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Traffic conflict surveys: some study design considerations

by

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CONTENTS

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TRAFFIC CONFLICT SURVEYS : SOME STUDY DESIGN CONSIDERATIONS

ABSTRACT

The traffic conflicts technique is a device for indirect safety measurement. It requires at present the conduct of a field survey to count conflict occurrence. On this basis the rate at which conflicts occur is estimated. This report deals with the accuracy of such estimation and its dependence on the design of the field survey.

First, present practice in conflict count duration is reviewed. Next, the relationship between count duration and estimation accuracy is examined. Using data obtained from several sources the daily variability of conflict counts is described. It is concluded that the expected conflict rate varies from day to day. Use of the negative binomial distribution is suggested as appropriate for the representation of the distribution of sample means obtained from conflict studies. On this basis, confidence limits and probabilities of Type I and Type II errors in hypothesis testing are obtained and tabulated. Their use in study design is illustrated by numerical examples.

The marginal increase in estimation accuracy diminishes rapidly as conflict counting time increases. Thus, there is little to be gained by counting longer than three days. This establishes a practical limit to the accuracy with which expected daily conflict rates can be estimated.

1. INTRODUCTION

The Traffic Conflicts Technique is a device for indirect measurement of safety. Its early history may be traced in references 5, 6, 7, and 8, recent applications are described in references 2, 3, 9, 12, and 13, and state of the art surveys are available in references 1, 10, and 13.

The Traffic Conflicts Technique is applicable to a variety of situations: to assess changes in safety through "before" and "after" studies and by comparison with control sites; to investigate effectiveness of devices, layouts, designs, procedures etc; to identify and diagnose hazards and so on.

All such uses require at present the conduct of a field study the purpose of which is to observe and count the occurrence of conflicts so as to obtain an estimate of the rate at which conflicts occur. The purpose of this paper is to examine the available empirical evidence in order to provide guidance for the conduct of conflict surveys. Discussion will centre on questions such as conflict rate estimation accuracy, survey duration, sample size selection. On the basis of information from several sources the variability of daily conflict counts will be characterized. A model will be suggested as fitting this counting distribution. Various aspects of the conflict study design will be illustrated by numerical examples. Tables and graphs will be supplied for use in survey design.

Present practice in conflict count duration is summarized in Table 1.

Thorson and Glennon in their recent paper[1] raise grave questions about the validity of present practice. They conclude that "For all three potential uses of conflict counts, existing relationships do not allow practical sample sizes". The conclusion, if true, would have far reaching consequences. Not only does present practice in the conduct of conflict studies seem inadequate, there also is little hope that the sample sizes required according to Thorson and Glennon would leave much interest in applying the Traffic Conflicts Technique in any circumstances. As this very important conclusion has been reached on the basis of limited empirical evidence, careful re-examination is in order.

2. THE EXPECTED CONFLICT RATE

The aim of a conflict survey is to obtain satisfactory estimates of the "expected conflict rate". This is not a simple concept and requires delineation. In intuitive terms, the concept of "expectation" is closely associated with the notion of 'average in the long run'. We tend to believe that just as throws of a die will in the long run average at 3.5, so would repeated conflict counts reveal a permanent characteristic of the site. The analogy, however, is incomplete. Unlike the die, the site changes its "average" property. There is little reason to assume that the expected conflict rate is the same during peak and off peak; Sundays and Mondays, Winter and Summer. It is essential therefore to specify which "expected" rate is subject to estimation.

We will proceed on the assumption that it is the expected weekday conflict rate which is of interest. That is, the 'average' number of conflicts occurring per unit of time during a specified period of observation characterizing any weekday during a certain season of the year. There are two reasons for this choice. First, because surveys are designed in terms of "team days". Thus, it makes little sense to be concerned much about, say, hourly variations. Second, because the principal use of the traffic conflicts technique is in comparisons (between sites, devices, treatments etc), which are usually performed within a relatively short period of time thereby eliminating the need to consider seasonal variation.

3. COUNTING, ESTIMATION AND ACCURACY

In Fig 1, circles represent the number of conflicts counted on 19 consecutive weekdays between 7-10 am and 3-6 pm at the intersection of St Clair and Keele streets in Toronto. The bars in the same figure represent the estimate of the expected conflict rate obtained by averaging the first 1, 2 ..... 19 daily counts.

This simple graph illustrates all major features of the problem at hand.

TABLE 1

Summary of present practice in Conflict Count Duration

Authors	Ref No and Date	Survey description	Survey conduct
Baker	(7) 1972	392 intersections before, 193 after modification (USA).	1 day; 15 min. samples on each approach with breaks between counts. Two man team
Perkins and Harris	(5) 1963	30 intersections signalised and non-signalised (USA)	3 days, 12 hrs per day. Alternate sampling per direction
Cooper	(11) 1973	59 non-signalised intersections; 51 urban, 5 rural (Canada)	2 days, 14 hrs per day. Continuous counting. Five man team. (3 for conflicts)
Spicer	(8) 1973	6 rural junctions (UK)	1 day, 10 hrs per day Continuous counting. Three or four man team. Also, 16 mm time lapse photography
Hyden	(3) 1975	50 urban intersections, varied control (Sweden)	2 days 9.5 hrs per day. Continuous counting. One or two man teams
Malaterre and Muhlrad	(12) 1976	8 intersections, urban (France)	1 day, 7 am to midnight. Sample varies 13% - 57% of hour 2 man team
Amundsen	(13) 1974	31 intersections, low volume, non signalised (Norway)	1 day, 7 hrs per day, Two or three man team (1 for conflicts)

Firstly, the tangible evidence - the daily conflict count is subject to considerable variability. It is the variability (or random fluctuation) which is the root source of difficulties in estimation.

Secondly, the fluctuating daily conflict counts are used to obtain an estimate of the 'expected conflict rate'. In the present case the simple average is used for estimation. Unlike the daily counts, the estimate of the expected rate is characterized by pronounced stability.

Thirdly, the accuracy of the estimate increases with the number of daily counts. At first, every added count increases accuracy markedly. Beyond a certain point, not much accuracy is gained by counting more.

The qualitative observations made on the basis of an illustrative example need to be quantified. This will be done on the basis of data from several sources. For quantification, methods of mathematical statistics are useful. These allow measurement of variability in daily counts, characterization of accuracy of estimation etc. However, how accurate the estimate should be can not be determined using statistics only. Standards of accuracy should depend on the circumstances of the survey and on the use to which its results will be put.

This is unfortunate. One usually prefers to have firm and explicit standards for guidance. Conduct of an elaborate decision analysis study in every case is impractical. There is a strong temptation therefore to simply adopt commonly used 'significance levels' on the strength of the argument that use in medicine, sociology, quality control, psychology and other fields lends them sufficient authority.

A word of caution is in order. It is wrong to transfer without questioning levels of significance which are well suited for say, concrete quality control into management of safety. The costs of conducting experiments are different; the implications of error are not the same. For most safety countermeasures, statistically conclusive evidence of effectiveness is practically not obtainable. Recognizing this as a fact of life, does one proceed and recommend that driver licensing, vehicle inspection etc be discontinued because neither can be shown effective at the 5 per cent level of significance? 'The research community should consider carefully before doing so'[4]. Uncritical use of high significance levels 'can lead to the erroneous rejection of effective programs...'[15]. Rather, standards of accuracy need to be adopted which reflect both the benefit lost by not implementing measures which are likely beneficial but can not be shown as such; and the cost of implementing measures which are not effective.

4. DATA BASE

To investigate the distribution of daily conflict counts information is needed on the number of conflicts occurring at several sites over a relatively long period of time. Such information is not easy to come by. Partly, because conflicts are rarely counted for more than a couple of days; partly because usually only the average number is retained and archived, the daily counts are discarded or difficult to access.

Fortunately, a good data base for the present purpose has been generated in the course of a study on the effectiveness of law enforcement[2]. Conflicts were counted at seven urban intersections for 39 weekdays (at each) between 7-10 am and 3-6 pm. The first two weeks (10 survey days) with normal police activity were followed by four weeks (19 survey days) with increased enforcement and another two weeks (10 survey days) with normal enforcement again. At each location seven conflict types were recorded. In the analysis below, the initial ten days of the survey will not be used because 'Initially, all observers tended to overcount drastically ... stabilization of these counts did not proceed as quickly as anticipated and in most cases could not realistically have occurred by the beginning of increased enforement'[2]. Thus, data from seven locations, seven conflict types and two sequences of 19 and 10 days are used. It should be noted that the variability of the count will of necessity be overestimated because some variability will have been generated by the changes in police activity even within the phases which are analysed separately.

To avoid reliance on one source of data, however extensive, two additional smaller sets of data were used. Firstly, conflict counts from 20 sites published by Hydén[3]. In this case, two days of observation for each site are available. Secondly, data collected by the Transport and Road Research Laboratory on four junctions. For three of those only two days of conflict counts exist, for the remaining junction three days of counts are available.

5. THE VARIABILITY OF DAILY CONFLICT COUNTS

Variability is usually measured by sample variance. In Figs 2 and 3, sample variance is plotted against sample mean. Each point in Fig 2 represents the sample mean and variance of a homogeneous conflict class (cross traffic, rear end etc) at seven intersections for two phases of the study[2] with different enforcement levels. In Fig 3 the sum of all conflict classes has been used for the calculation of sample mean and variance. Also shown are data from TRRL and Hydén[3].

Several observations follow:

Firstly, the variance of the conflict count increases with the mean count. Such a relationship is to be expected. Obviously, when the mean count is zero, so is the variance. Thus the origin is the starting point of the curve describing the relationship. In the range of mean conflict counts for which data are available, it is simplest to represent the relationship by a line through the origin. When conflicts for each homogeneous class are counted separately, the average variance to mean ratio is 1.4. When the sum of all conflict classes is of interest, the average variance to mean ratio is 2.2.

In their paper evaluating the traffic conflicts technique[1] Thorson and Glennon conclude that the daily conflict counts are characterized by a constant variance of 530 $(\text{conflicts/day})^2$ irrespective of the daily conflict rate. It is on the basis of this variance that they derive the number of days needed for conflict surveys. Our data do not confirm the assumption of constant variance; on the contrary as in most known counting distributions, variance is found to increase with the mean. Nor can one find support for the high value of the variance used by Thorson and Glennon.

The second observation to be made on the basis of Figs 2 and 3 pertains to the Poisson hypothesis. In the absence of empirical evidence to the contrary it is usually assumed that rare events with a constant mean follow the Poisson distribution. Were this so, one would expect the line Variance=Mean to fit the data. It is apparent, that the Poisson hypothesis does not hold. This may be so because the expected rate of conflict occurrence at intersections changes from day to day due to changes in weather, vehicular flow, pedestrian volumes etc. In addition, some variability is introduced through the subjectivity of conflict identification by observers.

Thirdly, there is no assurance that the same distribution describes the conflict counting process irrespective of the conflict type counted, the counting procedure used, the definition of the conflict event, the specific circumstances of the site etc. Hydén's results, for example, suggest a smaller variability than the rest of the data. When specific information about count variability is not available, use of the average values obtained in this paper is recommended.

6. THE MODEL

To facilitate survey design and analysis in customary statistical terms, one has to adopt a model probability distribution which is simple in use, fits the data and represents a process which bears reasonable semblance to our perception of reality.

The negative binomial distribution has been used for similar purposes in the past[14]. It is founded on the assumption that the daily expected conflict rate follows a gamma distribution and the actual daily conflict counts a Poisson distribution with the aforementioned daily expected conflict rate as a mean.

Adopting the negative binomial distribution, it is shown in the appendix that the distribution of the sample mean ($\bar{X}$) obtained from a count over j days is given by:

$$P\ (\bar{X} = n/j) = (-1)^n \binom{-\nu j}{n} p^n q^{\nu j},\ n = 1, 2, \ldots$$

with

$$E\left\{\bar{X}\right\} = \nu/a$$

$$VAR\left\{\bar{X}\right\} = E\left\{\bar{X}\right\}\ (1+a)/(aj) \qquad \ldots. (1)$$

where

$\bar{X}$ = sum of j daily conflict counts divided by j

$p = 1/(1+a)$

$q = 1-p$

ν = a.(Expected Daily Conflict Rate)

$$a = \begin{cases} 2.5 & \text{for homogeneous conflict classes} \\ 0.83 & \text{for the sum of several conflict classes.} \end{cases}$$

Figure 4 serves to illustrate the probability distribution function of X for counts of 1, 2 and 6 days duration if it is the sum of all conflict types which is of interest and the expected daily conflict rate is 20. For expected conflict rates above 20 per day tables of the normal distribution approximate the distribution (1) sufficiently closely. In Fig 4 the circles are derived using the normal probability distribution tables.

