceed $R^2 = .36$. Better results are sometimes found for certain types of traffic conflict. Pugh & Halpin (24), using the same classification as Harris and Perkins, find closer correlations for conflicts relating to cutting in on vehicles ahead or head-to-tail conflicts than for conflicts with traffic turning off left or intersecting. These results are not always identical. Campbell & King, in fact, found it was the head-to-tail conflicts that caused a lower correlation. In Baker's research the higher values were provided mainly by conflicts with intersecting traffic. Both Pugh & Halpin and Baker find that correlations vary with the type of intersection. Spicer (25, 26, 27) finds high correlations by paying attention to specific locations within a given intersection. In a Swedish project (23) the conflicts are classified, inter alia, by types of road users. Spicer attributes the meagre results to the wide definition of a traffic conflict. In his research he retains the same definition, but also divides observed conflicts into categories of severity, from precautionary braking or lane changing to serious collision (See Table 1). He, too, finds disappointing results if the research comprises all conflicts. Much better accident predictors appear to be serious conflicts (classification 3 to 5). He finds a correlation between accidents and serious conflicts of $r_{sp} = .93$. It should be noted that there are only six measurements, made at a single intersection, and that this is a rank correlation (the pm-correlation is $r = .80$).

Better results are also found in Sweden by using serious conflicts. They only studied accidents involving pedestrians. It was found, among other things, that at zebra crossings without signal-control there were more conflicts between pedestrians and vehicles driving into the street than between pedestrians and those leaving the street (See Figure 1). This corresponds to the comparable accident statistics, but cannot be inferred from the density statistics (one can reasonably expect as many vehicles to enter the street as leave it).

4. Validity and reliability

The fact that it is mainly the number of serious conflicts which is related to the number of accidents indicates that every conflict must not be regarded as a potential accident. The ratio between serious and slight conflicts is apparently not constant. This leads to the question whether such a constant ratio does exist between serious conflicts and accidents. In other words, even if a correlation is found between serious conflicts and accidents, this does not necessarily mean that traffic conflict analysis is warranted instead of accident analysis. This would require more than correlation. For an explanatory factor it may suffice if a significant correlation is demonstrated with the criterion. For instance, it is wise to wear safety belts if a negative correlation is demonstrated between wearing one and the risk of being killed. In the case of the traffic conflict technique, however, we are not particularly interested in a potential correlation between serious conflicts and road accidents, but in the degree of correlation. If we regard reduction of the number of accidents as the criterion of road safety research and the relevant measures, then we seek in the traffic conflict technique for a substitute criterion variable instead of an explanatory variable. And for such a substitute criterion, an important question is how well it replaces the real criterion. Technically speaking, it is not a question of whether the correlation between serious conflicts and accidents differs from zero, which is verified in most cases, but how close the correlation is to unity. This is known as the validity question: how well is the criterion replaced. Amundsen (1), for instance, wrongly says, with reference to a correlation significantly differing from zero between accidents and conflicts, that this means that "situations which result in conflicts also result in accidents of the same type".

From Figure 2, a figure taken from Baker (3), it can be seen, for instance, how many "incorrect positives" (c), how many "incorrect negatives" (a) and how many correct positives (b) would be obtained if conflicts were used instead of accidents in order to indicate the 30% (i.e. 20) locations with the most accidents. The correlation here is $r = .653$, meaning that nearly 60% of the variance in the number of accidents is not explained by the conflicts. Although the results are hopeful, this does show that an effort must be made to increase the predictive validity of the conflict method. Using "serious conflicts" instead of "conflicts" seems to be a move in the right direction. Perkins and Harris's criticism of this method concerns the subjectivity of the scoring technique. Applying braking lights and changing lanes can readily be measured. Measuring the severity of a conflict demands an opinion from the observer. His opinion will be partly governed by his idiosyncracies; one observer will tend to deem a situation serious quicker than another. Hence, analysis of the same situation may lead to big differences in scoring. This is the problem of the reliability of the technique: a measurement is reliable if the error in measuring is slight. A big error in measuring the seriousness of the conflicts may make the validity of the conflicts disappointing as a substitute criterion of accidents.

