

# THE TRAFFIC CONFLICTS TECHNIQUE - FUNDAMENTAL ISSUES

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## ABSTRACT

The question is posed which are the circumstances for the Traffic Conflicts Technique to generate more reliable accident rate estimates than those obtained from the history of accident occurrence. To provide an answer, expressions for the variance of the expected annual accident rate are derived for both methods. Based on several applications of the Traffic Conflicts Technique by various researchers, the variability of the "accident-to-conflict" ratio is examined. The analytical machinery so created allows provision of answers to the aforementioned question. It facilitates also derivation of guidelines with respect to the conduct of Traffic Conflicts studies. It appears that the Traffic Conflicts Technique can be used to advantage at locations with less than 4 accidents per year or when accident records are not usable. One day appears to be the best duration of a field count of conflicts. Adoption of a narrower operational definition of "conflict" is suggested.

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The safety performance of the road is usually measured and described by using historical records of accident occurrence. Such practice is not without limitations. Firstly, accident record files contain information on "reportable accidents" only. Moreover, only a fraction of those is actually reported. Secondly, as accidents are relatively rare events, it is often impossible to distinguish between genuine accident rates and random fluctuations. Thirdly, the time needed for the accumulation of a sufficiently large number of accidents to tell success of a corrective measure from its failure is too long to claim "no change" in all other conditions. These features of accident occurrence are largely immutable and render the pinpointing of hazardous locations unreliable; investment in corrective action wasteful; and conclusions drawn from "before" and "after" studies questionable.

The "Traffic Conflicts Technique" (denoted by TCT in the following) has been introduced<sup>(1)</sup> to circumvent the aforementioned shortcomings. It is founded on the belief

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that on the site of a hazardous location one will be able to observe many "near misses" or "conflicts". Thus accident occurrence as an indicator of hazardousness is to be replaced by a directly measurable phenomenon. This "measurable phenomenon" is to be

- a) amenable to reliable estimation in relatively short time periods. (Thereby alleviating problems of statistical reliability and facilitating almost instantaneous evaluation of the effectiveness of countermeasures);
- b) closely associated with the expected (not the observed) accident occurrence.

It is relatively easy to produce statistically reliable estimates of the rate at which conflicts occur. However, the purpose in counting conflicts is to obtain an estimate of the expected accident rate, not of the rate at which conflicts occur. Some researchers were disappointed on this score observing poor correlation between conflicts and accidents<sup>(2,3,4)</sup>. The following fundamental issue arises: Is a statistically reliable estimate of the rate at which "conflicts" occur a better indicator of the expected accident rate than the statistically less reliable estimate derived directly from records of accident occurrence. Scepticism on this matter has been expressed in the past<sup>(5)</sup>.

To illustrate, consider the game history (hockey, soccer, etc.) of two teams. The task is to estimate the expected

number of goals to be scored by one team against the other in their forthcoming game. The recorded history of "number of goals scored" could be used for this purpose. Some discretion is necessary, as team composition and other factors change relatively fast when compared to the frequency of games between the teams. Use of game records from the distant past should best be avoided. This may leave only a small number of records on which to base the estimate and result in poor quality of prediction. An alternative, however, is available. One could use the more plentiful statistic of "shots on goal". The number of "shots on goal per game" derived from recent games multiplied by the probability of conversion of a "shot" into a "goal" is an alternative estimate of the number of goals to be scored in the future game. It is far from obvious which of the two methods produces better estimates.

Reverting from sport to traffic safety, the question is raised whether the TCT (Traffic Conflicts Technique) can possibly produce better estimates of the expected accident rate than the time honoured reliance on accident history. If answered in the negative, further attempts to use conflicts as indicators of hazard should be discontinued. If positively answered a host of important issues emerges: Under what circumstances can the TCT outperform the "accident history method"; what operational definition of the term "conflict" to adopt in order to obtain best results; what accuracy to require in sampling for conflicts, etc.

These issues demand sound answers to insure successful and efficient application of the intuitively appealing Traffic Conflicts Technique.

2. Variance of Two Estimates of the Expected Annual Accident Rate

In what follows, the Expected Annual Accident Rate is understood to mean the expected number of accidents for a specific site and year. It reflects the true (but unknown) probability of accident occurrence at that site and during that year. Due to chance, sites with a high probability of accident occurrence may experience few accidents and vice versa. Thus, the actual number of accidents occurring at a site is but an indication of the expected annual accident rate, not its equivalent. For purposes of traffic safety management one is invariably interested in the expected annual accident rate. Its actual value remains unknown and is only subject to inference and estimation.

Two alternative methods for the estimation of the expected annual accident rate are to be compared: the customary method using records of accident history for the site and the challenger - the Traffic Conflicts Technique. The task here is to compare the performance of the two contenders. As accuracy in prediction is the goal, the variance of the estimate of the expected annual accident

rate is a reasonable yardstick to judge performance by. The estimation method characterized by the larger variance will be deemed inferior.

Derivation of expressions for the variance of the estimate produced by the two contending methods is the subject matter of Sections 2.1 and 2.2

## 2.1 Variance of the Expected Annual Accident Rate Estimate Derived From Accident Records

The difference between the prevailing expected annual accident rate and its estimate (when based on accident records) stems from two sources. Firstly, the estimate is based on accident occurrences of the past. As these are random variables, so is the estimate derived therefrom. Secondly, year differs from year in quantity and timing of precipitation, occurrence of transit strikes or fuel shortages, public school registrations, construction activity near the site and a host of other factors all of which exert their influence on the accident rate prevailing on the road or at the intersection. Consequently, the expected accident rate itself varies from year to year; the prevailing one being a specific realization from a probability distribution. Analysis must take both sources of variability into account.