7. ACCURACY, ERRORS AND DECISIONS

Using the data on daily variability in conflict counts and the suggested probability model one can tabulate the probability distribution of conflict counts. This is the basic information needed for statistical considerations of any kind. Table 2 gives the probability distribution for counts of homogeneous conflict classes with an average of 10 conflicts per day*.

The various uses of results obtained so far are best discussed within the framework of illustrative examples.

Example 1 - Confidence limits

From a 2 day survey of "cross traffic" conflicts, an average daily count of 10.0 conflicts has been obtained. Find 50 per cent, 75 per cent, 90 per cent and 95 per cent confidence limits.

Solution: From Table 2, the confidence limits are:

	Larger than	Less than
50%	7.5	11.5
75%	6.5	13.0
90%	5.5	14.5
95%	4.5	15.0

Discussion: For high confidence levels, the interval is large. Thus, either one has to adopt modest standards of accuracy or invest in longer counts. (The fact that the limits are not symmetric with respect to the mean stems from the skewness of the distribution).

Example 2 - Survey design for specified confidence limits

How many days need one count so as to obtain a 90% confidence interval of 4 or less under the conditions of the previous example?

Solution: From Table 2, the 90% confidence limits are:

Number of Survey Days	2	3	4	5	6
90% Confidence Limits	5.5-14.1	6.3-13.4	6.8-12.9	7.2-12.7	7.3-12.3

* Tables of the probability distribution and confidence intervals for expected daily conflict rates between 2 and 20 are available from the TRRL (Road User Characteristics Division).

TABLE 2 Probability distribution of $\overline{X}$ for homogeneous conflict classes $E\{\overline{X}\}$ = 10 conflicts per day

NUMBER OF SURVEY DAYS											
1		2		3		4		5		6	
X	F(X) *	X	F(X)	X	F(X)	X	F(X)	X	F(X)	X	F(X)
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000
1.00	0.002	3.00	0.001	4.00	0.001	4.50	0.001	5.00	0.001	5.50	0.001
2.00	0.008	3.50	0.003	4.33	0.002	4.75	0.001	5.20	0.001	5.67	0.001
3.00	• 0.023	4.00	0.007	4.67	0.004	5.00	0.002	5.40	0.001	5.83	0.002
4.00	0.053	4.50	• 0.013	5.00	0.006	5.25	0.003	5.60	0.002	6.00	0.003
5.00	-- 0.103	5.00	0.025	5.33	0.011	5.50	0.005	5.80	0.004	6.17	0.004
6.00	— 0.175	5.50	•• 0.042	5.67	• 0.018	5.75	0.008	6.00	0.006	6.33	0.006
7.00	0.266	6.00	0.068	6.00	0.029	6.00	0.013	6.20	0.009	6.50	0.008
8.00	0.370	6.50	-- 0.102	6.33	•• 0.043	6.25	• 0.019	6.40	0.013	6.67	0.012
9.00	0.479	7.00	0.147	6.67	0.063	6.50	0.028	6.60	• 0.018	6.83	0.016
10.00	— 0.584	7.50	— 0.201	7.00	0.088	6.75	•• 0.039	6.80	0.025	7.00	• 0.022
11.00	0.680	8.00	0.264	7.33	-- 0.119	7.00	0.054	7.00	0.034	7.17	0.030
12.00	0.763	8.50	0.334	7.67	0.157	7.25	0.073	7.20	•• 0.046	7.33	•• 0.039
13.00	-- 0.830	9.00	0.409	8.00	— 0.201	7.50	-- 0.097	7.40	0.061	7.50	0.051
14.00	0.881	9.50	0.485	8.33	0.251	7.75	0.125	7.60	0.079	7.67	0.064
15.00	•• 0.920	10.00	0.560	8.67	0.306	8.00	0.157	7.80	-- 0.100	7.83	0.081
16.00	0.948	10.50	0.631	9.00	0.365	8.25	0.195	8.00	0.125	8.00	-- 0.101
17.00	• 0.967	11.00	— 0.697	9.33	0.426	8.50	— 0.237	8.20	0.154	8.17	0.123
18.00	0.979	11.50	0.756	9.67	0.488	8.75	0.282	8.40	0.187	8.33	0.149
19.00	0.987	12.00	0.807	10.00	0.549	9.00	0.331	8.60	— 0.223	8.50	0.178
20.00	0.992	12.50	-- 0.851	10.33	0.608	9.25	0.383	8.80	0.262	8.67	0.209
21.00	0.996	13.00	0.886	10.67	— 0.665	9.50	0.436	9.00	0.304	8.83	— 0.244
22.00	0.998	13.50	0.915	11.00	0.717	9.75	0.489	9.20	0.349	9.00	0.281
23.00	0.999	14.00	-- 0.938	11.33	0.764	10.00	0.543	9.40	0.395	9.17	0.321
24.00	0.999	14.50	• 0.955	11.67	0.806	10.25	0.594	9.60	0.443	9.33	0.362
0.00	0.000	15.00	0.968	12.00	-- 0.843	10.50	0.644	9.80	0.490	9.50	0.404
0.00	0.000	15.50	0.978	12.33	0.874	10.75	0.691	10.00	0.538	9.67	0.448
0.00	0.000	16.00	0.985	12.67	0.901	11.00	— 0.735	10.20	0.585	9.83	0.491
0.00	0.000	16.50	0.990	13.00	0.923	11.25	0.775	10.40	0.630	10.00	0.535
0.00	0.000	17.00	0.993	13.33	•• 0.940	11.50	0.811	10.60	0.673	10.17	0.577
0.00	0.000	17.50	0.995	13.67	0.955	11.75	-- 0.842	10.80	— 0.713	10.33	0.619
0.00	0.000	18.00	0.997	14.00	• 0.966	12.00	0.870	11.00	0.751	10.50	0.659
0.00	0.000	18.50	0.998	14.33	0.975	12.25	0.894	11.20	0.786	10.67	0.697
0.00	0.000	19.00	0.999	14.67	0.982	12.50	0.915	11.40	0.817	10.83	— 0.733
0.00	0.000	19.50	0.999	15.00	0.987	12.75	•• 0.932	11.60	-- 0.845	11.00	0.766
0.00	0.000	0.00	0.000	15.33	0.990	13.00	0.946	11.80	0.870	11.17	0.797
0.00	0.000	0.00	0.000	15.67	0.993	13.25	0.958	12.00	0.892	11.33	0.825
0.00	0.000	0.00	0.000	16.00	0.995	13.50	• 0.968	12.20	0.911	11.50	-- 0.850
0.00	0.000	0.00	0.000	16.33	0.997	13.75	0.975	12.40	0.927	11.67	0.872
0.00	0.000	0.00	0.000	16.67	0.998	14.00	0.981	12.60	•• 0.941	11.83	0.892
0.00	0.000	0.00	0.000	17.00	0.998	14.25	0.986	12.80	0.953	12.00	0.910
0.00	0.000	0.00	0.000	17.33	0.999	14.50	0.989	13.00	• 0.962	12.17	0.925
0.00	0.000	0.00	0.000	17.67	0.999	14.75	0.992	13.20	0.970	12.33	•• 0.938
0.00	0.000	0.00	0.000	0.00	0.000	15.00	0.994	13.40	0.977	12.50	0.949
0.00	0.000	0.00	0.000	0.00	0.000	15.25	0.996	13.60	0.982	12.67	0.959
0.00	0.000	0.00	0.000	0.00	0.000	15.50	0.997	13.80	0.986	12.83	• 0.967
0.00	0.000	0.00	0.000	0.00	0.000	15.75	0.998	14.00	0.989	13.00	0.973
0.00	0.000	0.00	0.000	0.00	0.000	16.00	0.998	14.20	0.992	13.17	0.979
0.00	0.000	0.00	0.000	0.00	0.000	16.25	0.999	14.40	0.994	13.33	0.983
0.00	0.000	0.00	0.000	0.00	0.000	16.50	0.999	14.60	0.995	13.50	0.987
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	14.80	0.997	13.67	0.990
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.00	0.997	13.83	0.992
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.20	0.998	14.00	0.994
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.40	0.999	14.17	0.995
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.60	0.999	14.33	0.996
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	14.50	0.997
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	14.67	0.998
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	14.83	0.998
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.00	0.999
0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	15.17	0.999

* F (X) = $P(\overline{X} \leq X)$

Confidence limits		
	50%	—
	75%	--
	90%	••
	95%	•

Discussion: It appears that attainment of the specified accuracy is difficult. A count duration in excess of 10 days would be needed. As may be seen, the reduction in the confidence interval by counting longer diminishes. One should weigh therefore the increase in accuracy against the cost of prolonging the survey.

Example 3 - Confidence limits for daily conflict rates larger than 20

Anticipating a daily conflict rate of 40 (sum of all conflict classes) how many days need one count so that a 75 per cent confidence interval is less than 10 conflicts per day?

Solution: As the conflict rate exceeds 20, tables of the normal probability distribution may be used. For the sum of all conflict classes, a = 0.83 (equation 1). Also from equation 1, $VAR\{\bar{X}\} = 40 \times (1 + 0.83)/(0.83j)$. To determine 75 per cent confidence limits, multiply $(VAR\{\bar{X}\})^{\frac{1}{2}}$ by 1.15 (obtained from tables of the normal probability distribution). Thus

Number of Survey Days (j)	1	2	3	4	5	6
$(VAR\{\bar{X}\})^{\frac{1}{2}}$	9.4	6.6	5.4	4.7	4.2	3.8
75% Confidence Limits	±10.0	±7.6	±6.2	±5.4	±4.8	±4.4

For the prescribed accuracy, 5 days of counting are needed.

Discussion: for 50 per cent, 60 per cent, 70 per cent, 80 per cent, 90 per cent and 95 per cent confidence limits, 0.67, 0.84, 1.04, 1.28, 1.64 and 1.96 are the appropriate multipliers.

Determination of confidence limits for conflict counts is relatively easy. Their interpretation is straightforward. This is therefore likely to be the best basis on which to make intuitive decisions about survey duration. After all,one can readily assess the gain in accuracy from prolonging the survey one more day and the cost of doing so.

Figures 5 and 6 give the size of confidence intervals in dependence on survey duration and expected conflict rate. This should prove to be effective guidance in many circumstances.

In some situations, the probability distribution of count averages and the associated confidence intervals may not be deemed sufficient for conflict survey design and survey result analysis. Notably, when 'treatment effectiveness' is the main concern. This is most common in so called 'before' and 'after' studies. In this context, one usually wishes to ascertain whether some treatment is effective in reducing the number of conflicts. A positive answer may lead to the modification of design standards, installation of new equipment, reconstruction of inferior site features etc.

While the question is simple ('is the treatment effective?') the answer is not. Indeed a straightforward response is not forthcoming. It is for this reason that use of confidence limits may be preferred as the device which is least given to misinterpretation.

To provide an answer of a sort, the problem of treatment effectiveness needs first to be recast into the terms of testing a statistical hypothesis. The outcome of such a 'test' is not a statement: the hypothesis is true (false). It is merely a statement specifying the chance of error should one decide on the basis of conflict studies to accept or reject the hypothesis. It is customary (for little good reason) to 'test' the hypothesis: 'the treatment is not effective'. If so, concluding on the basis of data that the treatment is effective when in fact it is useless constitutes an 'Error of Type I'. Conversely, maintaining on the basis of empirical evidence that the treatment has no effect while in fact it is useful is an 'Error of Type II'. These errors depend on the decision rule which determines acceptance or rejection of the hypothesis. For errors of Type I, tables and examples are provided for a variety of decision rules. For errors of Type II, due to space limitations, tables are given only for the decision rule: the treatment is not effective if after treatment the conflict count has not been reduced. While essential for formal decision analysis, this information is one removed from intuition and given to misinterpretation. It invites therefore use of arbitrary 'significance levels' which are not derived from the reality of the situation at hand. As statistical hypothesis testing is deeply ingrained in present practice, the two types of error are tabulated below. To guard against the possibility of misinterpretation, they are described in as clear a language as possible. Also, their use is introduced and illustrated by numerical examples.