Güttinger (8) had observers classify traffic situations as dangerous, not so dangerous or safe. His investigations examined how well a particular observer's scores could be reproduced by the same observer, and also how closely the scores of different observers corresponded. Kraay (14) uses for this the terms "internal" and "external reliability". The results of Güttinger's research suggest that training is needed, but that a reasonably high degree of reliability can then probably be obtained. Recent Swedish research announcements show that the reliability of scoring by observers after training is fairly high. But this reliability research was only on a very limited scale. Finnish research (9), using a wide definition of conflict, produced internal reliability of r= .95 and external reliability of r = .88. Research in Rotterdam (28) gave a correlation of r = .91 between a first and a second series of traffic conflict measurements. If conflicts with pedestrians are eliminated, the correlation is only r = .75. This would suggest that a conflict is clearer to indicate if pedestrians are involved than if only other road users are taken. Little is known about the influence of external factors such as weather conditions, time of day, etc. on the reliability of measurements. It would be advisable to examine reliability for the greatest possible variation in situations.

Problems of scoring reliability have led to more objective scoring techniques being sought. In Sweden, the seriousness is determined by measuring the distance between the road users involved in the traffic conflict. This can readily be found with film or video systems. If the distance is less than one metre, this is classified as a serious conflict. Hayward (12) has the criticism that this distance alone is not a standard of severity: the seriousness of a conflict also depends on the speed of those involved and the angle between their paths. He therefore measures the time that would have elapsed from the conflict-avoiding action until the accident that would have occurred without it. He uses some very effective equipment for his investigations: a circulating-tape video-recorder linked to a film camera which can record on command the last twenty seconds of the video picture on film. He speaks of a "near-miss traffic event" if the time up to the accident is less than 0,5 second. A fairly arbitrary value, based on reactiontime data. How good the technique is for accident prediction is not known.

The announcement mentioned above shows that Swedish research now uses a time criterion, too, instead of a distance criterion. A (notional) limit of 1.5 seconds has been chosen for a serious conflict.

In the foregoing definitions of a serious conflict we find a number of aspects that will play a part. Though it seems rather naive to follow Güttinger (7) in interpreting a serious conflict in terms of sudden action - one wonders whether the observer could not better be allowed to score directly whether the conflict is serious or not - suddenness is certainly an important aspect. An example in which more objective criteria (blood pressure, EEG, etc.) are used for measuring this aspect is found in Babkov (2). But it will have to be examined, for instance, whether the very lack of such a reaction to a conflict does not cause an accident. In other words, the unexpected may be more important than the sudden. Besides this, the kind of traffic should play a part in defining a serious conflict: a pedestrian/cyclist conflict is not as serious as a pedestrian/car conflict if it is a matter of predicting severe accidents. Hence, it is necessary first to examine what turns a conflict into an accident before arriving at an operational definition of a serious conflict, thereby distinguishing between relevant and non-relevant conflicts. An attempt to solve this problem in a different way is found in Malaterre and Muhlrad (16). Here each conflict is weighted so as to indicate its relevance in explaining accidents. This weighting is the total result of a number of part-weightings of relevant factors such as type of conflict, kind of traffic, impact angle and speed. It is not clear how the weighting was effected (multiple correlation, subjective weighting method?). Using the weighting principle for the relevant aspects of a conflict would seem to be a step in the right direction, provided it is used objectively.

Although training observers or applying more objective techniques can improve the reliability of measuring the severity of conflicts, the question still remains of how well accidents can ultimately be predicted by conflict measurements. Pugh & Halpin calculated, for their 240 intersections, also the correlation between accidents and accidents in various years. For 1970 and 1971 they find a correlation of r = .69; for 1970 and 1972 of r = .62, and for 1971 and 1972 of r = .67. On the assumption that accident prediction based on traffic conflicts is unlikely to be much better than accident prediction based on accidents, the correlation between traffic conflicts and road accidents cannot give values much higher than .65. Even if accident data are collected for a number of years the values will not be very high. Over a three-year period an upper limit of r=.85 is likely. These limitations on research of course apply equally to road accident research and traffic conflict analysis. But they greatly impede evaluation of conflict analysis in terms of accidents. An aspect disregarded in all the research is the possible importance of conflicts or encounters as a criterion of exposure to traffic (See inter alia 17).