Let  $\lambda_i$  be the expected annual accident rates prevailing during years  $i=1,2,\dots,n$ .

$a_i$  the reported and recorded number of accidents  
in years  $i=1,2,\dots,n$ .

The sample mean  $\bar{a} = \sum_{i=1}^n a_i / n$  is an unbiased and popular estimate of the accident rate  $\lambda$  prevailing at present. We wish to gauge the magnitude of the variance  $E\{(\bar{a} - \lambda)^2\}$ .

As  $\lambda$  relates to the present whereas  $\bar{a}$  is derived from realizations of the past, the two random variables are causally and thus statistically independent. Consequently,

$$E\{(\bar{a} - \lambda)^2\} = \text{VAR}\{\bar{a}\} + \text{VAR}\{\lambda\} \quad \dots 1$$

Assuming that realizations  $a_i$  are independent and Poissonly distributed with expectations  $\lambda_i$ ,

$$\text{VAR}\{\bar{a}\} = \sum_{i=1}^n \text{VAR}\{a_i\} / n^2 = \sum_{i=1}^n \lambda_i / n^2.$$

Since  $E\{\sum_{i=1}^n \lambda_i / n\} = \lambda$ , an unbiased estimate of  $\text{VAR}\{\bar{a}\}$  is given by

$$\hat{\text{VAR}}\{\bar{a}\} = \lambda / n \quad \dots 2$$

The second component of the right hand side in Equation 1 follows from the analysis of accident histories at many sites. Using accident records for 1800 intersections and road sections in Metropolitan Toronto for the period 1970-1974 it has been found<sup>(6)</sup> that

$$\text{VAR}\{\lambda\} = \lambda^2 (0.055 + 1.4e^{-\lambda}) \quad \dots 3$$

where

$$\lambda = E\{\lambda_i\}$$

Using results of Equations 2 and 3 to obtain an estimate of the variance from Equation 1,

$$\hat{E}\{(\bar{a} - \lambda)^2\} = \lambda / n + \lambda^2 (0.055 + 1.4e^{-\lambda}) \quad \dots 4$$

## 2.2 Variance of the Expected Annual Accident Rate Estimate Derived From Count of Traffic Conflicts

The product of the "annual number of conflicts at a site" and the "probability of a conflict to result in an accident" is an estimate of the expected annual accident rate. The difference between the prevailing expected annual accident rate and its estimate (when based on a count of traffic conflicts) stems from inaccuracies in the two factors of the product. The estimate of the annual number of conflicts is obtained from a field study of limited duration. Its accuracy depends (among other things) on the duration of the count. The estimate of the probability "accident given conflict" applicable to a certain site is obtained from research and experience conducted on other sites and therefore contains an element of uncertainty. Both sources of



uncertainty affect the accuracy of the estimate of the expected annual accident rate.

Formally, let  $\mu$  be the annual number of conflicts and  $p$  be the probability that a conflict results in an accident.

If so,

$$\lambda = \mu p \quad \dots 5$$

An estimate  $\hat{\mu}$  of  $\mu$  is obtained from a field count of conflicts. The conduct of a traffic conflict study yields the number of conflicts  $k$  counted during  $t$  hours. When  $t$  is expressed in fractions of a year,

$$\hat{\mu} = k / t \quad \dots 6$$

An estimate  $\hat{p}$  of  $p$  is obtained from information on the ratio of accidents and conflicts accumulated through research and experience. As the estimates  $\hat{\mu}$  and  $\hat{p}$  are obviously independent, it can be shown that<sup>(7)</sup>

$$\begin{aligned} \text{VAR}\{\hat{\lambda} = \hat{\mu} \hat{p}\} &= \\ &= [\text{VAR}\{k\} \text{VAR}\{\hat{p}\} + E^2\{k\} \text{VAR}\{\hat{p}\} + E^2\{\hat{p}\} \text{VAR}\{k\}] / t^2 \\ &= [\text{VAR}\{\hat{p}\} (\text{VAR}\{k\} + \mu^2 t^2) + \text{VAR}\{k\} p^2] / t^2 \quad \dots 7 \end{aligned}$$

If it is appropriate to assume that the occurrence of conflicts is subject to the Poisson probability law, Equation 7 may be

further simplified into:

$$\begin{aligned}\text{VAR}\{\hat{\lambda}\} &= \text{VAR}\{\hat{p}\} (\mu/t + \mu^2) + p^2 \mu/t \\ &= \frac{p\lambda}{t} (1 + c^2) + \lambda^2 c^2, \quad \dots 8\end{aligned}$$

where

$$c^2 = \text{VAR}\{\hat{p}\} / p^2.$$

### 2.3 Illustration

To translate analytical results obtained so far into practical terms, consider the following numerical example:

The annual accident rate of a certain intersection is approximately 10 accidents per year. The accuracy of estimates of the prevailing accident rate obtainable from accident record and using the TCT will be compared.

- a) If accident records for the past three years are used, from Equation 4,

$$\begin{aligned}E\{(\bar{a} - \lambda)^2\} &= 10/3 + 10^2 (0.055 + 1.4e^{-10}) \\ &= 3.3 + 5.5 \approx 9 \text{ (acc. / year)}^2 \\ \text{s.d.} &= \sqrt{9} = 3 \text{ acc. / year}\end{aligned}$$

The standard deviation of the estimate is quite large (3 acc./year). Not much improvement in the accuracy

of the estimate can be obtained by using accident records for more years as the bulk of the variance stems from the variability of the accident rate itself.

