Minnesota Experience in Counting Traffic on Low-Volume Roads

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Because expansion factors based on road groupings by similarity of pattern provided more accurate estimates of average daily traffic values for rural trunk highways than factors based on area groupings, a study was designed to test the accuracy of the same procedure for local rural roads. In 1956, 14 local road stations were selected to sample the two types of rural road use (farm-to-market roads and resort roads) in Minnesota.

The data were analyzed for seasonal variations, differences between various lengths of counting, and the development of expansion factors. The counts at each location were plotted as a percentage of the ADT. The possibility of reducing the range of seasonal variations was investigated by dividing the basic data into the two chosen groupings.

• EXTENSIVE PROGRAMS have been undertaken since 1936 to estimate average annual daily traffic on local rural roads and rural trunk highways. To gather the basic traffic information needed for estimating annual travel on these road systems, sampling procedures are employed.

Between 1936 and 1939, most of the basic information was obtained by observation. Information obtained in this manner was, for the most part, limited to travel during a single 8-hr period of the day. These limited data, adjusted by factors computed from observations extending over one weekday, a Saturday and a Sunday in each season of the year, produced estimates of average annual daily traffic on rural roads.

Since 1940, the basic traffic volume data for rural roads have been gathered with mechanical counters. The introduction of mechanical counters improved the accuracy with which ADT could be estimated. The improvement, however, was confined to the quality of basic data gathered. With mechanical counters, travel data were gathered for continuous periods of 48-, 72-, and 96-hr at a greater number of locations. Some of the locations were sampled three times a year to obtain seasonal variations. A method of deriving expansion factors from the sample counts made in the three seasons, with automatic traffic recorders (ATR's) supplying data for travel in winter, or the fourth season, was then adopted. This method employed a 21-day moving average to eliminate daily variations in the factors. Expansion factors were derived for each of five districts in Minnesota. Since it was assumed that the distributions of traffic was the same on all roads within the district, only one set of expansion factors was computed for each district. Although experience indicated an improvement should have been achieved, the degree of improvement could not be measured because procedures used in adjusting the basic sample precluded statistical evaluation.

Findings in studies directed by Petroff (*1*), revealed that factors developed on an area basis produced certain inherent inaccuracies which could neither be defined nor eliminated. This along with inability to evaluate the accuracy with which ADT was being estimated caused Minnesota to seek means of improving the estimating procedure and reducing the cost of field operations.

The initial phase of the state's study

consisted of comparing errors of estimate produced by factors computed by the method then employed to those produced by factors determined on the basis of patterns of road use as suggested by Petroff. His method assumes that roads with similar use patterns can be grouped regardless of area location. Therefore, if the seasonal distribution of travel on a given class of roads is known, the information can be employed to estimate the traffic on other roads having the same pattern characteristics. ATR data gathered at 27 rural trunk highway stations were used to determine factors for the new method based on patterns of road use. Statistical evaluation of the results proved that factors based on patterns of road use produced the most accurate estimate of the ADT.

With this knowledge, a study was designed to test the accuracy with which the same procedure would produce ADT's for local or low volume rural roads. In this study, low volume roads are those with ADT's of less than 1,000 vehicles per day. Early in 1956, 14 local road stations were selected to test the accuracy of the method for such roads. The stations were selected to obtain a sample of the two different types of rural road use in Minnesota; farm-to-market roads and resort roads. Seven stations were selected in each of two districts. Figures 1 and 2 show the general locations of the districts, both in the western part of the state. The main difference between the two districts is that there are almost ten times as many lakes in District 1, attracting a large amount of recreational and vacation travel, as there are in District 3.