Examples 4 to 7 deal with the chance of failing to detect (through a reduction in the count of conflicts) a real decrease in the expected rate at which conflicts occur. The subsequent examples focus on the probability of observing a reduction in conflict counts when in fact there has been no change in the expected conflict rate.

<u>Example 4 - Failure to observe improvement when improvement exists</u>

Due to a successful treatment, the expected daily rate of cross traffic conflicts has been reduced from 12 to 8. Thus, in the long run the number of such conflicts is reduced by 33 per cent. Determine the probability of observing no reduction in the average conflict count if two days of counting 'before' are compared to two days of counting 'after'. Such a result (failure to observe reduction in conflicts when improvement exists) might lead one to conclude erroneously that the treatment had no beneficial effect.

<u>Solution</u>: Table 3 lists the probability of no reduction in the average conflict count for combinations of before and after conflict rates and survey durations. For this example, the probability is 0.156.

<u>Discussion</u>: To aid interpretation, consider 100 sites at which treatment reduces the expected daily conflict rate from 12 to 8. Counting conflicts for 2 days before and after treatment, approximately 84 sites will show a reduction in the average number of conflicts; at the remaining 16 sites, no reduction will be observed.

Note that if the daily rate concerned was that of the sum of all conflict classes and not one homogeneous class then Table 4 and not Table 3 should be used.

<u>Example 5 - Effect of survey duration on failure to observe improvement</u>

The probability of failing to observe a reduction in the conflict count when an actual reduction in the expected conflict rate exists can be reduced by prolonging the duration of the conflict count. Explore the effect of survey duration in the situation described in example 4.

Solution: Using Table 3 with expected daily conflict rates of 12 and 8, and for a homogeneous conflict class:

Survey Duration (days)	1	2	3	4	5	6
Probability of no reduction in the average conflict count	0.252	0.156	0.103	0.070	0.049	0.034

Discussion: It is natural to ask now how important it is to reduce the probability of failing to observe a reduction in the average conflict count. The answer depends on the specific objectives and circumstances of each survey. If the effect of the treatment is examined at 10 sites, by counting conflicts for 2 days, a reduction in conflicts should be obtained on the average at 8 sites. It can happen, of course, that a reduction will be observed at 5 sites or less. The probability of this event is less than 2 per cent. (Using the binomial distribution with $p = 0.156$). In this case, a 0.156 'level of significance' might offer sufficient insurance against the possibility that a reduction in conflicts will not be observed at most sites. If, however, the survey is carried out at 4 sites only, the probability of obtaining a reduction in conflict count at two sites or less (when counting two days before and two days after) is 12 per cent. By counting 3 days in this case, one can reduce the chance of not obtaining a reduction in conflicts at the majority of sites to 6 per cent.

Example 6 - Failure to observe improvement, use of the normal approximation for rates in excess of 20 conflicts per day

The expected daily conflict rates (sum of all classes) are 35 'before' and 30 'after'. What is the probability of average count 'after' not being less than the average conflict count 'before' when counting 1, 2 .... 6 days. (This is a repetition of examples 4 and 5 only with high daily conflict rates to illustrate the use of the normal approximation.)

Solution: The difference between the 'before' and 'after' sample means is approximately normally distributed with a mean = 35 - 30 = 5 conflicts per day and variance = sum of VAR $\{\bar{X}\}$ before and after = $(35 + 30)(1.83)/(0.83j)$. (See equation 1 and example 3). The standard normal variable in this case is $5/[(65)(1.83)/(0.83j)]^{\frac{1}{2}}$. The probability of the difference between the counts being negative is listed in tables of the normal probability distribution:

Number of Survey Days (j)	Standard Normal Variable	$P(\bar{X}_{after} \geq \bar{X}_{before})$
1	0.42	0.34
2	0.59	0.28
3	0.72	0.24
4	0.84	0.20
5	0.93	0.17
6	1.02	0.15

TABLE 3 $P(\overline{X}_{before} \leq \overline{X}_{after})$ when improvement does exist homogeneous conflict classes

m_1	j	m_2 = 2	4	6	8	10	12	14	16	18	20
2.	1	0.595									
2.	2	0.562									
2.	3	0.549									
2.	4	0.543									
2.	5	0.538									
2.	6	0.534									
4.	1	0.301	0.562								
4.	2	0.192	0.543								
4.	3	0.132	0.534								
4.	4	0.094	0.529								
4.	5	0.068	0.526								
4.	6	0.050	0.524								
6.	1	0.138	0.344	0.549							
6.	2	0.050	0.252	0.534							
6.	3	0.020	0.196	0.528							
6.	4	0.008	0.156	0.524							
6.	5	0.003	0.126	0.521							
6.	6	0.001	0.103	0.519							
8.	1	0.059	0.192	0.367	0.543						
8.	2	0.011	0.094	0.287	0.529						
8.	3	0.002	0.050	0.236	0.524						
8.	4	0.000	0.027	0.197	0.520						
8.	5	0.000	0.015	0.168	0.518						
8.	6	0.000	0.009	0.144	0.516						
10.	1	0.024	0.100	0.227	0.382	0.538					
10.	2	0.002	0.029	0.129	0.310	0.526					
10.	3	0.000	0.010	0.078	0.263	0.521					
10.	4	0.000	0.003	0.049	0.227	0.518					
10.	5	0.000	0.001	0.031	0.198	0.516					
10.	6	0.000	0.000	0.020	0.174	0.515					
12.	1	0.010	0.050	0.132	0.252	0.393	0.534				
12.	2	0.000	0.008	0.050	0.156	0.327	0.524				
12.	3	0.000	0.001	0.020	0.103	0.283	0.519				
12.	4	0.000	0.000	0.009	0.070	0.249	0.516				
12.	5	0.000	0.000	0.004	0.049	0.222	0.515				
12.	6	0.000	0.000	0.002	0.034	0.198	0.513				
14.	1	0.004	0.023	0.073	0.158	0.272	0.402	0.531			
14.	2	0.000	0.002	0.017	0.069	0.179	0.340	0.522			
14.	3	0.000	0.000	0.004	0.033	0.125	0.299	0.518			
14.	4	0.000	0.000	0.001	0.016	0.090	0.267	0.515			
14.	5	0.000	0.000	0.000	0.008	0.065	0.240	0.513			
14.	6	0.000	0.000	0.000	0.004	0.048	0.218	0.512			
16.	1	0.001	0.011	0.039	0.094	0.179	0.287	0.408	0.529		
16.	2	0.000	0.000	0.005	0.027	0.087	0.197	0.351	0.520		
16.	3	0.000	0.000	0.001	0.009	0.046	0.144	0.312	0.516		
16.	4	0.000	0.000	0.000	0.003	0.025	0.107	0.281	0.514		
16.	5	0.000	0.000	0.000	0.001	0.014	0.081	0.256	0.512		
16.	6	0.000	0.000	0.000	0.000	0.008	0.062	0.234	0.511		
18.	1	0.001	0.005	0.020	0.054	0.112	0.196	0.300	0.414	0.528	
18.	2	0.000	0.000	0.001	0.010	0.038	0.103	0.213	0.360	0.519	
18.	3	0.000	0.000	0.000	0.002	0.014	0.058	0.160	0.322	0.515	
18.	4	0.000	0.000	0.000	0.000	0.005	0.034	0.123	0.293	0.513	
18.	5	0.000	0.000	0.000	0.000	0.002	0.020	0.096	0.269	0.512	
18.	6	0.000	0.000	0.000	0.000	0.001	0.012	0.075	0.248	0.511	
20.	1	0.000	0.002	0.010	0.029	0.068	0.129	0.211	0.310	0.418	0.526
20.	2	0.000	0.000	0.000	0.003	0.015	0.049	0.118	0.227	0.367	0.518
20.	3	0.000	0.000	0.000	0.000	0.004	0.020	0.071	0.174	0.331	0.515
20.	4	0.000	0.000	0.000	0.000	0.001	0.009	0.044	0.137	0.303	0.512
20.	5	0.000	0.000	0.000	0.000	0.000	0.004	0.027	0.109	0.280	0.511
20.	6	0.000	0.000	0.000	0.000	0.000	0.002	0.017	0.088	0.260	0.510

m_1 Expected daily conflict rate 'before'
m_2 Expected daily conflict rate 'after'
j Number of survey days

TABLE 4 $P(\bar{X}_{before} \leq \bar{X}_{after})$ when improvement does exist
sum of all conflict classes

m_1	j	m_2 = 2	4	6	8	10	12	14	16	18	20
2.	1	0.592									
2.	2	0.554									
2.	3	0.542									
2.	4	0.535									
2.	5	0.531									
2.	6	0.528									
4.	1	0.337	0.554								
4.	2	0.239	0.535								
4.	3	0.183	0.528								
4.	4	0.144	0.524								
4.	5	0.115	0.521								
4.	6	0.093	0.519								
6.	1	0.186	0.372	0.542							
6.	2	0.091	0.295	0.528							
6.	3	0.048	0.246	0.522							
6.	4	0.027	0.209	0.519							
6.	5	0.015	0.180	0.517							
6.	6	0.009	0.156	0.515							
8.	1	0.100	0.239	0.392	0.535						
8.	2	0.031	0.144	0.326	0.524						
8.	3	0.011	0.093	0.282	0.519						
8.	4	0.004	0.062	0.243	0.516						
8.	5	0.001	0.042	0.220	0.514						
8.	6	0.001	0.029	0.197	0.513						
10.	1	0.053	0.149	0.272	0.405	0.531					
10.	2	0.010	0.064	0.181	0.346	0.521					
10.	3	0.002	0.030	0.123	0.306	0.517					
10.	4	0.001	0.015	0.093	0.274	0.514					
10.	5	0.000	0.007	0.069	0.249	0.513					
10.	6	0.000	0.004	0.051	0.227	0.511					
12.	1	0.023	0.091	0.183	0.295	0.414	0.528				
12.	2	0.003	0.027	0.093	0.209	0.360	0.519				
12.	3	0.000	0.009	0.051	0.156	0.323	0.515				
12.	4	0.000	0.003	0.027	0.119	0.294	0.513				
12.	5	0.000	0.001	0.017	0.093	0.270	0.511				
12.	6	0.000	0.000	0.010	0.073	0.249	0.510				
14.	1	0.015	0.054	0.120	0.209	0.312	0.421	0.525			
14.	2	0.001	0.011	0.045	0.117	0.231	0.371	0.517			
14.	3	0.000	0.002	0.018	0.070	0.179	0.337	0.514			
14.	4	0.000	0.001	0.008	0.044	0.142	0.309	0.512			
14.	5	0.000	0.000	0.003	0.028	0.114	0.287	0.510			
14.	6	0.000	0.000	0.001	0.018	0.092	0.267	0.510			
16.	1	0.003	0.031	0.077	0.144	0.229	0.326	0.426	0.524		
16.	2	0.000	0.004	0.020	0.062	0.138	0.248	0.380	0.516		
16.	3	0.000	0.001	0.006	0.029	0.082	0.197	0.347	0.513		
16.	4	0.000	0.000	0.002	0.014	0.058	0.161	0.322	0.511		
16.	5	0.000	0.000	0.001	0.007	0.039	0.132	0.300	0.510		
16.	6	0.000	0.000	0.000	0.003	0.027	0.110	0.281	0.509		
18.	1	0.004	0.018	0.048	0.097	0.164	0.246	0.337	0.430	0.522	
18.	2	0.000	0.001	0.009	0.031	0.078	0.156	0.262	0.387	0.515	
18.	3	0.000	0.000	0.002	0.011	0.040	0.105	0.213	0.356	0.512	
18.	4	0.000	0.000	0.000	0.004	0.021	0.073	0.177	0.332	0.510	
18.	5	0.000	0.000	0.000	0.001	0.011	0.051	0.149	0.311	0.509	
18.	6	0.000	0.000	0.000	0.001	0.006	0.036	0.126	0.293	0.508	
20.	1	0.002	0.010	0.030	0.064	0.115	0.181	0.260	0.346	0.434	0.521
20.	2	0.000	0.001	0.004	0.015	0.042	0.093	0.172	0.274	0.393	0.514
20.	3	0.000	0.000	0.000	0.004	0.017	0.051	0.120	0.227	0.364	0.511
20.	4	0.000	0.000	0.000	0.001	0.007	0.029	0.086	0.191	0.341	0.510
20.	5	0.000	0.000	0.000	0.000	0.003	0.017	0.063	0.163	0.321	0.509
20.	6	0.000	0.000	0.000	0.000	0.001	0.010	0.046	0.140	0.304	0.508

m_1 Expected daily conflict rate 'before'
m_2 Expected daily conflict rate 'after'
j Number of survey days

Discussion: The value of the standard normal variable for any two expected daily conflict rates is given by

$$\frac{\text{Difference between the expected daily conflict rates}}{\left[\text{Sum of expected conflict rates} \cdot (1 + a)/(aj)\right]^{\frac{1}{2}}}$$

where a and j are defined by equation 1.