- b) Assume now that a three day conflict count has been conducted at the same intersection. The operational definition of the term "conflict" is such that there are 2 accidents for every 10,000 conflicts ( $p = 2 \times 10^{-4}$ ). The accuracy with which this value of  $p$  is known to apply to the intersection at hand is characterized by  $c^2 = 0.20$ . Using Equation 8,

$$\begin{aligned} \text{VAR}\{\hat{\lambda}\} &= \frac{2 \times 10^{-4} \times 10}{3/365} (1 + 0.20) + 10^2 \times 0.20 \\ &= .3 + 20.0 \approx 20 \text{ (acc. / year)}^2 \\ \text{s.d.} &= \sqrt{20} = 4.5 \text{ acc. / year.} \end{aligned}$$

It will become evident in Section 3 that the numerical values selected for the illustrative example correspond roughly to the present practice and are quite realistic. Consequently, for the situation described, the estimate of the prevailing accident rate derived using TCT is inferior to that obtained using accident records.

More importantly, however, the basic issues surrounding the TCT emerge now with more clarity.

Firstly, in spite of its intuitive appeal, the superiority of the TCT is by no means automatically assured.

Secondly, to obtain an estimate of the prevailing annual accident rate using the TCT, the applicable value of the "accident-to-conflict ratio" ( $p$ ) must be known. The value of this accident-to-conflict ratio can not be obtained from field observations on the site. It must be assumed on the basis of accumulated research and experience.

Thirdly, the quality of prediction (when using the TCT) depends almost entirely upon the accuracy with which the accident-to-conflict ratio is known. This accuracy is characterized by the numerical value of  $c^2$ .

Finally, the quality of the estimate obtained using the TCT depends on the operational definition of the term "conflict". One could define it very narrowly. For example, one could say that only actual collisions count as conflicts. In this case, the value of the accident-to-conflict ratio is unity and its value known with certainty (i.e.  $c^2 = 0$ ). Such definition of the term conflict is obviously impractical because of its demand on the duration of field observations. Alternatively, a very broad operational definition of the term "conflict" could be adopted. For example, each passage of a car through the intersection could count as a conflict. In this case a reliable count of conflicts can be obtained easily. However, the value of the applicable accident-to-conflict ratio can not be accurately determined. As a consequence, the accident rate estimate so obtained will be very unreliable and therefore useless. Thus, for best results using the TCT an operational definition of the term

"conflict" needs to be adopted which is a compromise between two considerations. The definition must be broad enough so that a reliable count of the rate of conflict occurrence can be obtained in a reasonably short span of time. It must, however, be sufficiently narrow to allow accurate estimation of the "accident-to-conflict" ratio.

Fortunately, during the relatively brief application history of the TCT, different agencies tended to adopt slightly different definitions of the term "conflict". Thus some (admittedly limited) experimental information is available for tentative analysis.

### 3. The "Accident-to-Conflict" Ratio and its Accuracy

When applying the TCT, researchers of the Transport and Road Research Laboratory defined<sup>(8)</sup> as "serious conflict" the following events:

- a) Rapid deceleration, lane change or stopping to avoid collision, resulting in a near miss situation. No time for steady controlled manoeuvre.
- b) Emergency braking or violent swerve to avoid collision resulting a a very near miss situation or minor collision.
- c) Emergency action followed by collision.

The event "controlled braking or lane change to avoid collision but with ample time for manoeuvre" was explicitly excluded from the "serious conflict" category.

In contrast, the GMR Procedures Manual<sup>(1)</sup> defines, say, rear end conflicts as

"a situation in which two vehicles are travelling as a pair and the first vehicle stops or appreciably slows unexpectedly as viewed by the second vehicle. The second vehicle is caused to take evasive action, brake or weave, to avoid an impending rear-end collision".

Thus "controlled braking" or other evasive action appear to be included in the count of conflicts if the GMR procedure is followed.

As a result of difference in definition, using these two methods under identical conditions would produce a different count of conflicts for each. The narrower the definition of the term "conflict" the less conflicts are counted, the larger the value of the accident-to-conflict ratio ( $p$ ).

Results of several applications of the TCT were analysed to obtain estimates of the accident-to-conflict ratio ( $p$ ) and its variability ( $c^2$ ). These are plotted in Figure 1. On a-priory grounds it can be argued that when  $p \rightarrow 1$ ,  $c^2 \rightarrow 0$  and when  $p \rightarrow 0$ ,  $c^2 \rightarrow \infty$ . The function