Because day-to-day variations in travel on low-volume roads are greatest during the winter months, no sample counts are scheduled then. Expansion factors were needed only for May through October. Only three counts, each for 7 consecutive days, were taken during the winter period to produce a fairly reliable estimate of the ADT. Four stations in each district were counted continuously from May through October; whereas, counts at the other three stations in each district were limited to 7 consecutive days in each month. These 7-day counts were scheduled to miss the three major holidays of the period. In District 1, Stations 102, 103, 105, and 106 were counted continuously; in District 3, Stations 301, 302, 304, and 305 were counted continuously.

The ADT's for the 14 stations ranged from 280 vehicles at Station 305 to 750 vehicles at Station 104. The mean traffic volume for the 14 stations was 428 vehicles.

To compare variations in weekly travel, the average daily traffic for each week was converted to a percentage of the ADT. The percentages of annual daily travel performed each week at each of the 14 rural road locations were then graphed to determine variations in travel during specific weeks (Fig. 3). The extreme range in variations in weekly travel on low volume rural roads is apparent. The data show that seasonal travel ranged from 36.9 percent of the ADT in January to 242.1 percent of the ADT in July. Extreme variations in percentages of annual travel at each of the 14 locations during a specific week are also apparent. During July and August weekly travel ranged from about 100 percent of the ADT to about 240 percent of the ADT. Obviously, the use of a single expansion factor for sample counts taken on all roads in July or August could result in an error as large as 142 percent, which is equivalent to the range in variation during the two months. Single factors for other months could produce ADT's which were as much as 102 percent in error.

To reduce the possibility of such large errors in estimating ADT's, the 14 locations were grouped according to similarity of seasonal patterns. The stations were divided into two groups; one group consists of primarily farm-to-market roads and the other group of primarily resort roads (Figs. 4 and 5). The ADT itself did not influence the placement of the stations into farm or resort groups. The proximity of Stations 101, 102, 103,