Example 7 - Critique of results by Thorson and Glennon

Thorson and Glennon[1] use the probability of failure to observe a reduction in the count of conflicts as their criterion for survey duration determination. It is natural therefore to discuss their results at this point in the context of the following example:

Determine the duration of conflict survey needed to assure that the probability to obtain a reduction in conflict count is 0.025, 0.05.... 0.40 given that the expected daily conflict rate before treatment is 50 and the reduction after treatment is 5 per cent, 10 per cent .... 25 per cent.

Solution: Using the normal approximation as in example 6,

TABLE 5

Number of survey days to attain given probabilities of failure to observe a reduction in the count of conflicts when the expected daily conflict rate before treatment is 50.

(Sum of all conflict classes)

Reduction in expected conflict rate	Thorson & Glennon (1) (0.05)	Probability of no reduction in conflict count after treatment					
		0.025	0.05	0.10	0.20	0.30	0.40
25% (50x0.75=37.5)	26	5	4	3	2	1	1
20%	41	8	6	5	3	2	1
15%	72	14	12	9	6	4	2
10%	162	32	27	21	14	8	4
5%	650	132	110	86	56	35	17
Column Number	1	2	3	4	5	6	7

Discussion: Column 1 gives results obtained by Thorson and Glennon[1]. It is on this basis that they conclude that the required survey duration is not practical. The survey durations according to our analysis are approximately five times shorter for the same probability of failure to obtain reduction in counts (see Column 3). The discrepancy between the two results stems from the difference in the assumed variability of daily conflict counts. While Thorson and Glennon assume a constant variance of 530, our calculations are based on a variance to mean ratio of 2.2 as obtained from the data described in Section 4.

On the basis of Table 5 it appears that as long as the difference between the 'before' and 'after' expected conflict rates is large, surveys of modest duration guard sufficiently against the probability of not observing a reduction in counts. When the difference between the expected conflict rates is small, even very long surveys do not offer protection against the chance that the 'after' count is larger than the 'before' count.

With four days as a largest practical survey duration the solid line in Table 5 is the boundary of combinations of expected conflict rate reductions and probabilities of failure to observe a reduction in conflict counts. If the probability is to be as low as 0.05 (as in Reference (1)) a conflict survey seems practical only when the 'before' and 'after' rates differ by more than 25 per cent. If a 0.3 probability of not observing a reduction in conflict count is still acceptable, differences as low as 15 per cent can be measured. (It need be remembered that if the effectiveness of the treatment is tested at say 20 sites, then with a probability of 0.3 pertaining to each site, the chance of not obtaining a reduction at the majority of sites is less than 5 per cent.)

In summary, there is nothing sacred about a 'confidence level' of 0.05. In many circumstances, lesser levels may be regarded satisfactory. However, small differences between expected daily conflict rates can not be measured even with very modest 'confidence levels'. This limitation is inherent in every estimation based on random variables with large variance.

In spite of this limitation, one needs to retain the proper perspective. At present, safety can be measured using accident records or conflict counts. Accident records fluctuate no less than conflict counts. If a site has on the average 50 conflicts per day, then, for a 10 per cent 'confidence level' in a 25 per cent reduction in the rates one needs to count conflicts for three days. If the same site has ten accidents per year, then, for a similar accuracy, accident records for 15 years (before and after treatment) need to be collected. Thus, the very real limitations on the conflict method of safety measurement discussed above are even more severe when accident data are used for the same purpose. (This comparison is not quite fair as it disregards the question of proportionality between conflicts and accidents. It serves, however, to illustrate the main attraction of measuring safety via conflicts and the accelerated collection of information.) The argument for indirect safety measurement (eg by conflict studies) cannot be based on a claim of great estimation accuracy. Such is ordinarily not attainable. It is based on the simple fact that in some circumstances indirect safety measurement is more accurate than any other method at our disposal.

So far we were concerned about the possibility of not being able to show through a reduction in the count of conflicts a real reduction in the expected conflict rate. This may be thought of as the danger of not recommending for implementation a treatment which in fact is effective. The converse, of course, must be also of concern. It is quite possible (in fact very likely) to obtain a reduction in the count of conflicts in spite of there being no change in the expected conflict rate. This error is associated with the danger of implementing treatments (because of reduction in conflict counts) which are without effect. Such practice is wasteful of resources which could be spent more effectively elsewhere.

Example 8 - Observing improvement when no improvement exists

The expected daily rear-end conflict rate is 16 and remains so after treatment. What is the probability of obtaining a reduction in the average daily conflict count of 2, 4, 6 or more in a two day 'before and after' survey?

Solution: From Table 6.

Difference between the Average Daily Conflict Count Before and After	2	4	6
Probability of Equalling or Exceeding the Difference	.35	.21	.11

Discussion: Note that even fairly large reductions are not unlikely in spite of there being no real change in the rate at which conflicts occur. Out of 100 such sites to which an ineffective treatment has been applied, in a two day survey, some 21 will show a reduction of 4 or more in the average daily conflict rate. Conversely, if only treatments which reduce the daily conflict count in a two day survey by 4 or more are implemented, then 21 per cent of all useless treatments under consideration will be implemented.

Also note that if the daily rate of the sum of all conflict classes is involved Table 7, and not Table 6, should be used.

Example 9 - Effect of survey duration

Continuing example 8, find the probability of observing a reduction in the average conflict count of 4 or more if survey durations up to 6 days are considered.

Solution: From Table 6.

Number of Days	1	2	3	4	5	6
Probability of Difference being 4 or more	.30	.21	.16	.12	.10	.08

Discussion: As expected, when counting longer, the probability of obtaining a reduction exceeding a specified magnitude diminishes. This is illustrated graphically in Figs 7 and 8.

Example 10 - Distribution of the difference between count averages. Use of the normal approximation

For large expected conflict rates, the normal approximation may be used. To illustrate, find the probability of the difference between the average counts (sum of all conflict classes) of two day surveys to exceed 10 if the expected daily conflict rate both 'before' and 'after' is 30.

TABLE 6 $P(\bar{X}_{before} - \bar{X}_{after} \geq r)$ when no improvement exists homogeneous conflict classes

m	j	Reduction in average daily conflict count (r)									
		1	2	3	4	5	6	7	8	9	10
2.	1	0.405	0.242	0.130	0.065	0.030	0.013	0.005	0.002	0.001	0.000
2.	2	0.318	0.139	0.049	0.014	0.003	0.000	0.000	0.000	0.000	0.000
2.	3	0.264	0.086	0.019	0.003	0.000	0.000	0.000	0.000	0.000	0.000
2.	4	0.224	0.055	0.008	0.001	0.000	0.000	0.000	0.000	0.000	0.000
2.	5	0.193	0.036	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.	6	0.168	0.023	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4.	1	0.437	0.318	0.217	0.139	0.084	0.049	0.027	0.014	0.007	0.003
4.	2	0.372	0.224	0.118	0.055	0.022	0.008	0.002	0.001	0.000	0.000
4.	3	0.330	0.168	0.069	0.023	0.006	0.001	0.000	0.000	0.000	0.000
4.	4	0.297	0.129	0.042	0.010	0.002	0.000	0.000	0.000	0.000	0.000
4.	5	0.271	0.100	0.026	0.004	0.000	0.000	0.000	0.000	0.000	0.000
4.	6	0.249	0.079	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000
6.	1	0.449	0.351	0.264	0.189	0.130	0.086	0.054	0.033	0.019	0.011
6.	2	0.395	0.269	0.168	0.095	0.049	0.023	0.010	0.004	0.001	0.000
6.	3	0.360	0.216	0.113	0.052	0.020	0.007	0.002	0.000	0.000	0.000
6.	4	0.332	0.178	0.079	0.029	0.008	0.002	0.000	0.000	0.000	0.000
6.	5	0.310	0.148	0.056	0.016	0.004	0.001	0.000	0.000	0.000	0.000
6.	6	0.290	0.124	0.040	0.009	0.001	0.000	0.000	0.000	0.000	0.000
8.	1	0.456	0.372	0.293	0.224	0.166	0.118	0.082	0.055	0.036	0.022
8.	2	0.409	0.297	0.202	0.129	0.076	0.042	0.021	0.010	0.004	0.002
8.	3	0.378	0.249	0.148	0.079	0.038	0.016	0.006	0.002	0.000	0.000
8.	4	0.354	0.212	0.111	0.050	0.019	0.006	0.002	0.000	0.000	0.000
8.	5	0.334	0.183	0.084	0.032	0.010	0.002	0.000	0.000	0.000	0.000
8.	6	0.316	0.157	0.065	0.021	0.005	0.001	0.000	0.000	0.000	0.000
10.	1	0.461	0.385	0.314	0.249	0.193	0.145	0.106	0.076	0.053	0.036
10.	2	0.419	0.318	0.228	0.156	0.100	0.061	0.035	0.019	0.010	0.004
10.	3	0.391	0.272	0.175	0.103	0.056	0.028	0.012	0.005	0.002	0.001
10.	4	0.369	0.238	0.137	0.070	0.032	0.013	0.004	0.001	0.000	0.000
10.	5	0.350	0.209	0.109	0.049	0.019	0.006	0.002	0.000	0.000	0.000
10.	6	0.334	0.186	0.087	0.034	0.011	0.003	0.001	0.000	0.000	0.000
12.	1	0.464	0.395	0.330	0.269	0.215	0.168	0.128	0.095	0.069	0.049
12.	2	0.426	0.332	0.249	0.178	0.121	0.079	0.049	0.029	0.016	0.008
12.	3	0.400	0.290	0.197	0.124	0.073	0.040	0.020	0.009	0.004	0.001
12.	4	0.380	0.257	0.159	0.089	0.045	0.021	0.008	0.003	0.001	0.000
12.	5	0.363	0.230	0.130	0.065	0.029	0.011	0.004	0.001	0.000	0.000
12.	6	0.348	0.208	0.108	0.048	0.018	0.006	0.002	0.000	0.000	0.000
14.	1	0.467	0.403	0.342	0.285	0.232	0.186	0.146	0.113	0.085	0.063
14.	2	0.431	0.344	0.265	0.196	0.140	0.095	0.063	0.039	0.024	0.014
14.	3	0.407	0.304	0.215	0.143	0.089	0.052	0.029	0.015	0.007	0.003
14.	4	0.389	0.273	0.178	0.107	0.059	0.030	0.014	0.006	0.002	0.001
14.	5	0.373	0.247	0.149	0.081	0.039	0.017	0.006	0.002	0.001	0.000
14.	6	0.359	0.225	0.126	0.062	0.027	0.010	0.003	0.001	0.000	0.000
16.	1	0.469	0.409	0.352	0.297	0.247	0.202	0.163	0.129	0.100	0.076
16.	2	0.436	0.354	0.279	0.212	0.156	0.111	0.076	0.050	0.032	0.019
16.	3	0.413	0.316	0.230	0.159	0.104	0.065	0.038	0.021	0.011	0.005
16.	4	0.396	0.286	0.194	0.122	0.072	0.039	0.019	0.009	0.004	0.001
16.	5	0.381	0.261	0.165	0.095	0.050	0.024	0.010	0.004	0.001	0.000
16.	6	0.367	0.240	0.142	0.075	0.035	0.015	0.005	0.002	0.000	0.000
18.	1	0.471	0.415	0.360	0.308	0.260	0.216	0.177	0.143	0.113	0.089
18.	2	0.439	0.362	0.290	0.225	0.170	0.124	0.088	0.060	0.040	0.025
18.	3	0.418	0.326	0.243	0.173	0.118	0.076	0.047	0.027	0.015	0.008
18.	4	0.402	0.297	0.208	0.136	0.084	0.048	0.026	0.013	0.006	0.002
18.	5	0.387	0.273	0.179	0.108	0.060	0.031	0.014	0.006	0.002	0.001
18.	6	0.375	0.253	0.156	0.087	0.044	0.020	0.008	0.003	0.001	0.000
20.	1	0.472	0.419	0.367	0.318	0.271	0.228	0.190	0.156	0.126	0.100
20.	2	0.443	0.369	0.300	0.238	0.183	0.137	0.100	0.070	0.048	0.032
20.	3	0.422	0.334	0.255	0.186	0.130	0.087	0.056	0.034	0.020	0.011
20.	4	0.406	0.307	0.220	0.149	0.095	0.057	0.032	0.017	0.008	0.004
20.	5	0.393	0.284	0.192	0.121	0.071	0.038	0.019	0.009	0.004	0.001
20.	6	0.381	0.264	0.169	0.099	0.053	0.026	0.011	0.004	0.002	0.000