$$c^2 = A(p^B - 1) \quad \dots 9$$

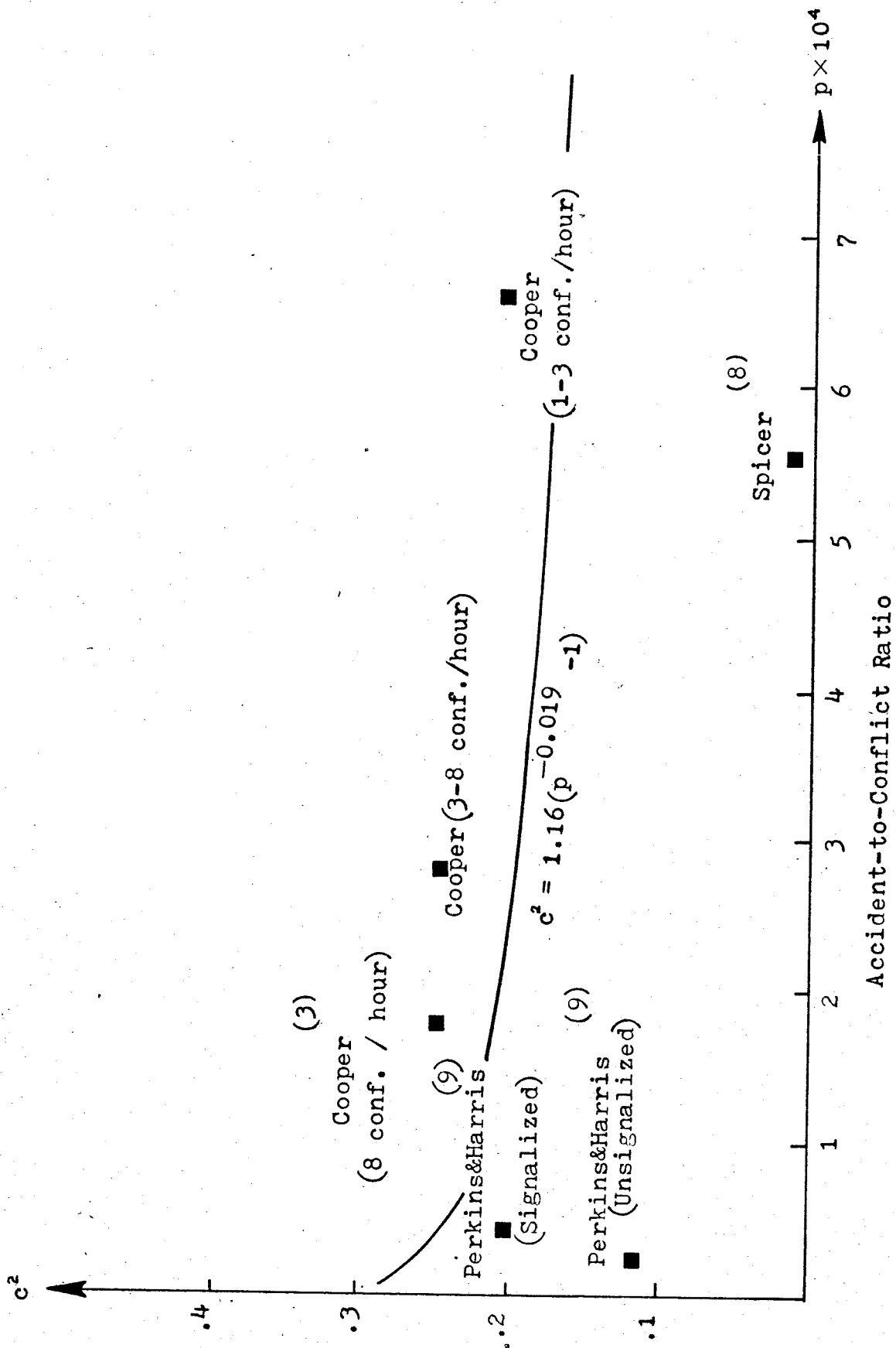


Figure 1 - Relationship between the Accident-to-Conflict ratio and its variability

satisfies both asymptotes and can be fitted to data with parsimonious use of parameters. A least squares fit produces values  $A = 1.16$  ,  $B = -0.019$ .

#### 4. Answers to Questions

In the introductory part of this paper several basic questions have been raised. Provision of answers can now be attempted.

Foremost is the problem of identifying conditions under which the TCT may successfully compete with, and possibly outperform, the "accident records" method. In other words, when should the TCT be considered for use.

Once this problem is satisfactorily resolved one can deal with questions revolving around the practical application of the TCT. Namely, what definition of "conflict" leads to most accurate results, how many days to count, etc.

##### 4.1 When to Use the Traffic Conflicts Technique

Comparing Equations 4 and 8 it follows, that for the TCT to produce better estimates than is possible by reliance on accident records, inequality 10 must be satisfied.

$$c^2 < \frac{1}{n\lambda} + 0.055 + 1.4e^{-\lambda} \quad \dots 10$$



In Figure 2 the largest values of  $c^2$  which satisfy this inequality are plotted against the annual accident rate ( $\lambda$ ) and the number of years ( $n$ ) for which usable accident records are available. It may be inferred from Figure 1 that present practice in North America is characterized by  $c^2 \approx 0.2$ . Consequently, the circumstances under which the TCT as presently used may have an edge belong to the shaded region in Figure 2. Thus, e.g., for intersections with about 5 accidents per year for which only one year of reliable accident records is available (point A in Figure 2) the TCT may produce better estimates than the accident records method. If, however, accident records for three years are available (point B in Figure 2) then, as long as  $c^2$  is not less than 0.2, the TCT can not yield estimates which are more reliable than those obtained from the accident history.

The following conclusions deserve explicit statement:

- a) The TCT should be considered for use for locations which have a small annual accident rate and/or for which only a few years of usable accident records are available.
- b) Considering its present accuracy (in North America) the TCT should be considered when the annual accident rate is less than 4 acc./year or when no accident records are available (as in "before" and "after" studies).

