at Annual Meeting Highway Research Board, Washington, D. C., 1936. Mr. W. F. Adams, in a letter to the writer, July 28, 1937, commented on this paper and pointed out the applicability of the Poisson series in such a study.

5. O. K. Normann, "Results of Highway Capacity Studies", *Public Roads* Figure 18, Page 72, June 1942.
6. "Tables for Statisticians and Biometricians", edited by Carl Pearson, Cambridge University Press, page 76, (1930).
7. Edward Charles Molina, "Poisson's Exponential Binomial Limit", Table I, D. Van Nostrand Company, Inc., (1942). The tables by Molina give not only the individual values of the general term of Poisson's Exponential Expansion, but also the cumulated terms up to $m = 100$. Reference (1) contains tables for values of m to 15.
8. E. H. Holmes, "Effect of Control Methods on Traffic Flow", *Public Roads*, Vol. 14, No. 12, p. 233.

SOME CRITERIA FOR SCHEDULING MECHANICAL TRAFFIC COUNTS

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SYNOPSIS

Traffic surveys will be needed to appraise the postwar use of rural roads. Most of the traffic counting work, particularly on low volume roads, is expected to be done with machines which do not record the traffic by the hour. Some criteria are needed for efficient scheduling of such counts. This study is only the beginning in a search for necessary information.

Practical considerations, indicated by experience, determine the minimum duration of a count to be 24 hr, or if longer, then in multiples of 24 hr. Coverage and control station counts are discussed. Coverage counts are defined as single observations which through the application of factors can be expanded to the annual average daily traffic. Control counts are defined as a system of observations from which expansion factors can be derived for application to coverage counts.

The prewar data from automatic traffic recorders at permanent locations were utilized. Ten stations with lowest volumes in the northern States and similarly ten stations in the southern States were selected. The application of the method of coefficients of variation which offer a measure of relative dispersion enabled the comparison of stations with different traffic volumes.

The study was divided into two parts. Part one deals with coverage counts and part two with control counts. Only weekdays were studied.

In part one it was sought to evaluate the length of a count in relation to the average weekday of each month. Counts of 24-, 48-, and 72-hr duration were studied. It was found that the range in terms of coefficients of variation is from 8.38 percent for the 72-hr counts in October in the southern States, to 32.73 percent for the 24-hr counts in March in the northern States. It was also found that October is one of the months when smallest coefficients of variation were observed and January is one of the months showing the largest. It was observed that the rate of increase in accuracy was higher when counts were prolonged from 24 to 48 hr than when the counts were prolonged from 48 to 72 hr.

In part two, various combinations of seasonally spaced weekday counts were compared with the annual average weekday. The number of all possible combinations is too great for use in this study. A preliminary analysis established certain limits to the study. In accordance with the results of the preliminary

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analysis, the main study or the study of samples was limited to combinations involving 24-hr and 48-hr counts. Combinations of four counts and six counts spaced three and two months apart, respectively, were analyzed. The results show 10 percent mean values of the coefficients of variation in the northern States for six 48-hr counts, spaced two months apart, and in the southern States for six 24-hr counts spaced two months apart; even lower values were produced in the southern States by four 48-hr and six 48-hr combinations of seasonally spaced counts.

The postwar revaluation of the use of rural roads will necessitate comprehensive traffic surveys. Most of the traffic counting work will be done by means of portable machines of the non-recording type. These machines, although introduced shortly before the war, already have established their value for economical counting of vehicles. Experience has also shown that the practical way of operating these machines in the rural areas is to keep them at the same location for a period of 24 consecutive hours or multiples thereof.

The purpose of this study was to obtain some information which would be helpful in determining the length and the frequency of the machine counts of vehicles on rural roads necessary for estimating the annual average daily traffic. The method involved the use of counts at a number of stations located in different States. The results were evaluated in terms of standard deviations of percentage errors, or coefficients of variation which offer a measure of relative dispersion enabling the comparison of stations whose traffic volumes vary.

At the present time there is no standardization of practices in scheduling machine traffic counts. At coverage stations in different States one, two, or more counts are made of one, two, or more days' duration. Neither are there any uniform criteria for establishing a system of control counts used for the expansion of coverage counts to the estimates of annual average daily volume.