m Expected daily conflict rate
j Number of survey days

TABLE 7 $P(\overline{X}_{before} - \overline{X}_{after} \geq r)$ when no improvement exists

sum of all conflict classes

m	j	Reduction in the average daily conflict count (r)									
		1	2	3	4	5	6	7	8	9	10
2.	1	0.406	0.261	0.162	0.099	0.059	0.035	0.020	0.011	0.006	0.003
2.	2	0.341	0.181	0.086	0.038	0.015	0.006	0.002	0.000	0.000	0.000
2.	3	0.299	0.131	0.046	0.015	0.004	0.001	0.000	0.000	0.000	0.000
2.	4	0.266	0.097	0.027	0.006	0.001	0.000	0.000	0.000	0.000	0.000
2.	5	0.239	0.073	0.016	0.002	0.000	0.000	0.000	0.000	0.000	0.000
2.	6	0.217	0.055	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000
4.	1	0.445	0.341	0.252	0.181	0.126	0.086	0.057	0.038	0.024	0.015
4.	2	0.393	0.266	0.166	0.097	0.053	0.027	0.013	0.006	0.003	0.001
4.	3	0.359	0.217	0.116	0.055	0.024	0.009	0.003	0.001	0.000	0.000
4.	4	0.333	0.180	0.082	0.032	0.011	0.003	0.001	0.000	0.000	0.000
4.	5	0.311	0.151	0.059	0.019	0.005	0.001	0.000	0.000	0.000	0.000
4.	6	0.292	0.128	0.043	0.011	0.002	0.000	0.000	0.000	0.000	0.000
6.	1	0.457	0.375	0.299	0.232	0.176	0.131	0.095	0.068	0.048	0.033
6.	2	0.414	0.308	0.217	0.144	0.091	0.055	0.032	0.017	0.009	0.004
6.	3	0.386	0.263	0.165	0.095	0.050	0.025	0.011	0.005	0.002	0.000
6.	4	0.363	0.228	0.128	0.064	0.029	0.011	0.004	0.001	0.000	0.000
6.	5	0.345	0.201	0.101	0.044	0.017	0.005	0.001	0.000	0.000	0.000
6.	6	0.328	0.177	0.080	0.030	0.009	0.002	0.000	0.000	0.000	0.000
8.	1	0.463	0.393	0.327	0.266	0.212	0.166	0.128	0.097	0.072	0.053
8.	2	0.426	0.333	0.250	0.180	0.124	0.082	0.052	0.032	0.019	0.011
8.	3	0.401	0.292	0.200	0.128	0.077	0.043	0.023	0.011	0.005	0.002
8.	4	0.382	0.260	0.163	0.094	0.049	0.024	0.010	0.004	0.001	0.000
8.	5	0.365	0.234	0.135	0.070	0.032	0.013	0.005	0.001	0.000	0.000
8.	6	0.351	0.212	0.112	0.052	0.021	0.007	0.002	0.000	0.000	0.000
10.	1	0.467	0.405	0.345	0.290	0.239	0.194	0.155	0.122	0.095	0.073
10.	2	0.434	0.350	0.274	0.207	0.151	0.107	0.073	0.048	0.031	0.019
10.	3	0.412	0.313	0.226	0.155	0.101	0.063	0.037	0.020	0.011	0.005
10.	4	0.394	0.283	0.190	0.119	0.070	0.038	0.019	0.009	0.004	0.001
10.	5	0.379	0.258	0.162	0.093	0.048	0.023	0.010	0.004	0.001	0.000
10.	6	0.366	0.237	0.139	0.073	0.034	0.014	0.005	0.002	0.000	0.000
12.	1	0.471	0.414	0.359	0.308	0.260	0.217	0.178	0.144	0.116	0.091
12.	2	0.440	0.363	0.292	0.228	0.173	0.128	0.092	0.064	0.043	0.029
12.	3	0.419	0.328	0.246	0.177	0.122	0.080	0.051	0.030	0.017	0.009
12.	4	0.403	0.301	0.212	0.141	0.088	0.052	0.029	0.015	0.007	0.003
12.	5	0.389	0.277	0.184	0.113	0.065	0.034	0.017	0.007	0.003	0.001
12.	6	0.377	0.257	0.161	0.092	0.048	0.023	0.010	0.004	0.001	0.000
14.	1	0.473	0.421	0.370	0.322	0.276	0.235	0.197	0.163	0.134	0.109
14.	2	0.444	0.373	0.307	0.246	0.192	0.147	0.109	0.079	0.056	0.039
14.	3	0.425	0.341	0.263	0.196	0.141	0.097	0.065	0.041	0.025	0.015
14.	4	0.410	0.316	0.230	0.160	0.105	0.066	0.039	0.022	0.012	0.006
14.	5	0.397	0.292	0.202	0.132	0.080	0.046	0.024	0.012	0.005	0.002
14.	6	0.386	0.273	0.180	0.109	0.062	0.032	0.015	0.006	0.002	0.001
16.	1	0.475	0.426	0.379	0.333	0.290	0.250	0.213	0.180	0.150	0.124
16.	2	0.448	0.382	0.318	0.260	0.208	0.163	0.125	0.094	0.069	0.049
16.	3	0.430	0.351	0.277	0.212	0.157	0.112	0.078	0.052	0.034	0.021
16.	4	0.416	0.326	0.245	0.176	0.121	0.080	0.050	0.030	0.017	0.009
16.	5	0.404	0.305	0.218	0.148	0.095	0.057	0.032	0.017	0.009	0.004
16.	6	0.393	0.286	0.196	0.125	0.075	0.041	0.021	0.010	0.004	0.002
18.	1	0.476	0.430	0.386	0.342	0.301	0.263	0.227	0.194	0.165	0.138
18.	2	0.451	0.388	0.328	0.272	0.222	0.177	0.139	0.107	0.080	0.059
18.	3	0.434	0.359	0.289	0.226	0.171	0.126	0.090	0.063	0.042	0.027
18.	4	0.421	0.335	0.257	0.190	0.135	0.092	0.060	0.038	0.023	0.013
18.	5	0.409	0.315	0.231	0.162	0.108	0.068	0.041	0.023	0.012	0.006
18.	6	0.399	0.298	0.210	0.139	0.087	0.051	0.028	0.014	0.007	0.003
20.	1	0.477	0.434	0.392	0.350	0.311	0.274	0.239	0.207	0.178	0.151
20.	2	0.454	0.394	0.337	0.283	0.234	0.190	0.152	0.119	0.092	0.070
20.	3	0.437	0.366	0.298	0.237	0.184	0.139	0.102	0.073	0.051	0.034
20.	4	0.425	0.343	0.268	0.203	0.148	0.104	0.070	0.046	0.029	0.017
20.	5	0.414	0.324	0.243	0.175	0.120	0.079	0.049	0.029	0.017	0.009
20.	6	0.404	0.307	0.222	0.152	0.099	0.060	0.035	0.019	0.010	0.005

m Expected daily conflict rate
j Number of survey days

Solution: The difference is approximately normally distributed with a mean of 0 and variance = $[(2)(30)(1.83)/(0.83)(j)] = 66$ (see equation 1 and examples 3, 6). The standard normal variate is $10/(66)^{\frac{1}{2}} = 1.23$. From tables of the normal distribution, the probability of the difference to exceed 10 is 0.11.

Discussion: In general, the standard normal variate is given by:

$$\frac{\text{Difference between conflict count averages}}{[2\ (\text{expected daily number of conflicts})(1+a)/(aj)]^{\frac{1}{2}}}$$

where a and j are defined in equation 1.

8. SUMMARY AND DISCUSSION

Counts of the number of conflicts occurring per day are characterized by considerable variation. Using available data it appears that for homogenous classes, the variance to mean ratio is 1.4; for sum of several (7) conflict classes the variance to mean ratio is 2.2. Accordingly, conflict counts do not follow a simple Poisson distribution. It is convenient to assume that the expected conflict rate varies from day to day. The negative binomial model is invoked to account for this variation.

Using the negative binomial model in conjunction with the aforementioned empirically derived variance to mean ratios the probability distribution has been tabulated, confidence intervals derived and probabilities of type I and II errors computed. Their use is introduced through ten illustrative examples substantiated by graphs and tables.

Interest centres on questions of result accuracy and survey duration. Result accuracy is characterized through confidence limits and probabilities or error in testing hypotheses with respect to treatment effectiveness. It is suggested that unless coupled with formal decision analysis the framework of hypothesis testing is given to misinterpretation. Thus, for judgemental decision on survey design and standards of accuracy, confidence limits may be preferred.

As illustrated, accuracy increases with survey duration. However, the increase in accuracy per additional survey day diminishes rapidly. In general, there is not much to be gained by counting longer than three days. Thus, there is a practical limit to the accuracy with which the value of the expected daily conflict rate can be estimated. Existence of this practical limit on estimation accuracy must be considered when investigating treatment effectiveness. Conflict rate differences of 15 per cent or less will prove difficult to demonstrate through conflict studies.

9. ACKNOWLEDGEMENTS

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11. APPENDIX

The purpose of this appendix is to show the origin of equation 1 and to provide useful auxilary information about characteristic functions, moments and estimation.

Let X be the number of conflicts counted on a day during a given period of time and

λ be the expected number of conflicts that day.

If the count of that day obeys the Poisson distribution,

$$P(X=k|\lambda) = (\lambda^k/k!)e^{-\lambda} \qquad \text{.... (2)}$$

Regarding λ as a continuous random variable which assumes different values on different days, the distribution of X over many days is given by

$$P(X=k) = \int_0^\infty P(X=k|\lambda)f(\lambda)d\lambda. \qquad \text{.... (3)}$$

When λ obeys the gamma distribution,

$$f(\lambda) = \begin{cases} (a^\nu/\Gamma(\nu))\lambda^{\nu-1}\ e^{-a\lambda} & \text{for } \lambda > 0 \\ 0 & \text{for } \lambda \leq 0 \end{cases} \qquad \text{.... (4)}$$

with $\nu > 0$ and $a > 0$.