It would seem worth while ascertaining whether in some cases the number of encounters is not a better exposure criterion than the densities that are mostly used. It is conceivable, for instance in the case of controlled traffic flows, that the product of densities widely used at intersections is less suitable for measuring the degree of exposure than the number of actual encounters.

The question that still remains is whether accident prediction is better with many traffic conflicts than with few road accidents (Pahl). Hauer (11) concludes, on the basis of published results and a theoretical model, that traffic conflict analysis can be used when the number of accidents in the research area is too small (say three or four a year) or when the measurement period is short (as is often the case with before and after-studies). Glennon and Thorson (6), whose article is an excellent presentation of American research using the method of conflict analysis, criticise the rationale of Hauer's model (besides several other minor objections). In my opinion this justifiable criticism can best be formulated with respect to the fundamental assumption that the ratio between numbers of accidents and conflicts is constant for every intersection. In other words in all conflicts there is a fixed risk p of the conflict resulting in an accident. Actually, Hauer assumes the predictive validity of conflicts for accidents to be equal to unity. Hauer, therefore, only takes into account the degree of reliability of the numbers of accidents and conflicts for estimating the expected number of accidents.

An alternative of the procedure used by Hauer for ascertaining whether, in a given case, it is better to use conflicts than accidents is illustrated in fig. 3.

Let us define unsafety operationally as the expected number of accidents. "Expected" means here something like: conditions being

the same (stochastic variables like traffic flow, whether conditions etc. equally distributed over the whole period of investigation), the mean number of accidents per year converges to some value if the number of years tends to infinity.
Call this number, A_{∞}, the criterion of unsafety, then the value of this criterion can be estimated from the number of accidents in a certain year, like generally a population mean is estimated from a sample mean.
If the reliability of the number of established accidents (A) as a predictor of the number of expected accidents (A_{∞}) is in the range A_1, A_2 or A_3 respectively, then prediction is possibly better with respect to traffic flow (TF), total number of conflicts (TC) or serious conflicts (SC) (at least with maximum reliability of TF, TC and SC).
Surpose, for instance, that the reliability of A (calculated with the split-half method) is $r_{A.A.} = .50$ and $r_{SC.A_{\infty}} = .80$.
Then if $r_{SC.SC} = .90$, $r_{SC.A}$ will be .54 and predict accidents better than the accidents itself, but if $r_{SC.SC} = .70$, $r_{SC.A}$ will be .47 and accidents predict better than serious conflicts.
Now if we see the reliability of the conflicts technique as a variable, the value of which depends on sample size, then it can be investigated in a given situation if conflicts predict accidents better than accident history does. And if the conflicts do, what minimum reliability is needed.
Furthermore Hauer, in his article, puts attention to the point that the conflicts must be recorded representatively for the whole year. Representativity regarding time of day and day of the week

might be added. The problems Hauer mentions concerning small numbers of accidents have in fact led to the Delft research (14) being based on traffic conflicts.

To sum up, it can be said that various definitions of a conflict have been given, but that the best results have been achieved with a definition limited to serious conflicts and near-misses. In this, however, the reliability of observations causes problems. A review of what has been done in conflict analysis is given in Table 2. The conflict analysis technique can be used in specific cases, especially where there are very few accidents. Much evaluating research will be needed, however, before the technique can be used on a large scale. But there are other research techniques, such as behaviour-observations and traffic-flow models, which can be used if analysis is impossible. Thus Van Minnen (15) uses a combination of behaviour-observations (right-of-way behaviour) and traffic conflict observations for studying road hazards at intersections. Such a combination of conflict measurements and traffic-flow models might be possible, say on motorways. If conflict analysis is used in this way, it will amount to research aiming at an hypothesis or theory formulation. For less specific problems, traffic accident analysis still seems to be the most appropriate method of improving road safety.