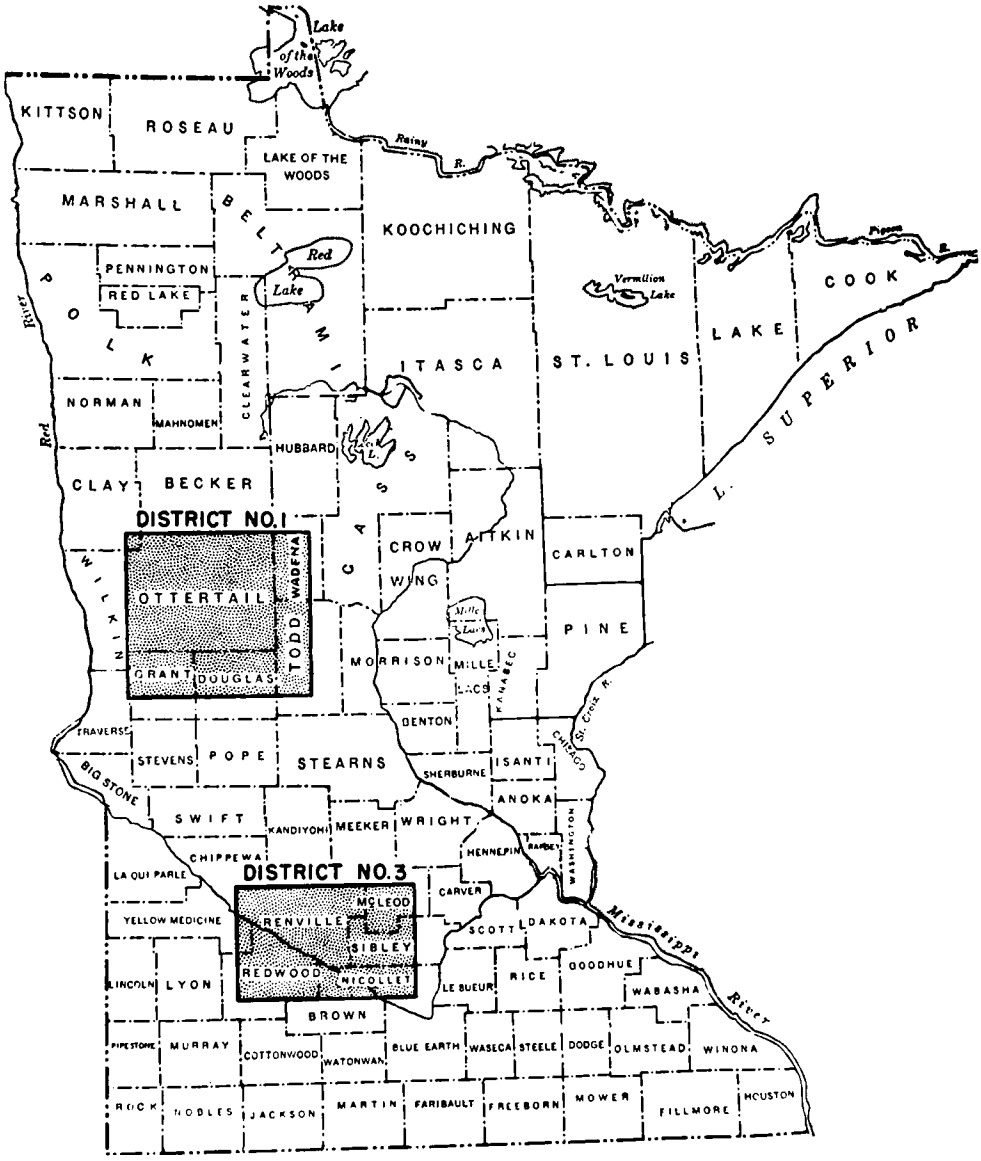

Figure 1. Locations of districts.