Thus the anticipated extensive use of the non-recording machine traffic counters presents a series of problems in the scheduling of operations. These problems must be solved in order to assure a more efficient use of counters. The present study is limited to a few criteria only and may be considered just the beginning in a series of solutions of pertinent problems.

The study was conducted in two parts. In part one, which deals with coverage counts, an answer was sought to the question: How long should machine counts be taken at a number of single count stations to be representative of the average weekday traffic during the month of the count? Part two deals with control counts. For the purpose of this paper control counts are defined as a system of observations of traffic volume flows from which factors can be derived for the expansion of coverage counts. A series of criteria are essential for full evaluation of control count schedules. Part two is the first step in this phase of research and deals with answers to the question: For how long and at what intervals should counts be taken at stations of a control system to produce a representative estimate of the annual average weekday traffic volume?

Certain theoretical considerations must be stated. The sampling procedure is not random and therefore probability theory is not properly applicable to the evaluation of the data. By implication, however, the samples used in this study are assumed to be representative of the possible infinite number of traffic count locations within the range of volumes used. Furthermore, it is assume that the distributions to which statistical measures have been applied are either normal or approximately normal. It must be also noted that since the study is based on samples the results are subject to sampling error.

PART ONE

The immediate purpose of this study was to determine how representative single 24-hr continuous counts or averages of two- or three-day successive counts made on weekdays are of the true average weekday traffic during the month. Monday through Friday were the days used. Coefficients of variation were employed as the means of evaluating the relationships between the true means and the sample observations.

The source material was limited to the data from automatic traffic recorders at permanent locations scattered throughout the Nation. These records were examined for traffic volumes and usableness. Since most of them are located on more important highways the choice of stations with low traffic volumes was extremely limited and all suitable stations were used. The States were divided into two groups, northern and southern, and ten stations having the lowest volume of traffic were selected in each group of States. Low volume stations were used because it is mainly on low volume roads that single count stations will be located. Figure 1 shows these station locations. The average weekday traffic at these stations was 114 vehicles in the northern and 184 vehicles in the southern States. The complete listing is given in Table 1.

TABLE 1
STATIONS USED IN THE SAMPLE STUDY

Northern States			Southern States		
State	Station number	Annual average weekday traffic	State	Station number	Annual average weekday traffic
		vehicles			*vehicles*
Iowa	602	131	Arizona	5	196
Iowa	609	94	Arkansas	7	174
Iowa	610	117	Arkansas	10	245
Iowa	611	68	Georgia	2	105
Iowa	612	70	Georgia	11	279
Minnesota	169	141	N. Carolina	5	133
Minnesota	178	125	N. Carolina	6	187
Montana	A2	137	N. Carolina	8	143
N. Dakota	104A	143	Tennessee	2	271
N. Dakota	107	110	Texas	14	103
Mean..	.....	114			184

The data used were for different prewar years, some as early as 1937 but most for 1939 and 1940. Saturdays, Sundays, and important holidays were omitted. Each 24-hr period began at midnight.

Three studies were made for:

A. 24 consecutive hours
B. 48 consecutive hours
C. 72 consecutive hours.

In all studies each individual unit was the number of vehicles during a 24-hr period. The operator's travel time, distances between stations, and the scheduling of machine installations and pick-ups on rural roads are usually such that the practical length of a count is in multiples of 24-hr when using the non-recording type counters without cutoff attachments. Thus in studies B and C each unit was the arithmetic mean of two and three 24-hr periods, respectively. Each unit was compared with the known average weekday traffic for each month at its station. The differences were computed in numbers and in percent of the true average weekday traffic. The coefficients of variation (the standard deviations of the percentages of variation from the true mean or the standard deviations as percentages of the true mean) were computed for each station for each month. This method permits the combination and comparison of data derived from different stations. Finally arithmetic means of coefficients of variation were computed for each group of ten stations.

The samples were taken to conform, as closely as the available data permitted, to the schedule shown in Table 2.