Substituting (4) into (3) and integrating, we obtain:

$$P(X=k) = (-1)^k \binom{-\nu}{k} p^k q^\nu, \quad k = 0, 1, 2, \ldots. \qquad \text{.... (5)}$$

where

$$p = 1/(1+a)$$
$$q = 1 - p$$
$$\binom{-\nu}{k} = (-\nu)(-\nu-1) \ldots (-\nu-k+1)/k!$$

The probability distribution defined by (5) is the negative binomial distribution. Its characteristic function is given by

$$\phi_X(t) = q^\nu\ (1 - pe^{it})^{-\nu} \qquad \text{.... (6)}$$

Ordinary moments of order r are given by

$$m_r = \sum_{i=o}^{r-1} (-1)^{r-1} \binom{r-1}{i} (p/q)^{r-i}\ (-\nu)_{r-i} \qquad \text{.... (7)}$$

and the two central moments by

$$\mu_1 = \nu\,(p/q) = \nu/a \qquad \text{.... (8)}$$

$$\mu_2 = \mu_1\,(1 + p/q) = \nu\,(1+a)/a^2 \qquad \text{.... (9)}$$

Thus, the negative binomial distribution is completely specified by the two parameters ν and a. To estimate their value, from (8) and (9),

$$a = 1/(\frac{\mu_2}{\mu_1} - 1). \qquad \text{.... (10)}$$

Also from (8) and using (10)

$$\nu = \mu_1/(\frac{\mu_2}{\mu_1} - 1) \qquad \text{.... (11)}$$

Thus, when conflicts belong to a homogeneous class, $a \cong 1/(1.4-1) = 2.5$. When the sum of all conflict classes is of interest, $a \cong 1/(2.2-1) = 0.83$. The variance to mean ratios 1.4 and 2.2 were obtained in section 5.

In the final account we are interested in the distribution of the average conflict count obtained from counting j days. Denote daily counts by $X_1, X_2, \ldots, X_i, \ldots X_j$ and

$$\bar{X} = \frac{1}{j}\sum_{1}^{j} X_i.$$

As counts on successive days are statistically independent, using (6),

$$\phi_{\bar{X}}(t) = \left[\phi_X(t/j)\right]^j = q^{\nu j}(1-pe^{it/j})^{-\nu j} \qquad \text{.... (12)}$$

The characteristics function in (12) belongs to the modified negative exponential distribution