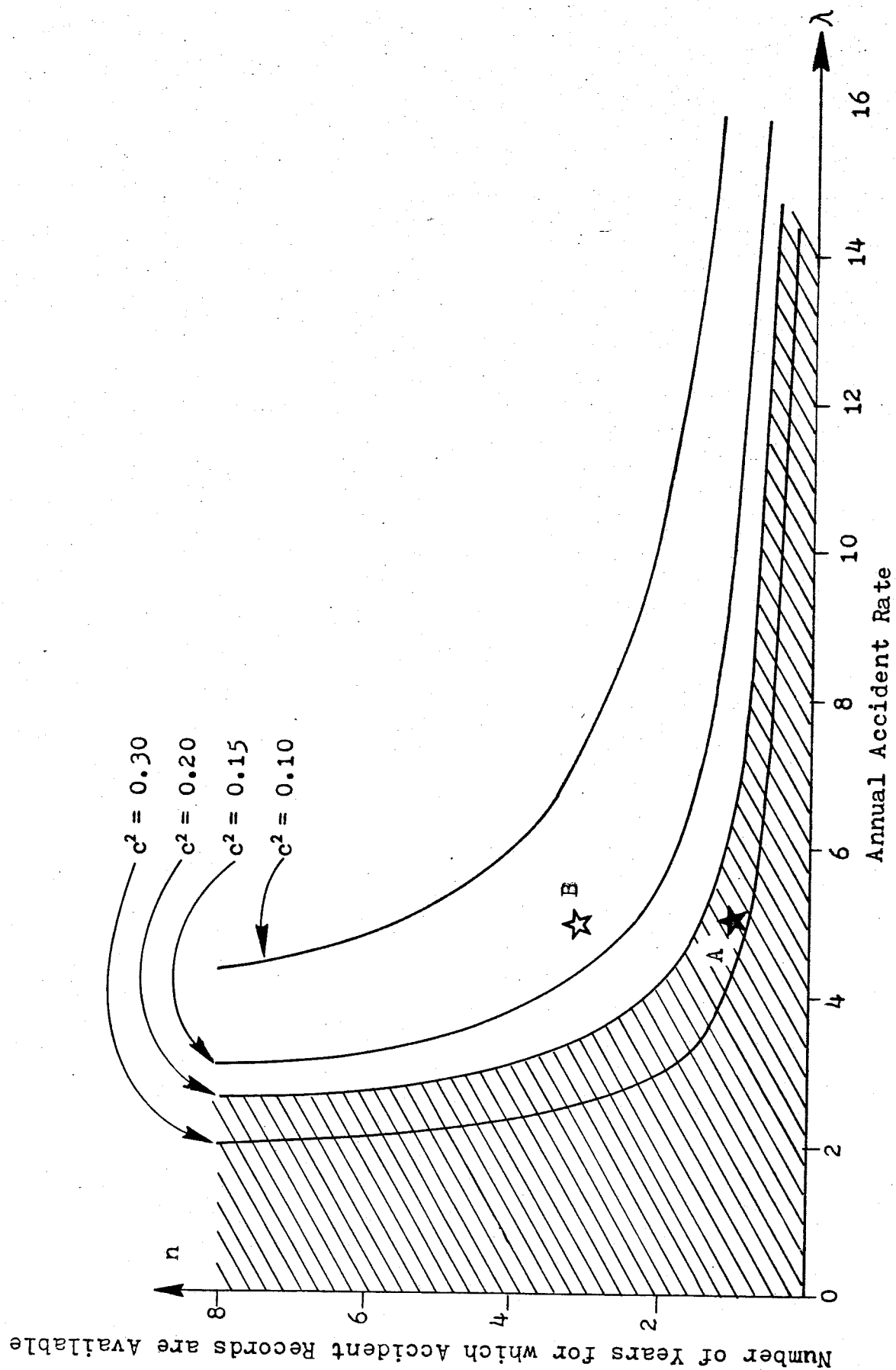


Figure 2 - Determination of Conditions in which the TCT could be considered

- c) Improvements of the TCT which would lead to smaller values of  $c^2$  can broaden the scope of applicability of this technique significantly. If it was possible to attain  $c^2 < 0.05$  (as in reference 8) the TCT would outperform the reliance on accident records in all cases of practical interest.

#### 4.2 Definition of "Conflict" and the Duration of Field Count

The magnitude of  $\text{VAR}\{\hat{\lambda}\}$  serves as an index of the quality of the estimation technique. This index has been found to depend on the operational definition of the term "conflict" which is embodied in the accident-to-conflict ratio ( $p$ ). The relationship between the accident-to-conflict ratio and  $c^2$  has been examined earlier and can be assumed known (subject to qualifications relating to the goodness of fit in Figure 1). It is feasible therefore to explore the dependence of the quality of estimation on the choice of conflict definition in quantitative terms.

In Figure 3, the variation of  $\text{VAR}\{\hat{\lambda}\}$  with  $p$  is illustrated for selected values of count duration and annual accident rate. Inspection reveals, that the accuracy of estimation improves initially with the increase in the accident-to-conflict ratio up to a certain point. The point at which the accuracy of prediction is largest is marked by + . From this point on, further increase in the value of  $p$  leads to an increased variance of the estimate. Thus, e.g.,

if at an intersection at which approximately 10 accidents occur annually the conflict count is to last one day, the best conflict definition to adopt is one for which  $p = 6 \times 10^{-4}$ .

Important insights follow from Figure 3. Firstly, accuracy of estimation degenerates fast for  $p < 10^{-4}$ . Reference back to Figure 1 indicates that some studies are dangerously close to this limit. One may observe that there is much less loss of accuracy in adopting a definition of conflict which is too narrow than there is in one which is too broad. This is particularly so when conflicts are counted for more than one day.

Secondly, the "optimal" operational definition of the term conflict is not the same for all locations or study designs. Indeed, the higher the annual accident rate the narrower the definition which leads to the highest accuracy. Similarly, the longer the conflict count duration, the narrower the definition which should be used.