TABLE 2

Weeks in each month	Study A 1-day counts	Study B 2-day counts	Study C 3-day counts
1st and 3rd	Mon	Mon and Tues	Mon, Tues, and Wed
2nd and 4th	Tues	Tues and Wed	Tues, Wed, and Thurs
1st and 3rd	Wed	Wed and Thurs	Wed, Thurs, and Fri
2nd and 4th	Thurs	Thurs and Fri	Mon, Tues, and Wed
1st and 3rd	Fri		Tues, Wed, and Thurs
2nd and 4th		Mon and Tues	
Number of counts. .	10	10	10

The arithmetic means of the coefficients of variation for each group of ten stations are shown in Table 3 and Figures 2 and 3.

The following observations are particularly noted:

1. The range is from the best, 8.38 percent in the October 72-hr count in the southern States to the worst, 32.73 percent in the March 24-hr count in the northern States.
2. In both the northern and the southern States the October coefficients of variation are among the smallest. They are maximum in March in the northern States and in January in the Southern States. Complete arrangement is shown in Table 4. The peculiar peaks in August, shown in Figure 2, are noteworthy. Presumably, the very great effect of the weather conditions on harvesting of crops and vacation travel causes the lack of stability in the traffic flow, thus rendering excessive variation in the weekday patterns.

TABLE 3
MONTHLY FLUCTUATIONS OF COEFFICIENTS OF VARIATION

Months	Northern States			Southern States		
	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr
	%	%	%	%	%	%
Jan.	30.65	24.08	19.26	26.01	19.89	18.79
Feb	27.03	20.24	15.30	22.90	17.87	12.86
Mar	32.73	25.58	23.81	18.40	14.35	11.61
Apr	24.84	18.46	14.85	22.97	13.81	10.58
May	17.62	15.13	12.49	19.65	16.05	14.43
June	21.79	15.32	13.27	18.71	13.65	9.81
July	21.25	18.55	16.32	15.01	12.54	10.39
Aug.	28.46	21.78	18.85	21.64	16.37	13.91
Sept	24.00	17.60	14.01	18.75	15.72	14.10
Oct	20.95	15.28	12.08	13.29	9.38	8.38
Nov	22.86	19.73	18.06	17.55	14.31	11.69
Dec	27.32	22.25	17.82	16.95	14.20	10.82
Mean	24.96	19.50	16.34	19.32	14.85	12.28

accuracy increases at a reduced rate, namely 16.2 percent and 17.3 percent, respectively.

To demonstrate some of the salient features of the data in Table 3, two additional analyses were made.

I. Theoretically, in a normal distribution 68.3 percent of cases should fall within the value of plus or minus one standard deviation from the mean. All units used in the study were compared with their respective true monthly averages. The individual differences of percentages not exceeding the corresponding coefficients of variation in Table 3 were counted. These numbers expressed as a percentage of the total number of counts in each appropriate group are shown in Table 5

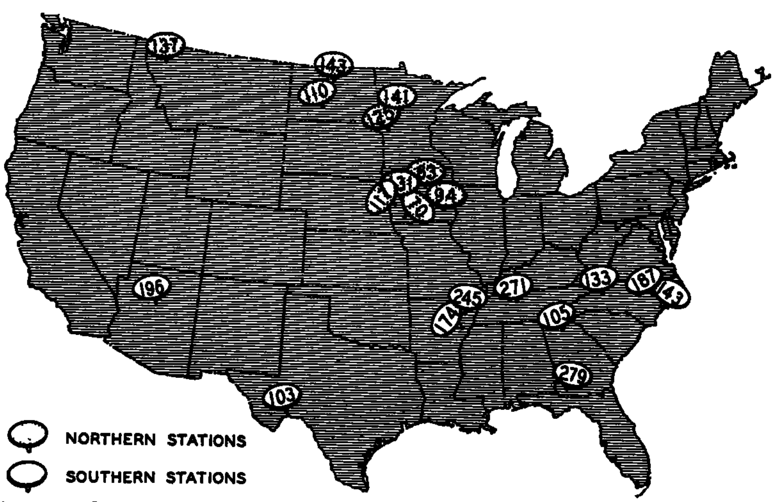

Figure 1. Sample Stations—Locations and Annual Average Weekday Traffic

3. Almost invariably the counts showed less variation in the southern States than in the northern States, with the yearly means about 5 percent less in every group of hours. This is probably due to the fact that the southern stations carried a larger volume of traffic and because of the more equable climate, factors usually contributing to the stability of the traffic flow.