$$P(\bar{X} = n/j) = (-1)^n \binom{-\nu j}{n} p^n q^{\nu j}$$

$$n = 0, 1, 2, \ldots.$$

with

$$E\{\bar{X}\} = \mu_1$$

$$VAR\{\bar{X}\} = \mu_2/j \qquad \text{.... (13)}$$

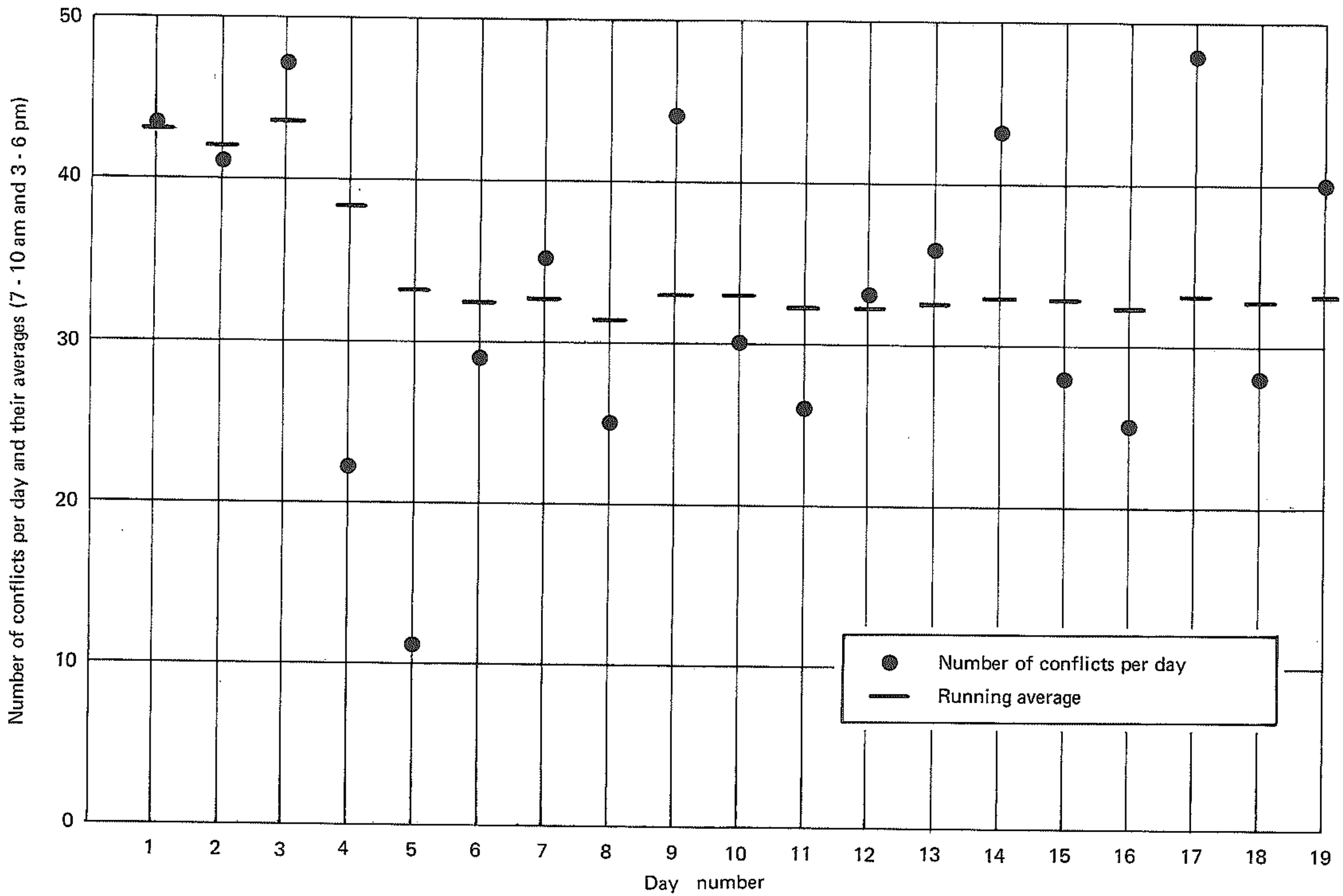

Fig.1 DAILY CONFLICT COUNTS AND THEIR RUNNING AVERAGES

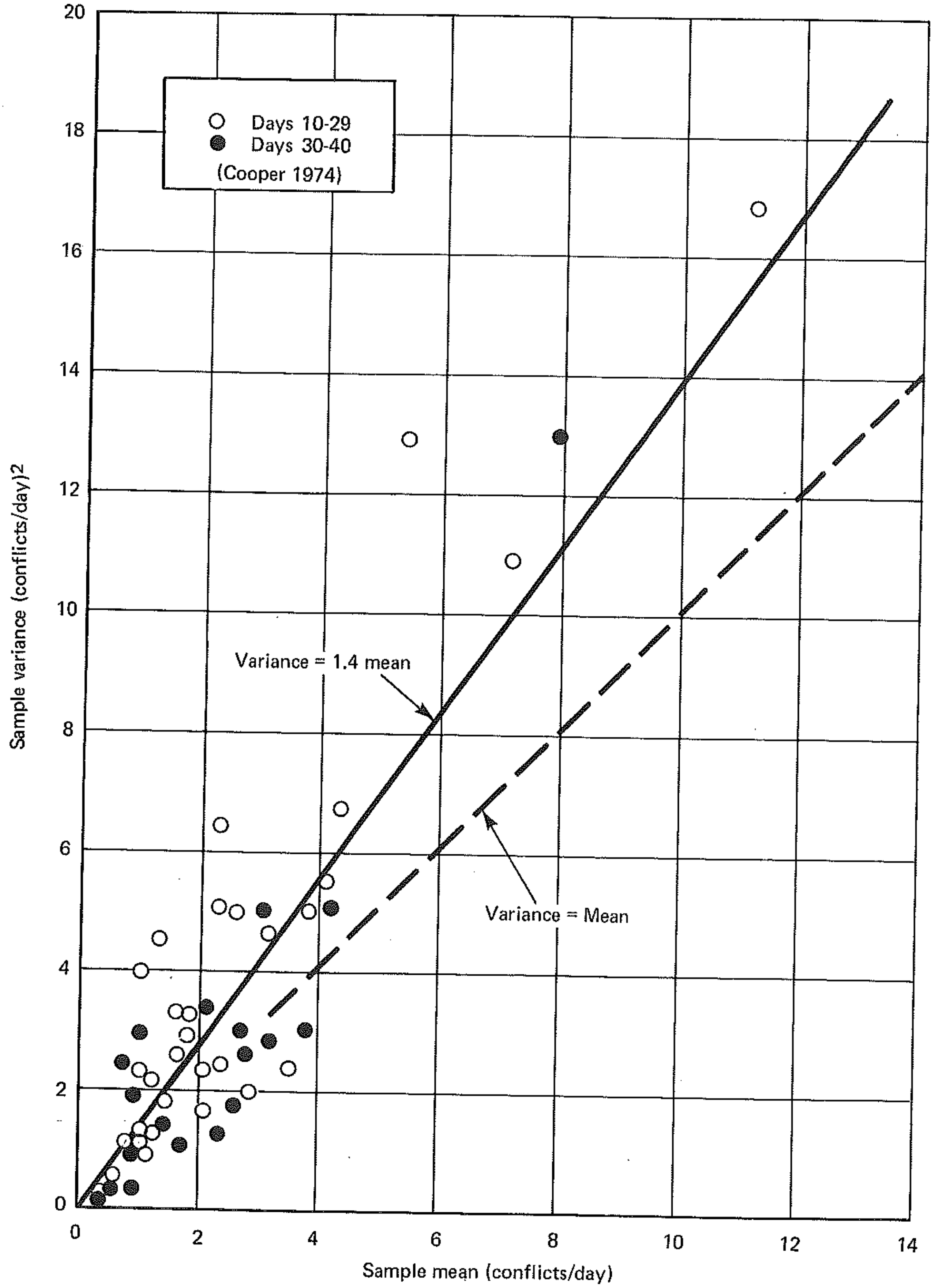

Fig. 2 SAMPLE MEAN AND VARIANCE FOR HOMOGENEOUS CONFLICT CLASSES

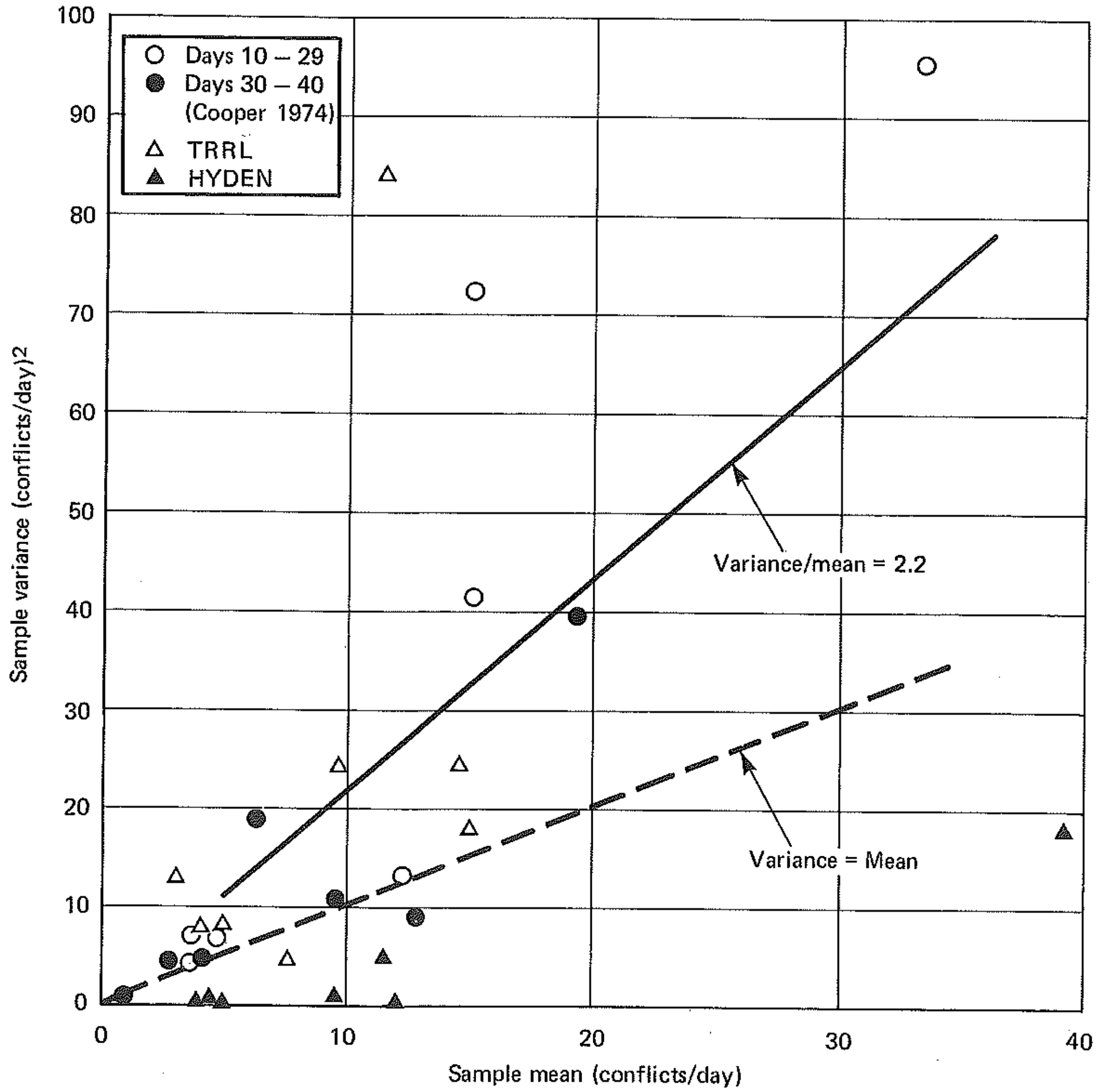

Fig. 3 SAMPLE MEAN AND VARIANCE FOR SUM OF CONFLICT CLASSES

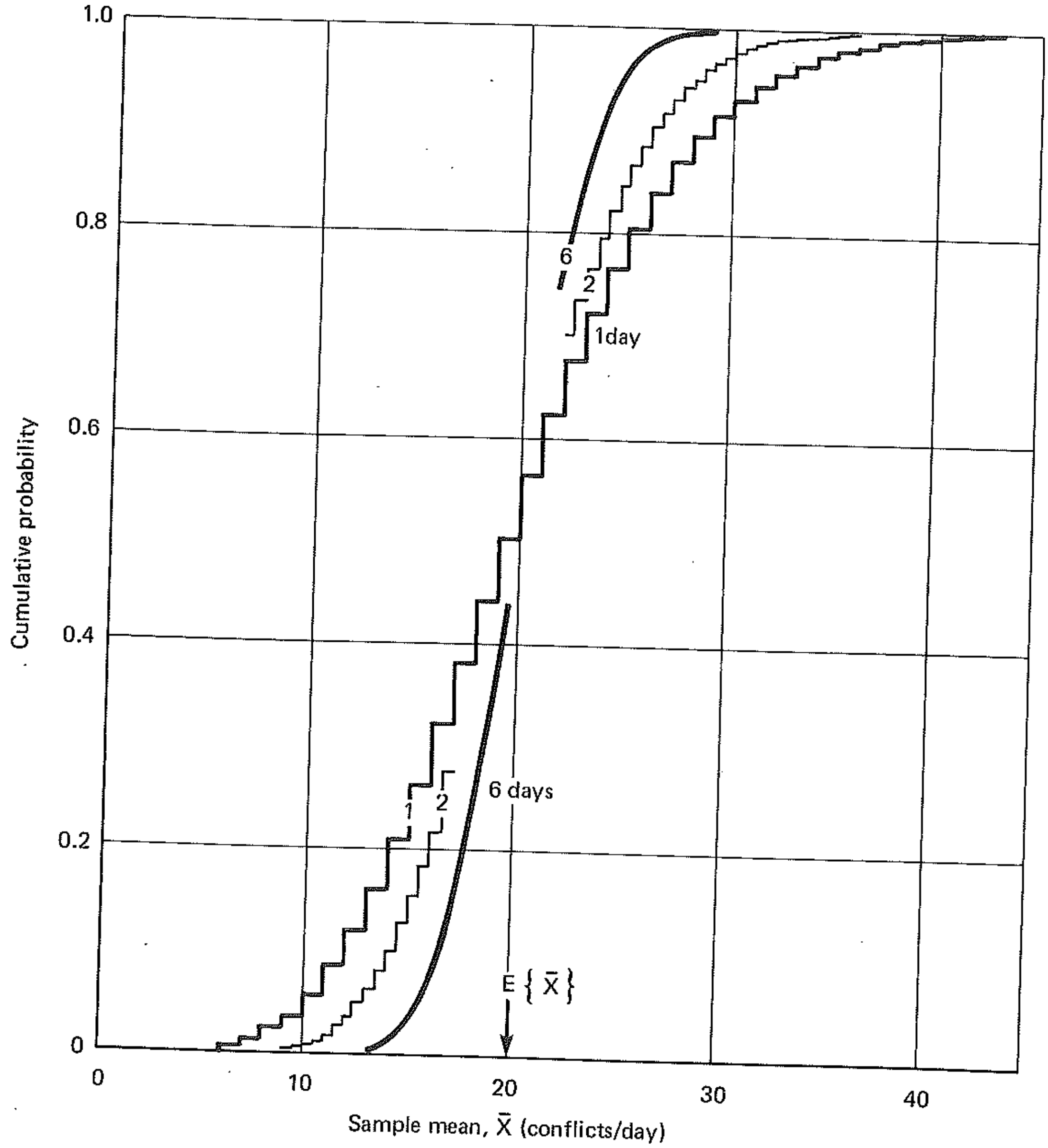

Fig. 4 PROBABILITY DISTRIBUTION OF SAMPLE MEAN ($\bar{X}$) FOR COUNTS OF 1, 2 AND 6 DAYS

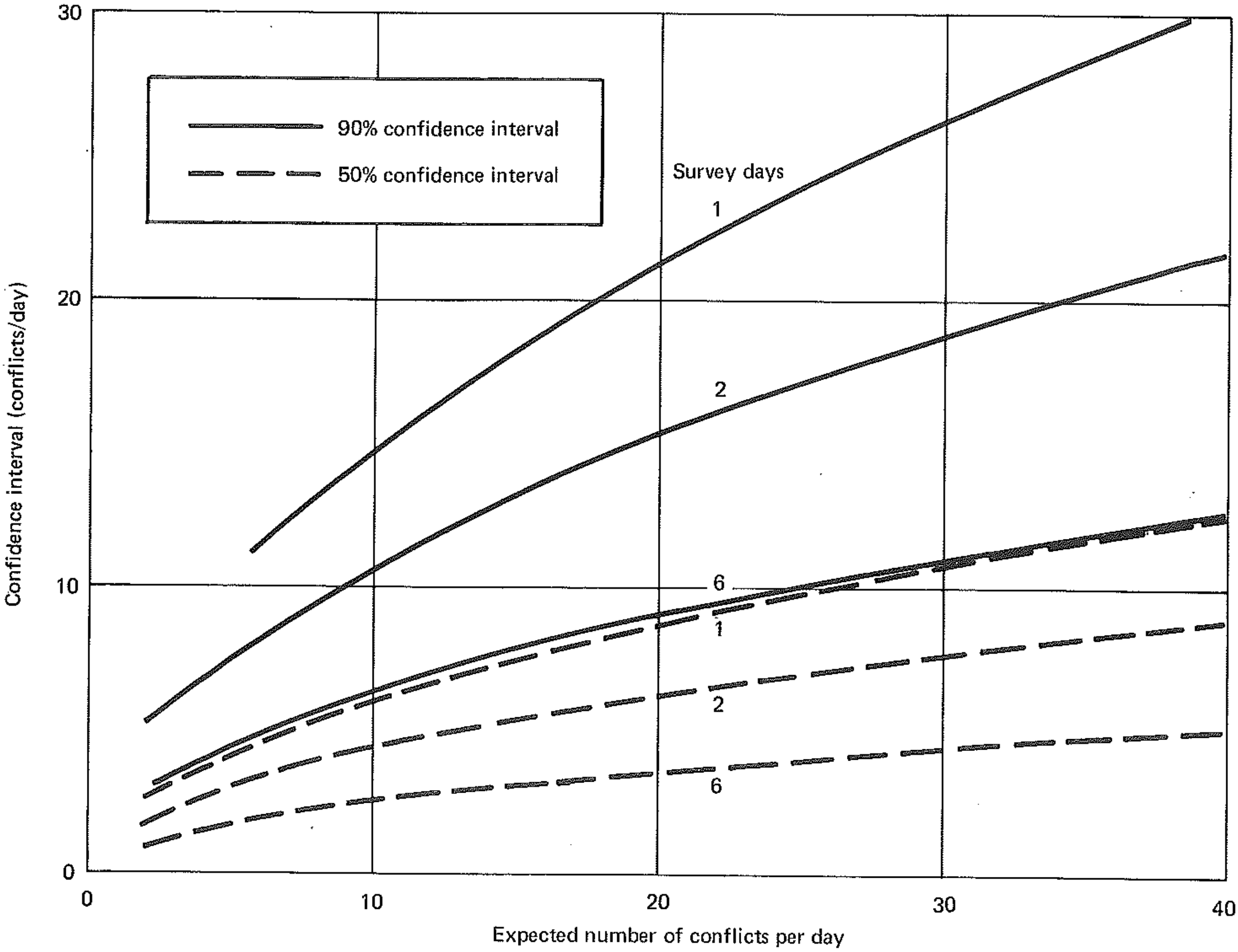

Fig. 5 CONFIDENCE INTERVALS FOR SUM OF CONFLICT CLASSES

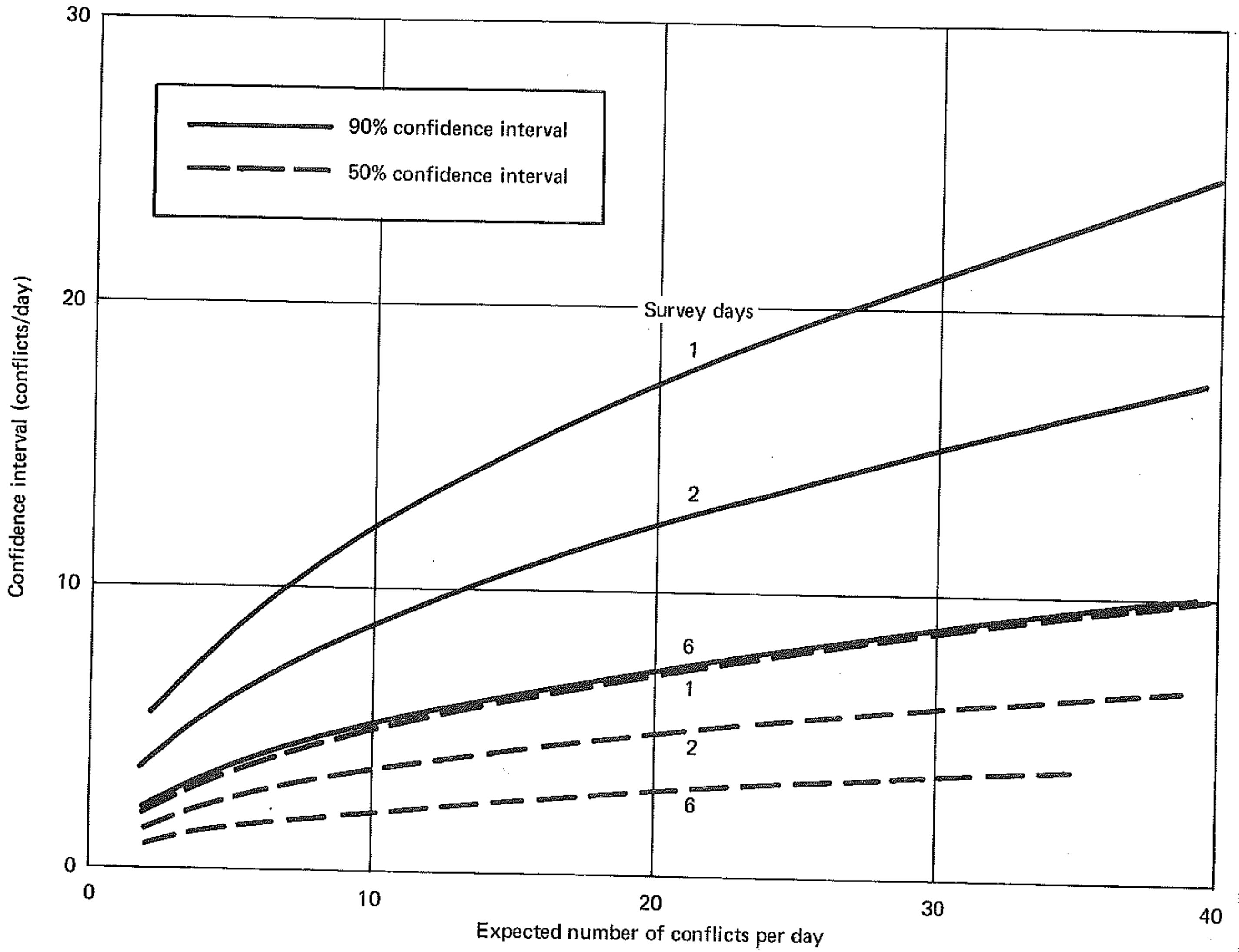

Fig. 6 CONFIDENCE INTERVALS FOR HOMOGENEOUS CONFLICT CLASSES

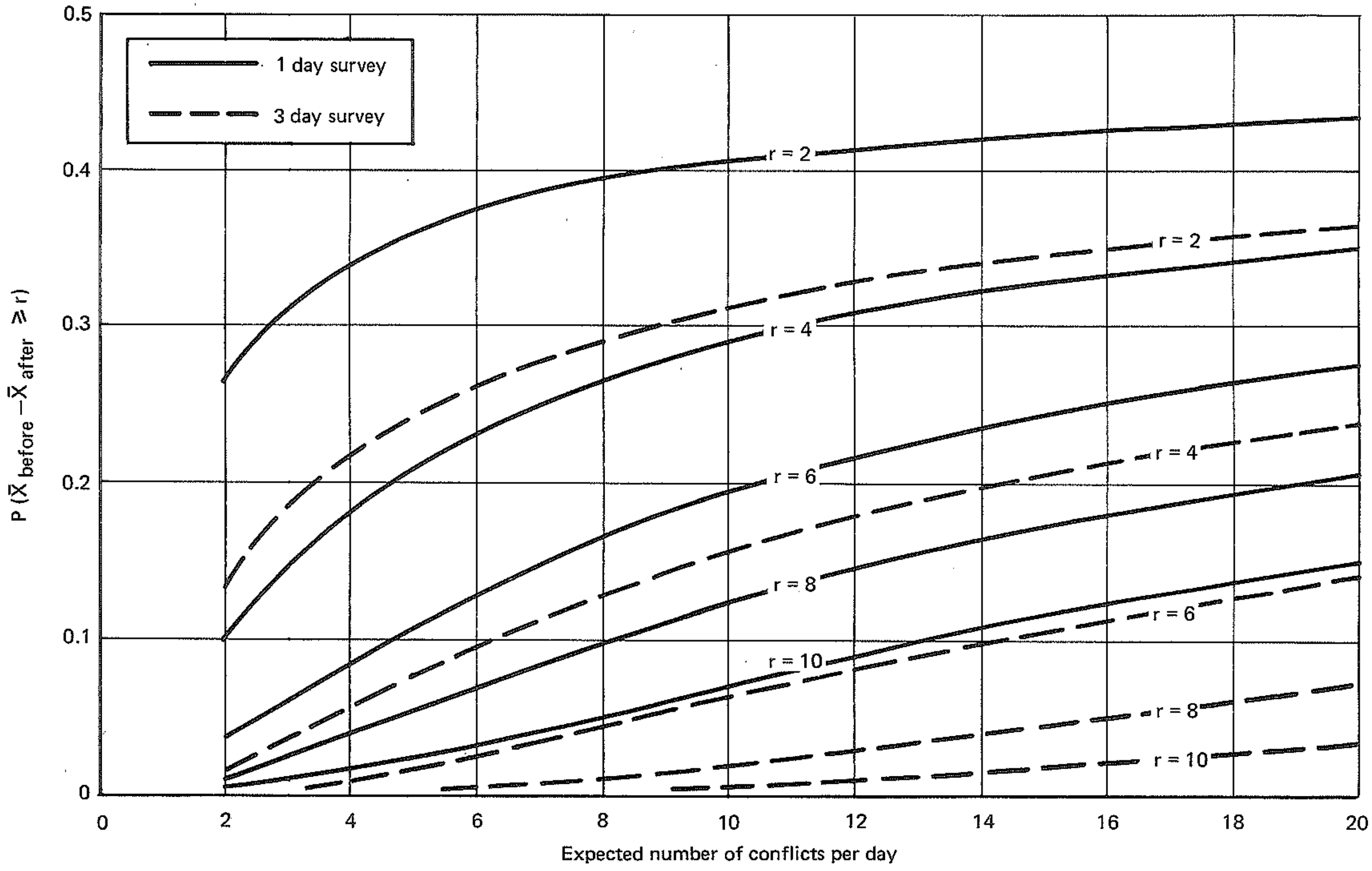

Fig. 7 P ($\overline{X}_{before} - \overline{X}_{after} \geq r$) **WHEN NO IMPROVEMENT EXISTS, SUM OF ALL CONFLICT CLASSES**

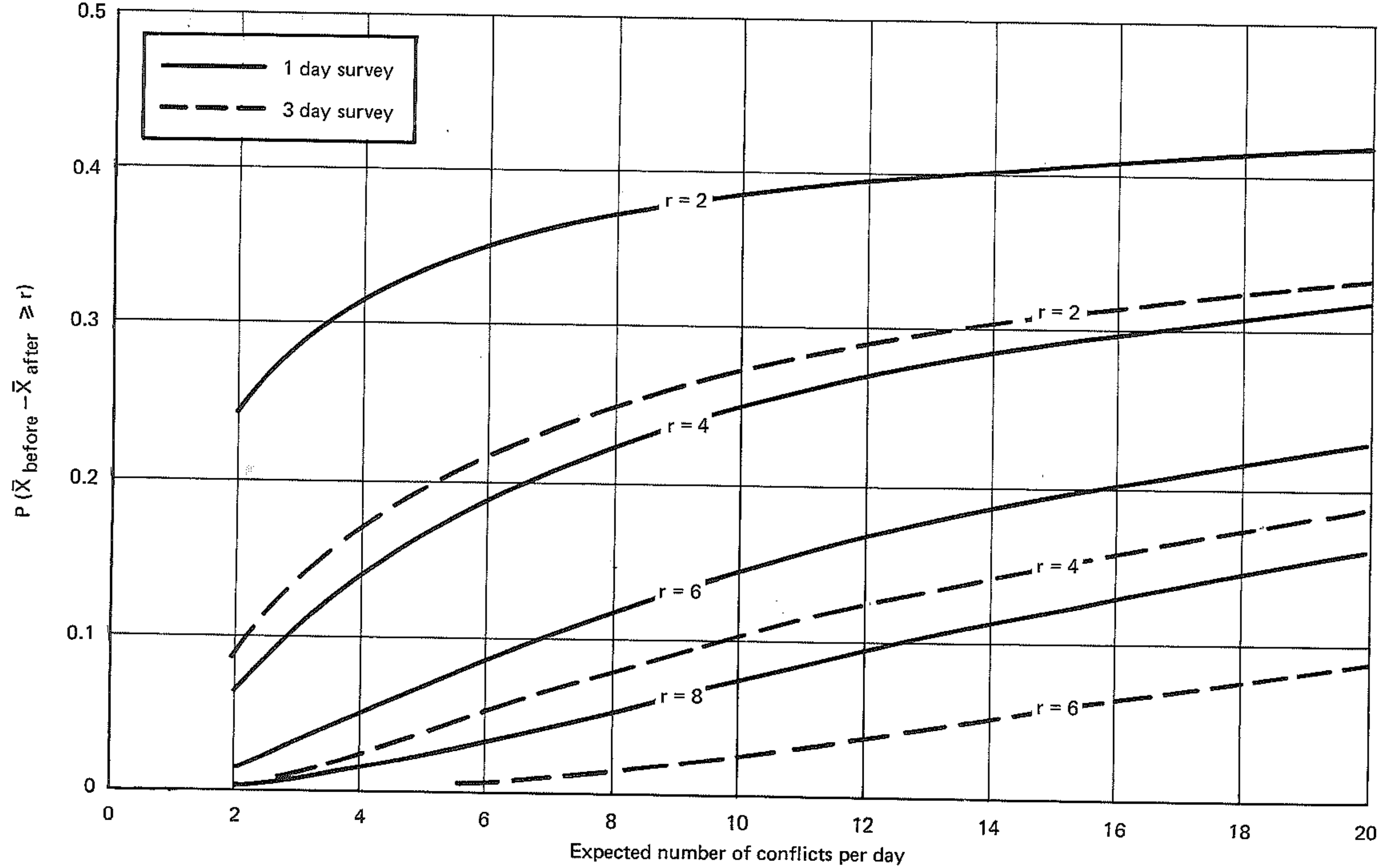

Fig. 8 P ($\bar{X}_{before} - \bar{X}_{after} \geq r$) WHEN NO IMPROVEMENT EXISTS, HOMOGENEOUS CONFLICT CLASSES

ABSTRACT

TRAFFIC CONFLICT SURVEYS : SOME STUDY DESIGN CONSIDERATIONS: *E Hauer:* Department of the Environment Department of Transport TRRL Supplementary Report 352: Crowthorne, 1978 (Transport and Road Research Laboratory). The traffic conflicts technique is a device for indirect safety measurement. It requires at present the conduct of a field survey to count conflict occurrence. On this basis the rate at which conflicts occur is estimated. This report deals with the accuracy of such estimation and its dependence on the design of the field survey.

First, present practice in conflict count duration is reviewed. Next, the relationship between count duration and estimation accuracy is examined. Using data obtained from several sources the daily variability of conflict counts is described. It is concluded that the expected conflict rate varies from day to day. Use of the negative binomial distribution is suggested as appropriate for the representation of the distribution of sample means obtained from conflict studies. On this basis, confidence limits and probabilities of Type I and Type II errors in hypothesis testing are obtained and tabulated. Their use in study design is illustrated by numerical examples.