Description	Classification
Precautionary braking or lane changing collision very unlikely	Slight 1
Controlled braking or lane changing to avoid collision but with ample time for manoeuvre	2
Rapid deceleration or lane change to avoid collision resulting in "near miss" situation	Serious 3
Very near miss or minor collision occurred	4
Serious collision	5

Table 1. Classification of traffic conflicts by severity, by Spicer (25).

Object	All conflicts	Serious conflicts
Total number of conflicts	1,3,5,10,16,19	1,16
Type of intersection	3,16,19,24	16
Location on intersection	-	25
Type of conflict	3,4,10,12,24,15	25
Slow traffic (mainly pedestrians)	9,24	23
Related to black spots	5,19	27
As regards traffic offences	4,9,15,24	

Table 2. Review of research into traffic conflicts. (The figures relate to the literature list).

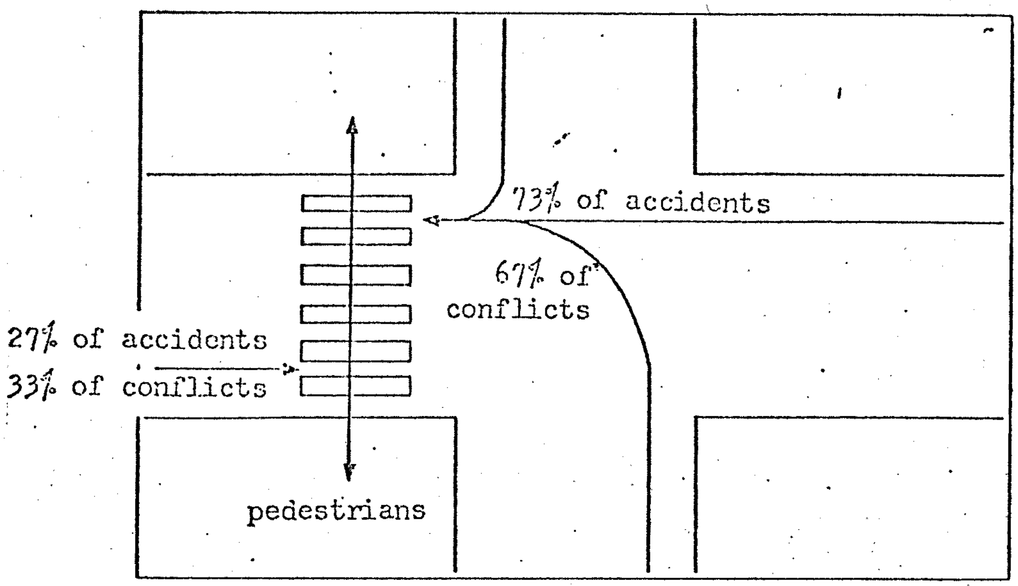

Figure 1

Relation between conflicts and accidents on zebras without signal-control in Sweden.