Finally, the straight lines in Figure 3 indicate the accuracy of estimation which can be attained by using accident records only. Clearly then, at locations with 10 accidents per year, the TCT will not produce estimates better than the accident records method even if only one year of data is available. This, irrespective of how long the field count of conflicts is within the practical range. At intersections with 5 accidents per annum for which only one year of usable records is available, the TCT may attain better accuracy.

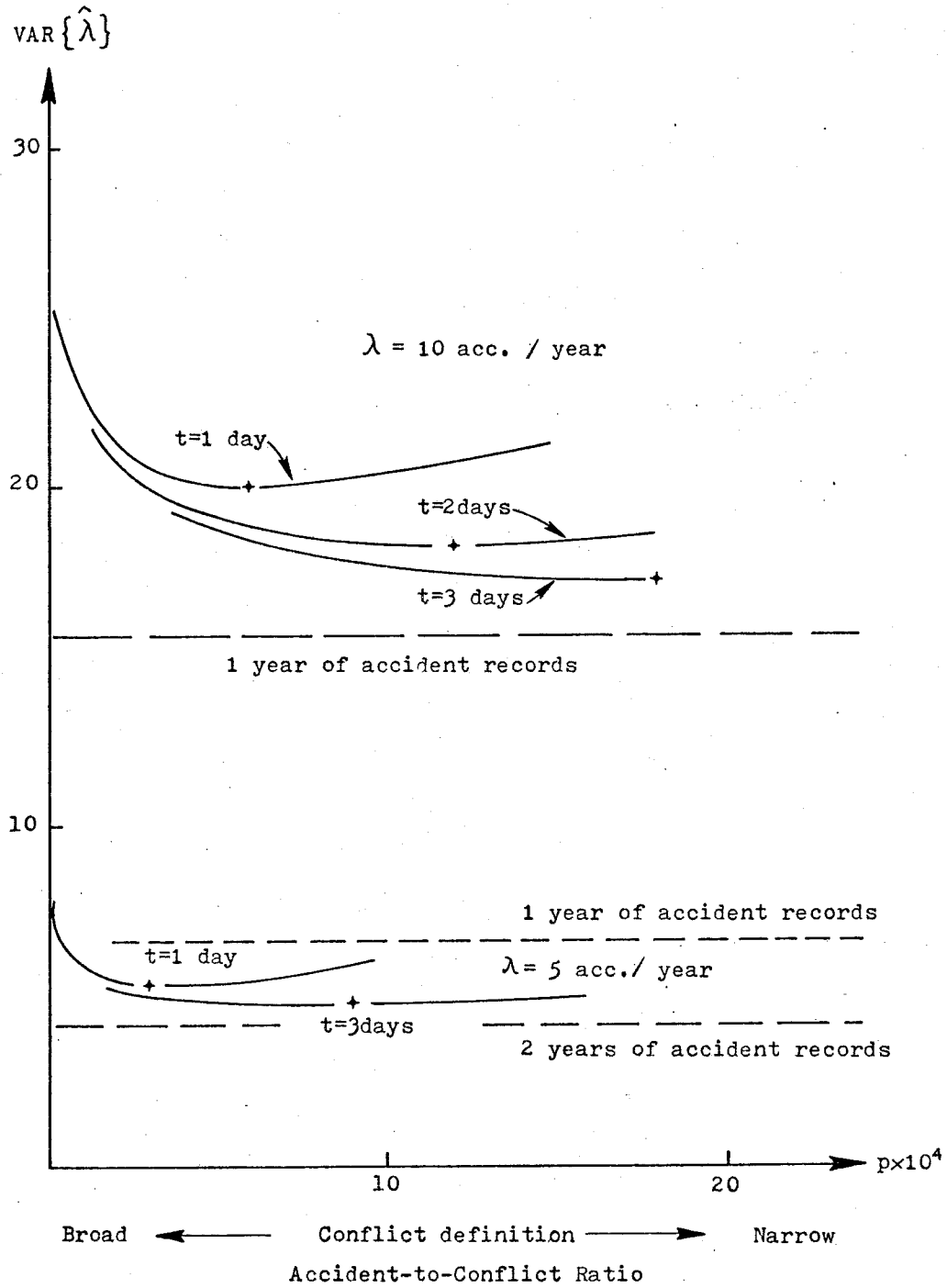


Figure 3 - Influence of Conflict Definition on Accuracy of Estimation

Imagine now that in Figure 3 (using, say,  $t = 1$ ) similar curves are plotted for many values of  $\lambda$  and the lowest point of each curve is marked by a + sign. These points correspond to the accident-to-conflict ratio producing most accurate estimates. The smooth curve passing through all + signs is depicted separately in Figures 4 and 5 for several values of the count duration ( $t$ ).

Consider an intersection characterized by approximately 4 accidents per year. Half a day's conflict count (point A in Figure 4) will yield an estimate of the expected annual accident rate with a variance of  $3.9 (\text{acc./year})^2$ . A rather broad definition of conflict should be used in this case for best results ( $p = 1.2 \times 10^{-4}$ , which corresponds roughly to the original GMR procedure). By counting conflicts for a longer time, the accuracy of the estimate can be somewhat increased. If  $t = 2$  days, the variance is reduced to  $3.3 (\text{acc./year})^2$ . In this case (point B in Figure 4) a narrower definition of conflict is called for ( $p = 4.8 \times 10^{-4}$  corresponding possibly to the TRRL practice).