From Figure 3 it is observed that the increase in accuracy, as manifested by the decrease in the yearly mean values of the coefficients of variation, is considerable when the duration of the count is extended from 24 hr to 48 hr, i.e. 21.9 percent for the northern and 23.1 percent for the southern States. When the counts are extended to 72 hr then the

II. A check study was made employing a new set of stations. Two groups of stations were chosen, ten each in the northern and southern States. These stations were all different from those used in the original study, some of them being in States not previously included. As only a few suitable stations in the lowest traffic volume group were available, stations with the next lowest traffic volumes were used. The average weekday traffic at the ten northern stations was 231 vehicles and at the ten southern stations it was 359 vehicles as shown in Table 6.

The range is 180–292 vehicles per day in the northern States and 224–550 vehicles per day in the southern States. Figure 4 shows the location of the check stations.

Generally speaking the check stations are more evenly distributed throughout the Nation than the stations in the original study.

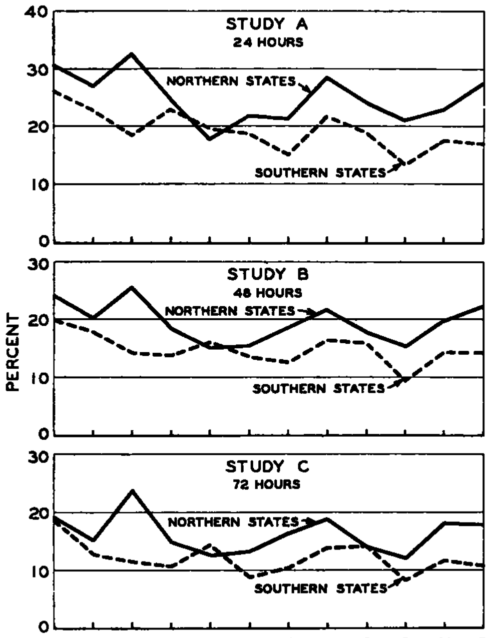

Figure 2. Monthly Fluctuations of Coefficients of Variation

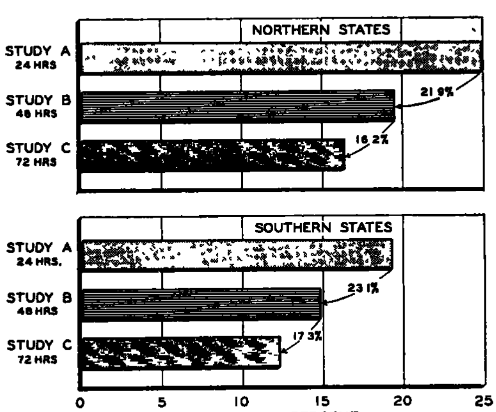

Figure 3. Annual Mean Coefficients of Variation

Samples of traffic counts were taken at each check station, the second week of each month and mostly in the year 1939, in accordance with the following schedule:

24-hr counts on Wednesday
48-hr counts on Tuesday and Wednesday
72-hr counts on Tuesday, Wednesday, and Thursday.

The percent of error from monthly average weekday traffic was computed for each check station. Then the number of counts with errors which fell within the coefficients of variation given in Table 3 were determined and the results expressed as percentages of the total number of counts. These results are given in Table 7 and are also shown in Figure 5.

TABLE 4
MONTHS ARRANGED IN THE ASCENDING ORDER OF COEFFICIENTS OF VARIATION IN TABLE 3

Ascending order of coefficient of variation	Northern States			Southern States		
	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr
1	May	May	Oct	Oct	Oct	Oct
2	Oct	Oct	May	July	July	June
3	July	June	June	Dec	June	July
4	June	Sept	Sept	Nov	Apr	Apr
5	Nov	Apr	Apr	Mar	Dec	Dec
6	Sept	July	Feb	June	Nov	Mar
7	Apr	Nov	July	Sept	Mar	Nov
8	Feb	Feb	Dec	May	Sept	Feb
9	Dec	Aug	Nov	Aug	May	Aug
10	Aug	Dec	Aug	Feb	Aug	Sept
11	Jan	Jan	Jan	Apr	Feb	May
12	Mar	Mar	Mar	Jan	Jan	Jan