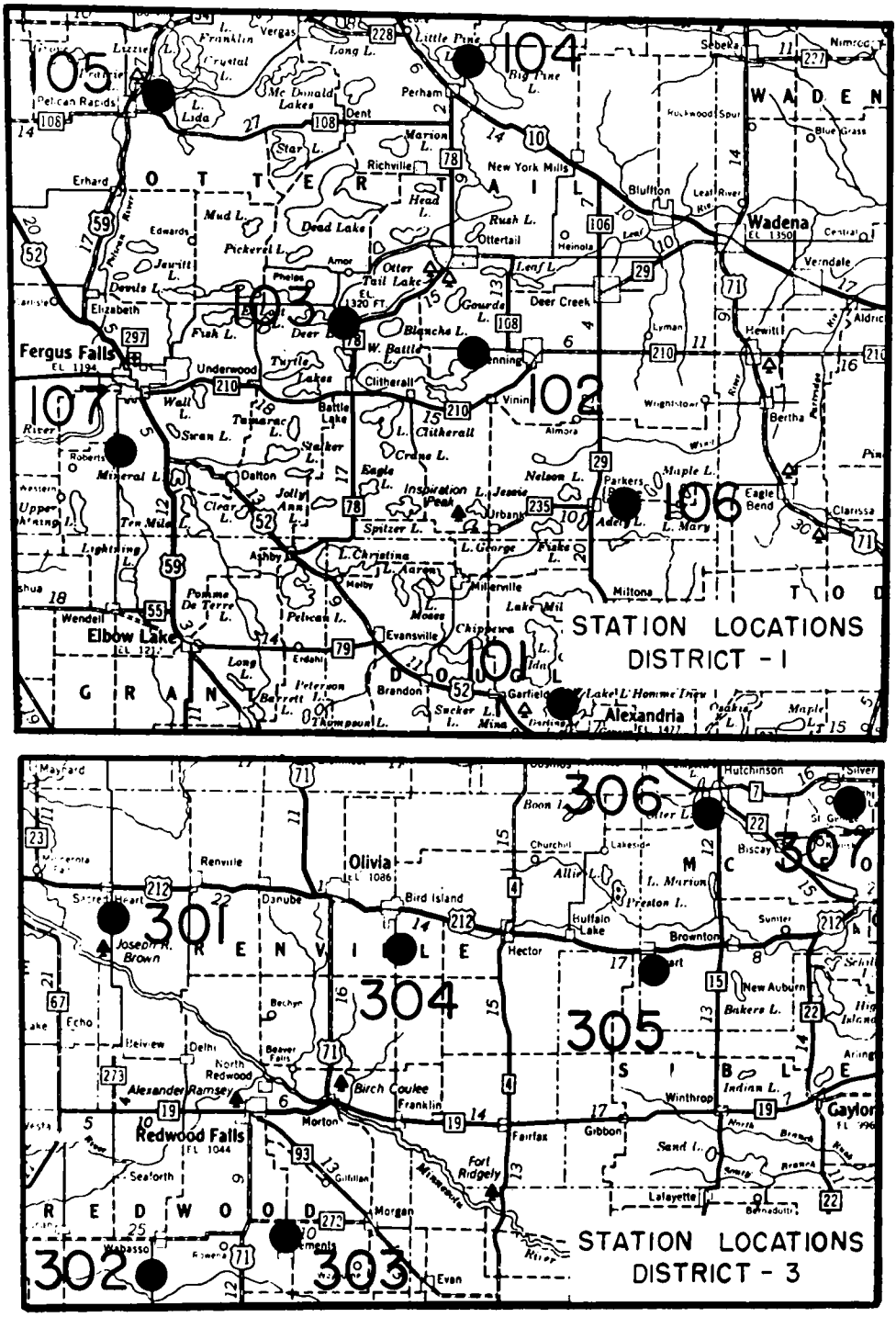

Figure 2. Locations of the 14 stations.

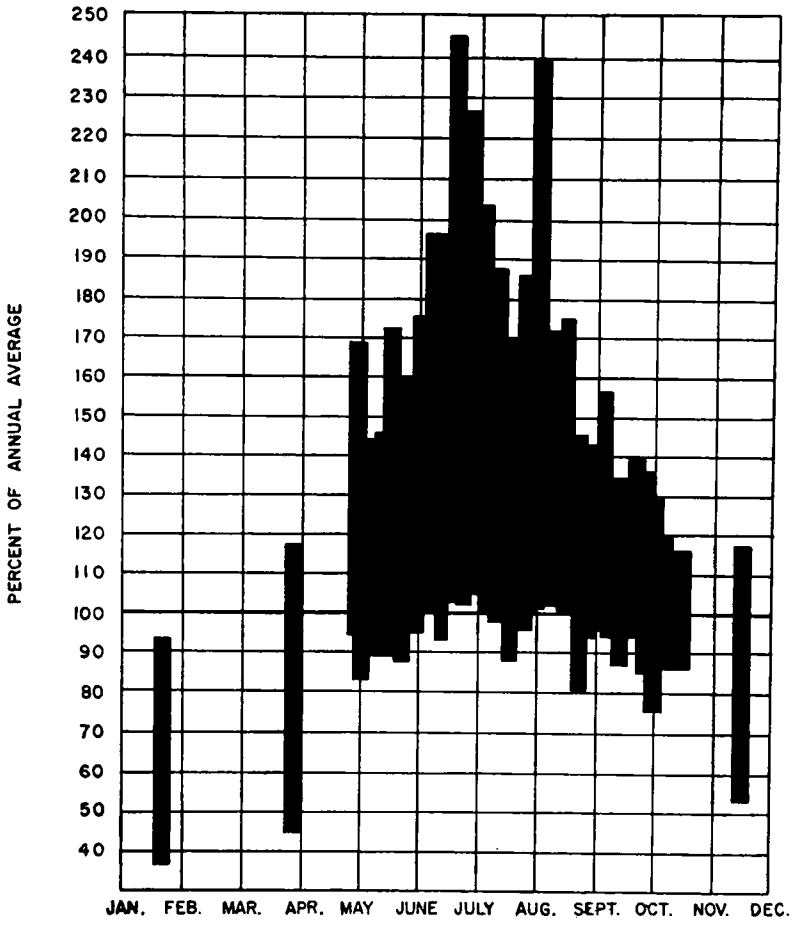

Figure 3. Weekly range of average daily traffic at all 14 stations.