The accuracy of estimation attainable by the use of accident records is depicted on the right hand side of Figures 4 and 5. Thus, for the same intersection ( $\lambda = 4$  accidents per year) use of a one year accident history yields an estimate of the expected annual accident rate with a variance of  $5.3 (\text{acc./year})^2$ . If two years of accident history are available (point C in Figure 4) the accuracy of a two day conflict count is matched. If more than two years of usable accident records exist the TCT should not be used.

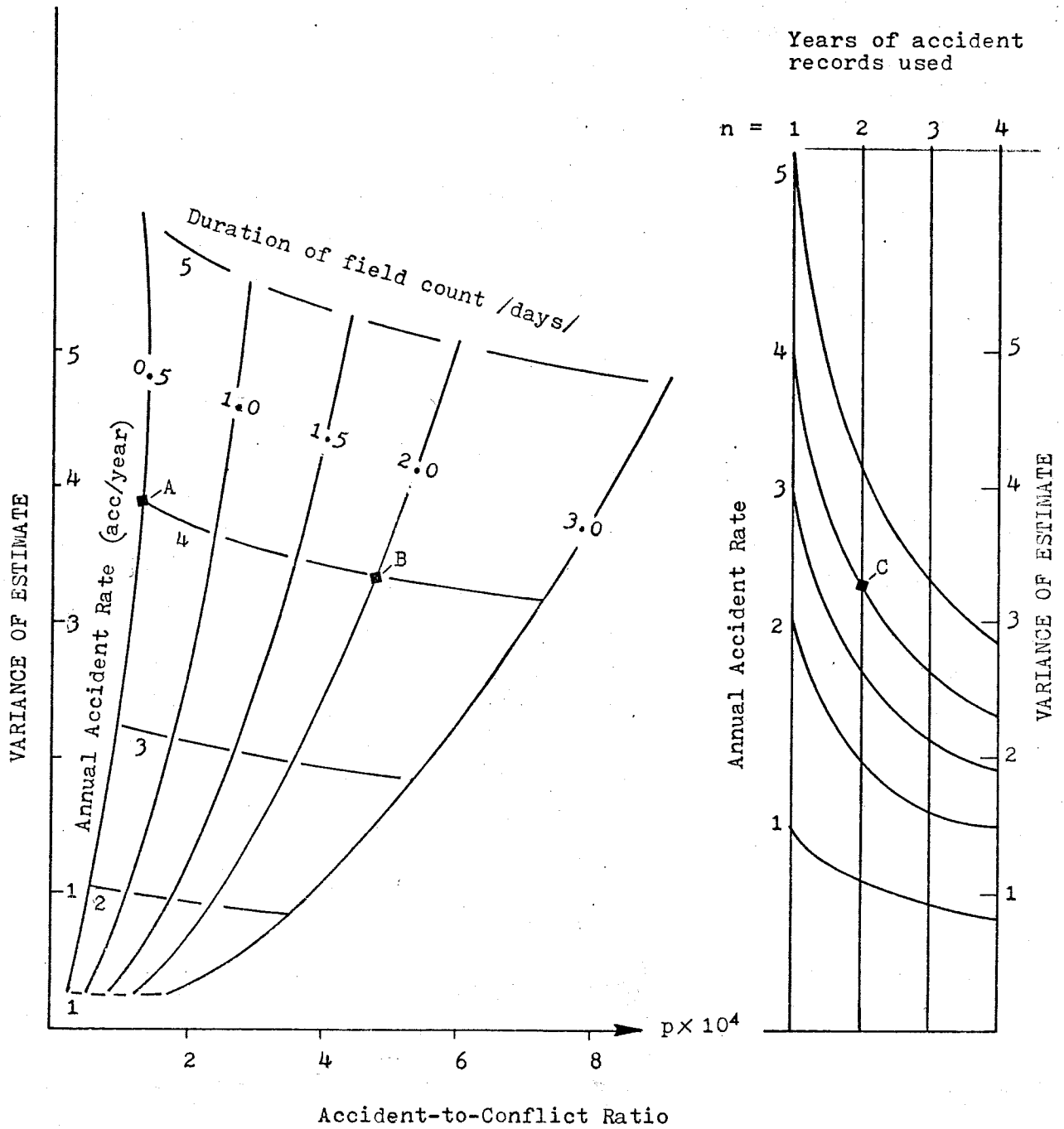


Figure 4 - Summary Nomograph for  $1 \leq \lambda \leq 5$  acc./year

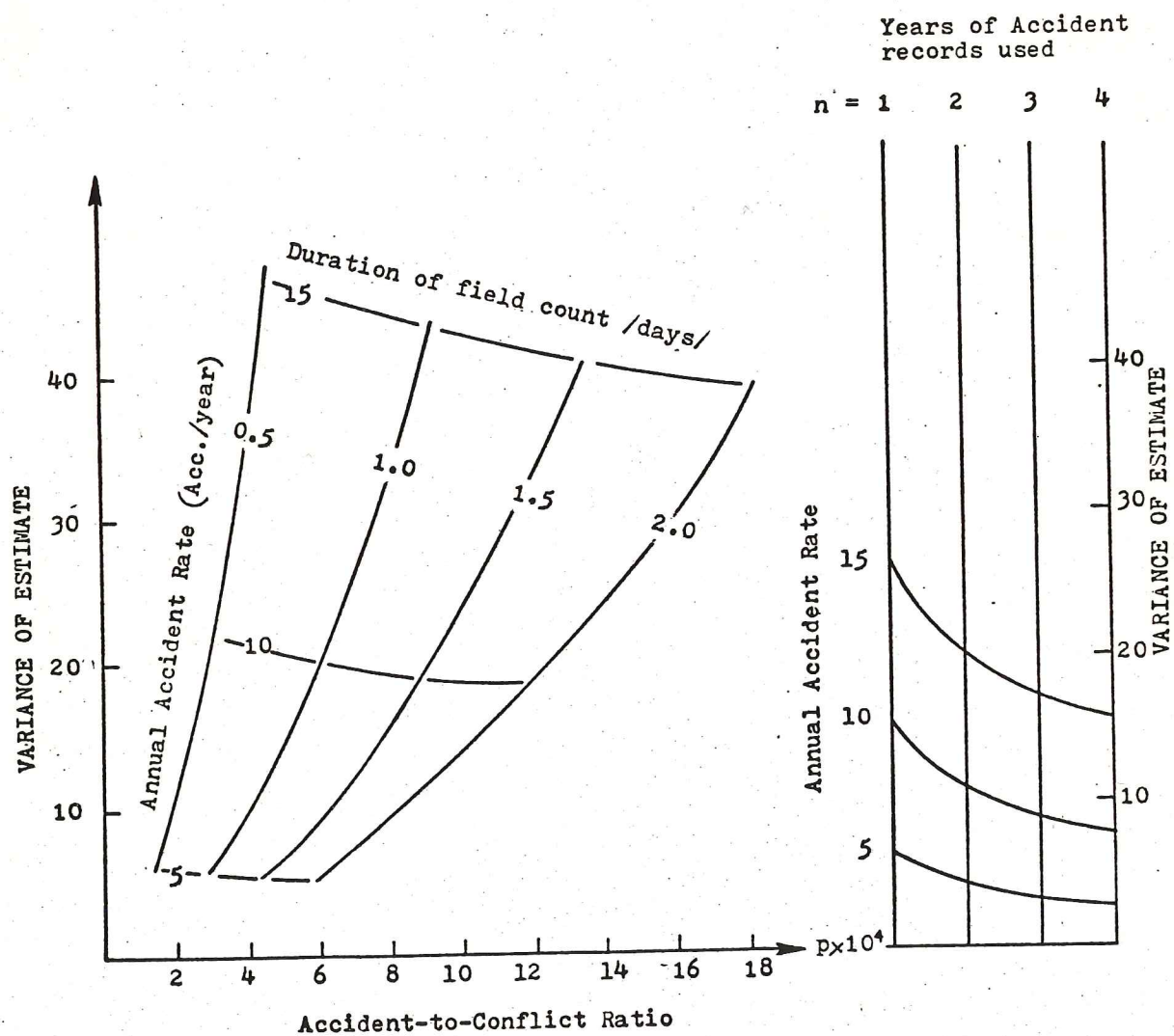


Figure 5 - Summary Nomograph for  $5 \leq \lambda \leq 15$  acc./year



## 5. Summary and Discussion

The following questions are posed:

- a) Under what circumstances will use of the TCT lead to accident rate estimates which are more reliable than those derived from accident records.
- b) For how long need conflicts be counted.
- c) Which of the operational definitions of "conflict" presently used is to be preferred.

To provide answers, an expression for the variance of the expected annual accident rate is derived for each method. The accuracy of the TCT appears to hinge on the precision with which the applicable accident-to-conflict ratio is known. Using published data on the application of the TCT the variability of the accident-to-conflict ratio is examined. The analytical machinery so created allows provision of answers to the aforementioned questions.

- a) The TCT is more accurate than the use of accident records in predicting the expected annual accident rate
  - at locations of low annual accident rate (up to 3 or 4 accidents per year);
  - and/or when the usable accident history is very short (as is often the case in "before" and "after" studies).

- b) The duration of the field count of conflicts seems to have a somewhat limited effect on the accuracy of estimation. Counting two full days instead of one half a day reduces the variance by some 20%. While the decision on count duration is mainly one of economy, a one day count seems to be a reasonable choice. It is difficult to envision a circumstance when the added accuracy obtained by a two day count is worth the doubling of effort.