TABLE 5
PERCENTAGE OF COUNTS NOT EXCEEDING THE COEFFICIENTS OF VARIATION IN TABLE 3

Month	Northern States			Southern States		
	24 hr	48 hr	72 hr	24 hr	48 hr	72 hr
	%	%	%	%	%	%
Jan	74	71	71	69	69	72
Feb	74	74	69	67	63	73
Mar	73	70	73	70	76	77
Apr	73	70	66	74	64	68
May	69	73	72	66	67	67
June	73	73	74	76	73	71
July	72	70	72	71	67	77
Aug	71	69	70	68	72	70
Sept	70	71	71	71	68	68
Oct	79	71	68	69	70	67
Nov	73	76	70	76	69	69
Dec	75	71	69	75	69	70
Mean	73 0	71 6	70 4	71.0	68.9	70 8

Had there been check stations available with traffic volumes similar to those in the original study a close agreement between the data in Tables 7 and 5 would be an excellent indication of the validity of the data in Table 3. Because the traffic volumes at the check sta-

TABLE 6
STATIONS USED IN THE CHECK STUDY

Northern States			Southern States		
State	Station number	Annual average weekday traffic vehicles	State	Station number	Annual average weekday traffic vehicles
Iowa	606	275	Alabama	1	409
Massachusetts	3	201	Arkansas	5	420
Montana	A6	219	Arkansas	8	550
Nebraska	A3	205	Arkansas	9	282
North Dakota	102	292	Kentucky	4	260
Ohio	9	215	Nevada	103	258
Oregon	1	257	Nevada	106	224
South Dakota	105A	228	Missouri	3	368
Wisconsin	19	180	Missouri	4	464
Wisconsin	20	242	Texas	20	·352
Mean		231			359

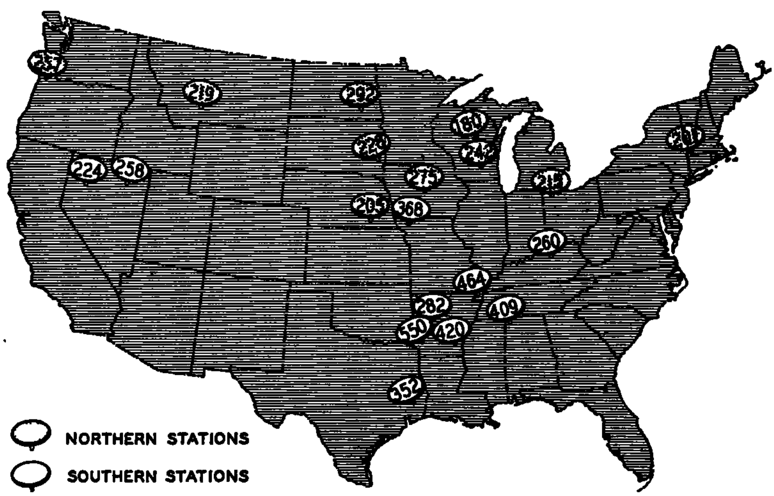

Figure 4. Check Stations—Locations and Annual Average Weekday Traffic

tions were about twice as large as at the stations of the original study, the values of coefficients of variation would be expected to be smaller; that is, if it is assumed that stability is greater with the higher traffic volumes. Therefore, the percentages of cases in the check study, which fall within the values of the coefficients of variation of the original study, are expected to be larger. Data in Table 7 and Figure 5 indicate this to be true. On the other hand, had the values at check stations been smaller than the theoretical 68.3 percent, then the validity of the data in Table 3 would be definitely questionable. Thus by inference, the data at the check stations tend to substantiate the soundness of the data of the original study.

PART TWO

According to its ultimate objective this study falls into the category of investigations necessary for the effective design of control station schedules. The immediate purpose was to measure the accuracy of estimate of annual average weekday traffic by means of several seasonally spaced counts.

Traffic data of the same stations which were used in part one were analyzed in part two to determine the number and length of counts required to give an estimate of annual average weekday traffic within a satisfactory degree of accuracy. This study was conducted in two steps:

I. The preliminary study. As the number of all possible combinations of samples would be too large for practical analysis this study was devised with the objective of determining some limitations to the study of the samples. The preliminary study was based on true monthly mean values of weekday traffic.