The marginal increase in estimation accuracy diminishes rapidly as conflict counting time increases. Thus, there is little to be gained by counting longer than three days. This establishes a practical limit to the accuracy with which expected daily conflict rates can be estimated.

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ABSTRACT

TRAFFIC CONFLICT SURVEYS : SOME STUDY DESIGN CONSIDERATIONS: *E Hauer:* Department of the Environment Department of Transport TRRL Supplementary Report 352: Crowthorne, 1978 (Transport and Road Research Laboratory). The traffic conflicts technique is a device for indirect safety measurement. It requires at present the conduct of a field survey to count conflict occurrence. On this basis the rate at which conflicts occur is estimated. This report deals with the accuracy of such estimation and its dependence on the design of the field survey.

First, present practice in conflict count duration is reviewed. Next, the relationship between count duration and estimation accuracy is examined. Using data obtained from several sources the daily variability of conflict counts is described. It is concluded that the expected conflict rate varies from day to day. Use of the negative binomial distribution is suggested as appropriate for the representation of the distribution of sample means obtained from conflict studies. On this basis, confidence limits and probabilities of Type I and Type II errors in hypothesis testing are obtained and tabulated. Their use in study design is illustrated by numerical examples.

The marginal increase in estimation accuracy diminishes rapidly as conflict counting time increases. Thus, there is little to be gained by counting longer than three days. This establishes a practical limit to the accuracy with which expected daily conflict rates can be estimated.

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