- c) A single operational definition of "conflict" which is optimal for all circumstances of annual accident rate and duration of conflict count does not exist. If adoption of a single definition is a practical necessity (training, uniformity in application, compatibility of results, etc.) a narrow definition (akin to that used by the TRRL) seems to be called for. Such would assure applicability of the TCT to conditions of relatively high accident rate while still working reasonably well for the low accident rate situations. At the same time the danger of very low accuracy associated with the broad GMR definition is largely avoided. More desirable, and possibly still practicable, would be the adoption of two operational definitions of conflicts. One for low accident rate conditions, the other for situations characterized by a high annual number of accidents.

The use of equations and smooth curves in graphs may create the unfounded impression of being accurate and definitive. It should be emphasized therefore that Figures 3, 4 and 5 are based on and conclusions drawn therefrom from the empirical evidence embodied in Figure 1. Analysis of additional data and conduct of traffic conflicts studies in the future may lead to changes in the functional relationship between  $c^2$  and  $p$  used here. Also, no attempt has been made to analyze conflicts by type and thereby to reduce the value of  $c^2$ .

It is hoped that the theoretical analysis in Section 2 is correct and assumptions made therein reasonable. However, one assumption hidden in the derivation has not been explicitly stated and deserves separate discussion as it has practical implications. When conducting the field count of conflicts it is implicitly assumed that the sample so obtained is characteristic of the occurrence of conflicts throughout the year. That such is not the case is clear. From the practical point of view, the need for careful selection of the time when conflicts are counted needs to be emphasized. As far as this paper goes, the reader should remember that an element of uncertainty inherent in the TCT has not been considered. Qualitatively, its neglect implies that the TCT is somewhat less accurate than implied by the theoretical analysis.

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