104, and 105, the resort group, to lakes can be seen on the map in Figure 2. In District 1, the remaining Stations, 106 and 107, were placed in the farm group. It was the seasonal pattern of travel that determined the placement of a local road location into a particular group. Being in a county with much resort activity did not necessarily place a local road location in the resort group. All five stations in the resort group were less than 3 mi from a large lake or a series of lakes. All the stations in District 3 were placed in the farm group.

This division placed 5 stations in the resort group and 9 stations in the farm group, and it reduced the maximum range of variations in weekly travel during July and August by as much as 53.8 percent in the resort group and by as much as 109.6 percent in the farm group. There was no overlapping of the two groups in the midsummer period. Roads in the farm-to-market group had the least variation in travel during each week of the 6-month period.

Although the formation of farm and resort pattern groupings provided two patterns by which the total range of seasonal variations was reduced, large variations in weekly travel during specific months were still present. To determine the significance of these variations, individual week counts were compared to the

full month counts. Because week-to-month comparisons could only be made at the 8 stations where full month counts had been taken, only these stations were used for future comparisons. The range of monthly and weekly travel at the eight continuous count stations are compared in Figure 6. The ranges of weekly counts deviated both higher and lower than the ranges of monthly counts for all the months with a range of deviations from 1.0 percent to 31.1 percent. The greatest differences were in June and July. The "t" test of significance was applied to determine the fiducial limits for means of month long counts. Figure 7 shows that, without exception, the means of the weekly counts fell within the fiducial limits of the month count mean; therefore, at the 5 percent level, the means of 7-day counts did not differ significantly from the means of month long counts.

Variations in weekly travel at the 5 resort group stations and the three farm group stations are compared in Figure 8. The ranges are similar to those of Figures 4 and 5 except that in this case the 6 stations with one 7-day count each month have been eliminated.

The "t" test of significance was also applied to the group month count means. Figures 9 and 10 show that at the 5 percent level, the means of 7-day counts did not differ significantly from the means of month counts. The fiducial limits of the resort group mean are considerably larger than the fiducial limits of the farm group mean. Some of this difference is due to the fact that there were only 3 resort group stations as compared to 5 farm group stations.

A comparison of means and fiducial limits shown in Figures 9 and 10 revealed that the road-use pattern groupings were quite different. In May the range of farm group means fell inside the fiducial limits for the resort groups. In June and July the ranges of means for each group fell outside of the fiducial limits for the other group. In August the upper portion of the farm group range was inside the fiducial limit for the resort group. In September and October the ranges of resort and farm group means overlapped. Because of