II. The study of samples using actual 24-hr and 48-hr weekday traffic data.

I. The Preliminary Study

The true mean weekday traffic at each station for each month was obtained. At each station these means were used in various combinations each representing an estimate of annual average weekday traffic. The differences between the estimates and the true annual averages were computed. The data in

Table 8 show the results expressed in terms of relative dispersion from the true annual mean weekday. For each combination of months, coefficients of variation were computed from ten values of percent differences (one for each station).

Figure 6 shows the relative dispersion from the true annual mean weekday. It demonstrates the range and the mean of the coefficients of variation. It is noted that the range as well as the mean decreases as the number of seasonal counts increases or, according to the presentation in Figure 6, as the number of months seasonally spaced between counts decreases. In the northern States particularly, the range is large in the combinations of 2-counts, six months apart, and 3-counts, four months apart. Although the 3-count combinations show an improvement over the 2-counts, the rate of increase of accuracy is much larger in the 4-count combinations when compared with the 3-counts, and still larger when the 6-counts are compared with the 4-counts. In consequence of the above observations, the study of the samples was limited to the combinations of 4-counts, three months apart, and the 6-counts, two months apart.

TABLE 7
PERCENTAGES OF COUNTS AT CHECK STATIONS FALLING WITHIN THE ANNUAL MEAN COEFFICIENTS OF VARIATION OF ORIGINAL SAMPLE STATIONS

Hr	Northern States		Southern States	
	Coefficient of variation	Percentage of counts	Coefficient of variation	Percentage of counts
24	24 96	89.2	19 32	84.2
48	19.50	90 8	14.85	85.0
72	16.34	87.5	12.28	86.7

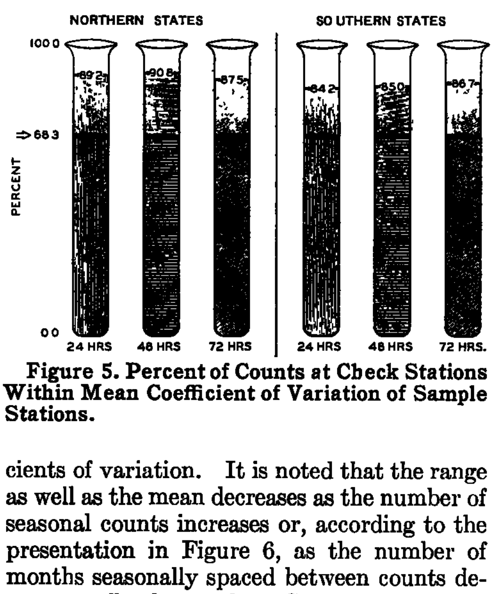

Figure 5. Percent of Counts at Check Stations Within Mean Coefficient of Variation of Sample Stations.

TABLE 8
COEFFICIENTS OF VARIATION FOR VARIOUS COMBINATIONS OF MONTHS, SEASONALLY SPACED

Seasonal Spacing of Counts	Northern States	Southern States
	Percent	*Percent*
Jan, July	11.0	12.1
Feb, Aug	20.6	6.2
Mar, Sept	7 2	6.7
Apr, Oct	8.2	4.4
May, Nov	6.2	6.9
June, Dec	11.3	6.1
Mean—2 months	10.75	7.07
Jan, May, Sept	6.7	5.9
Feb, June, Oct	8 8	4.4
Mar, July, Nov	6.7	7.5
Apr, Aug, Dec	11.2	7.9
Mean—3 months	8.35	6.43
Jan, Apr, July, Oct	5.3	4.8
Feb, May, Aug, Nov	8.8	4.0
Mar, June, Sept, Dec	4.6	4.0
Mean—4 months	6.23	4.27
Jan, Mar, May, July, Sept, Nov	2.8	3 1
Feb, Apr, June, Aug, Oct, Dec	2.7	3.0
Mean—6 months	2.75	3.05