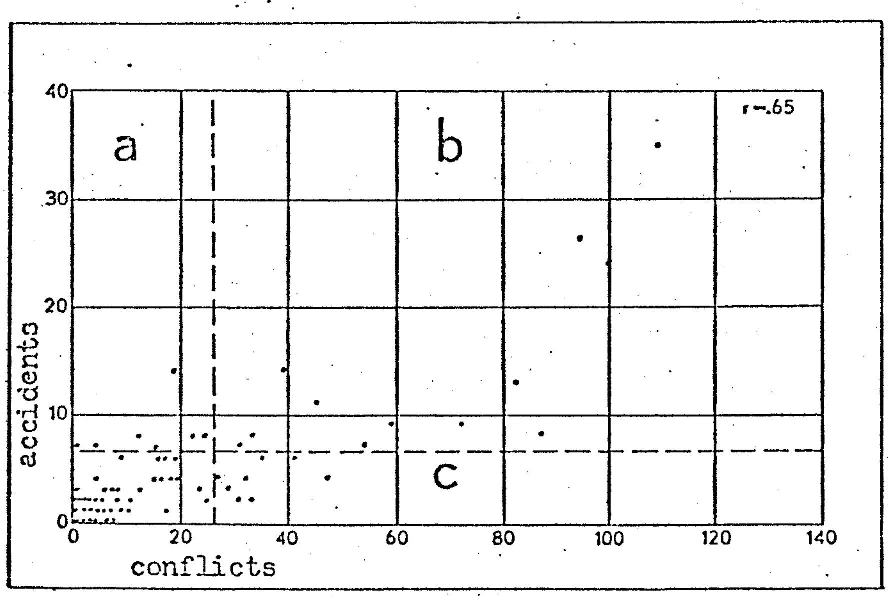

Figure 2

Number of incorrect positives (c) and incorrect negatives (a) in choice of 30% intersections with the highest number of conflicts instead of accidents (Baker (3)).

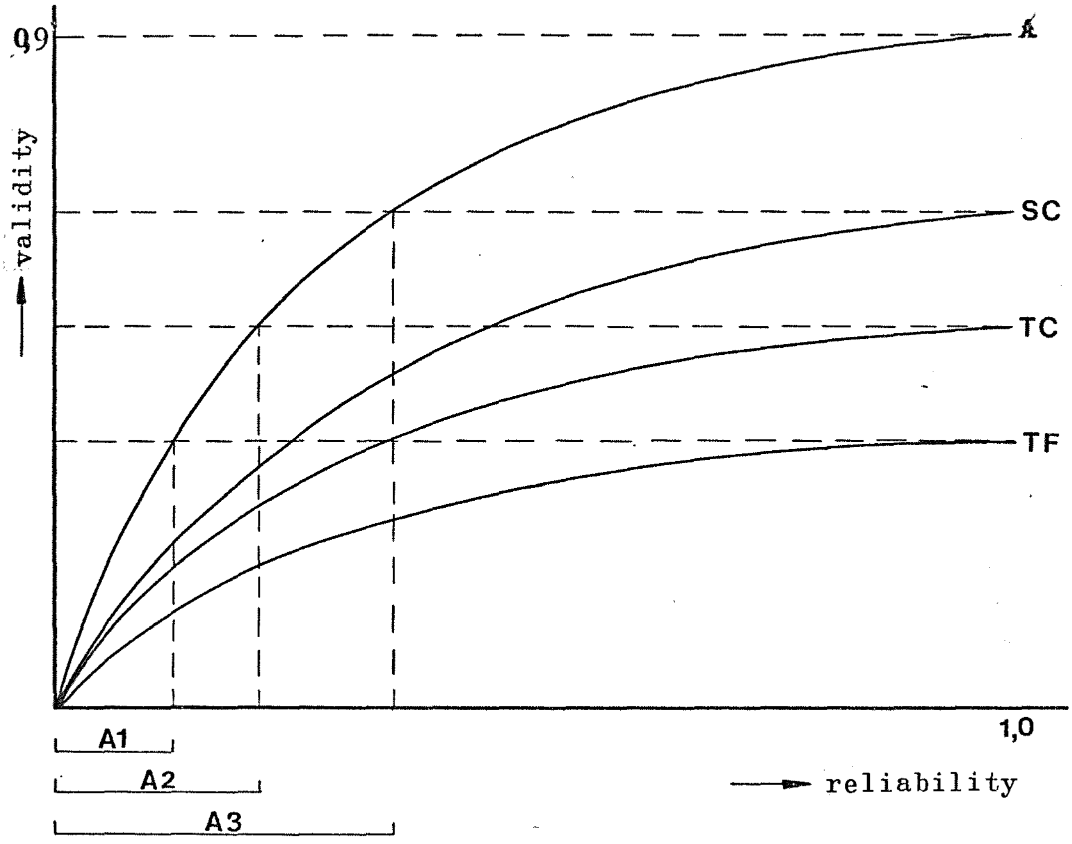

figure 3

Relation between validity and reliability as a prediction for accidents (A - Accidents, SC - Serious Conflicts, TC - Total number of conflicts, TF - Traffic Flow).

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