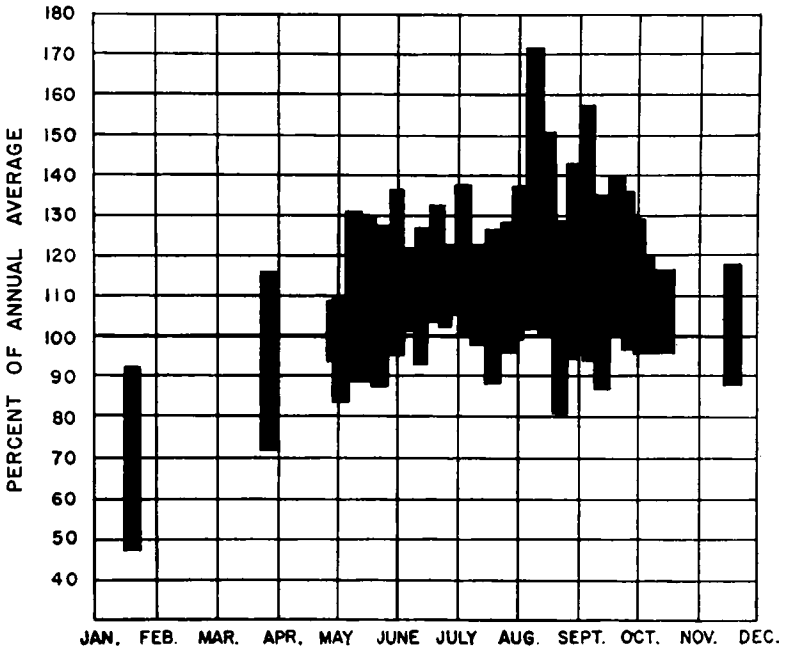

Figure 4. Weekly range of average daily traffic at farm group stations.

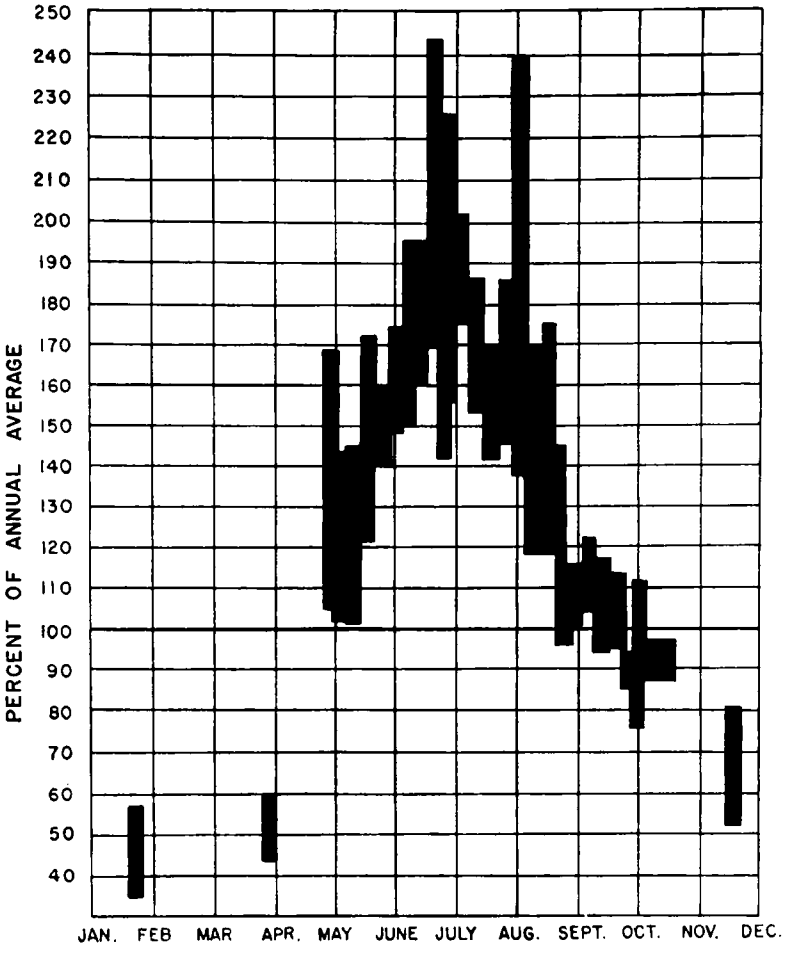

Figure 5. Weekly range of average daily traffic at resort group stations.