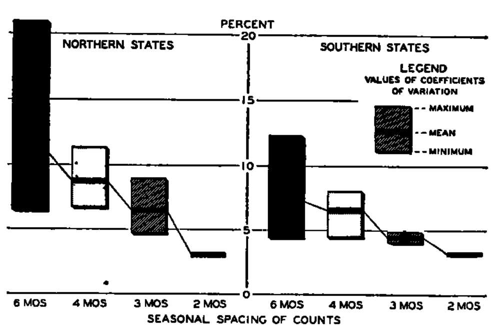

Figure 6. Relative Dispersion From True Annual Mean Weekday

II. The Study of Samples

Twentyfour-hr and 48-hr samples were taken in accordance with the same schedule used in part one. The number of the samples was also the same, i.e., ten 24-hr periods and ten 48-hr periods at each station in each month. The 24-hr and 48-hr samples were analyzed separately. Each unit was the number of vehicles in a 24-hr period. In computing estimates of average annual weekday traffic only the days holding the same relative position in each month were combined. For example, at each station, Monday of the first week in January was combined with Monday of the first week in April, Monday of the first week in July, and Monday of the first week in October; similarly Tuesdays of the second week in each of these months were combined. The 48-hr samples were combined in like manner. For example, at each station, Monday and Tuesday of the first week in January were combined with Monday and Tuesday of the first week in April, Monday and Tuesday of the first week in July, and Monday and Tuesday of the first week in October. Thus, there were ten estimates for each combination of cient of variation was computed for 100 values. Also, the number of cases that fell within the value of the appropriate coefficient of variation were counted and expressed in percent of total cases. The results are shown in Table 9.

The schedule described above was selected as most satisfactory for the purposes of this study as it eliminates the seasonal effect on the differences between weekdays. Thus the numerical results may be worse than if another schedule were used. It is probable that a different schedule could be designed which would account for both seasonal and daily variations, and would produce a narrower dispersion and smaller values for the mean of coefficients of variation.

TABLE 9

COEFFICIENTS OF VARIATION IN SAMPLE STUDY AND PERCENTAGES OF CASES NOT EXCEEDING THESE COEFFICIENTS OF VARIATION

Seasonal spacing of sample counts	Northern States				Southern States			
	24-hour		48-hour		24-hour		48-hour	
	Coefficient of variation	Percentage	Coefficient of variation	Percentage	Coefficient of variation	Percentage	Coefficient of variation	Percentage
Jan, Apr, July, Oct	12.2	67	11.8	71	11 1	64	9 0	73
Feb, May, Aug, Nov	16.3	78	13.4	72	10 2	61	10 0	73
Mar, June, Sept, Dec	14.5	71	12 2	75	11 2	68	9 1	79
Mean	14.33	72.0	12.47	72.7	10.83	64.3	9 37	75.0
Jan, Mar, May, July, Sept, Nov.	10.7	69	10.9	67	10.0	69	8.1	74
Feb,Apr,June,Aug,Oct,Dec	13.3	69	9.2	72	9.0	71	6 6	74
Mean	12 00	69 0	10.05	69.5	9 50	70.0	7.35	74 0

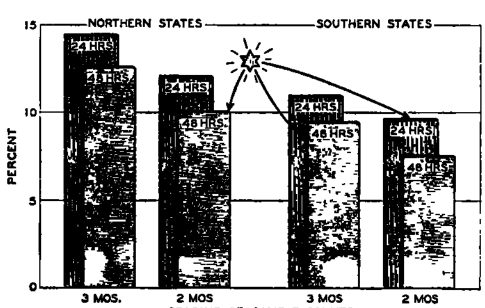

Figure 7. Mean Coefficients of Variation from True Annual Mean Weekday

months at each station. Each annual estimate was compared with its true value. The coefficients of variation were computed for each group of ten stations for each combination of months. In this manner, a coeffi-

Figure 7 shows the distribution of means of coefficients of variation from true annual mean weekday. The percent of cases falling within the values of coefficients of variarion are generally close to the theoretical 68.3 percent which is characteristic of a normal distribution.

If it were desired to obtain estimates, so that at two-thirds of the number of stations the errors of estimate would not be in excess of plus or minus ten percent of the true values, then, as is shown in Figure 7, six counts, seasonally spaced and of 48-hr duration each, would be recommended. In the southern States, though, the sampling could be reduced to either six 24-hr counts or four 48-hr counts seasonally spaced, as such a schedule would be within the allowable limits of sampling error.