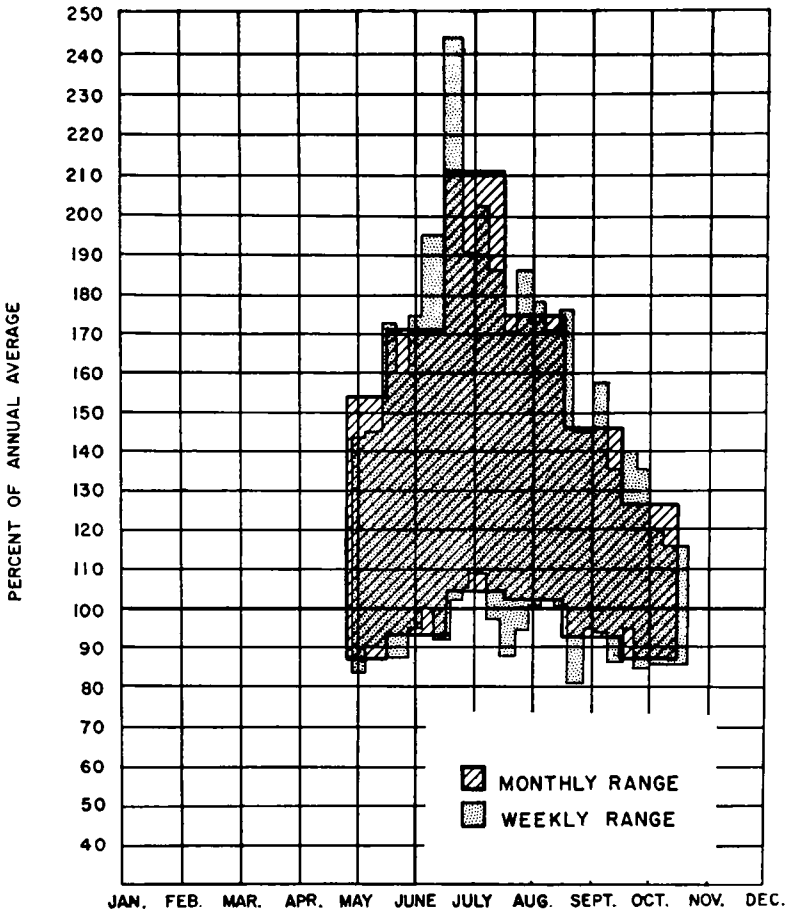

Figure 6. Monthly range of average daily traffic compared to weekly range.

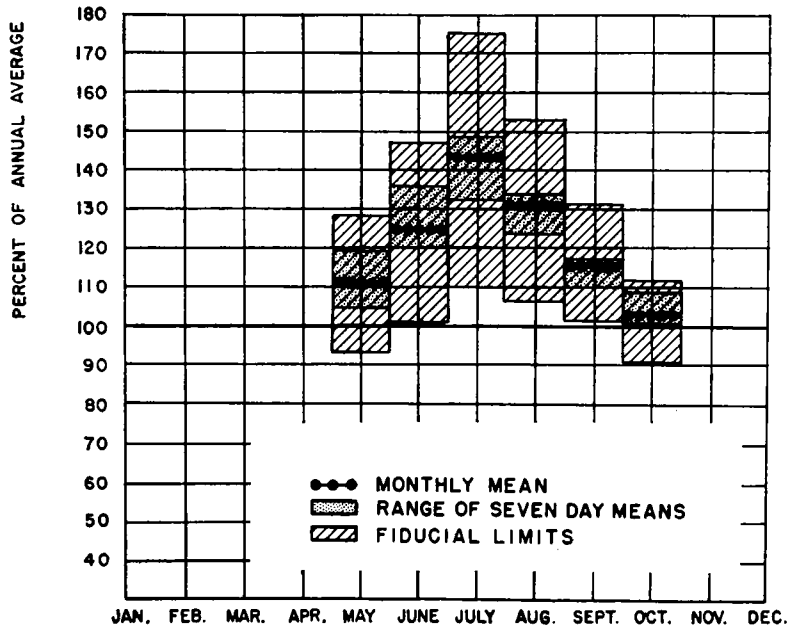

Figure 7. Fiducial limits of "t" test for monthly means of average daily traffic.

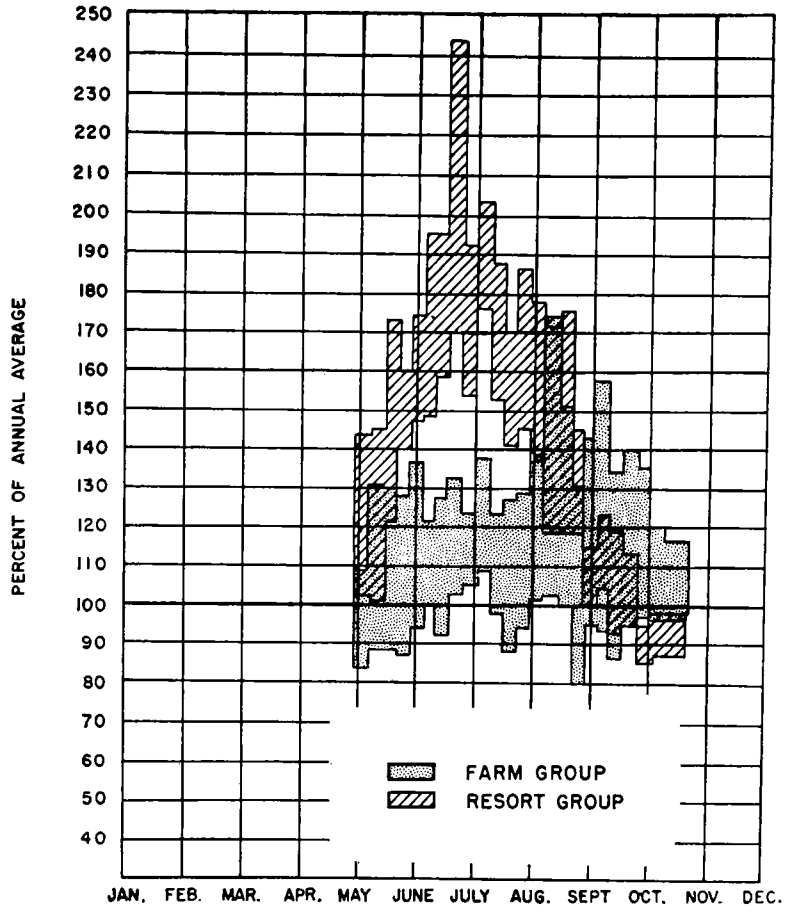

Figure 8. Comparison of weekly range of average daily traffic at farm and resort group stations.

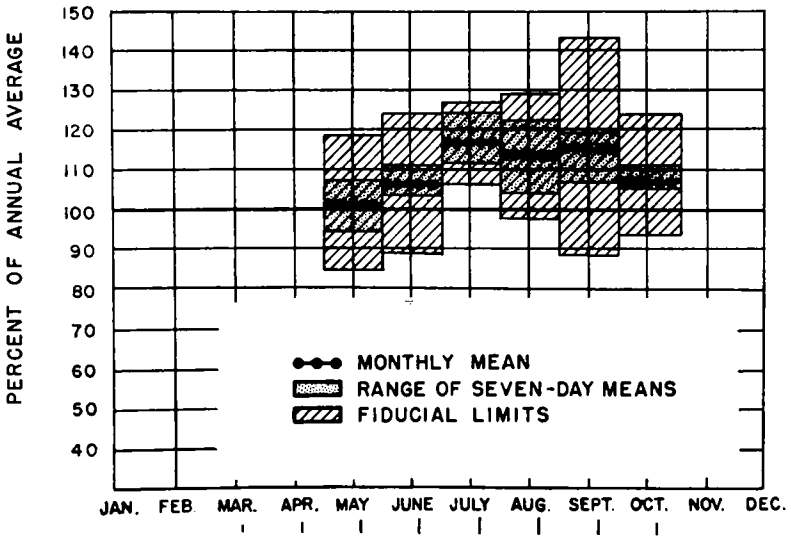

Figure 9. Fiducial limits of "t" test for monthly means of average daily traffic, farm group.

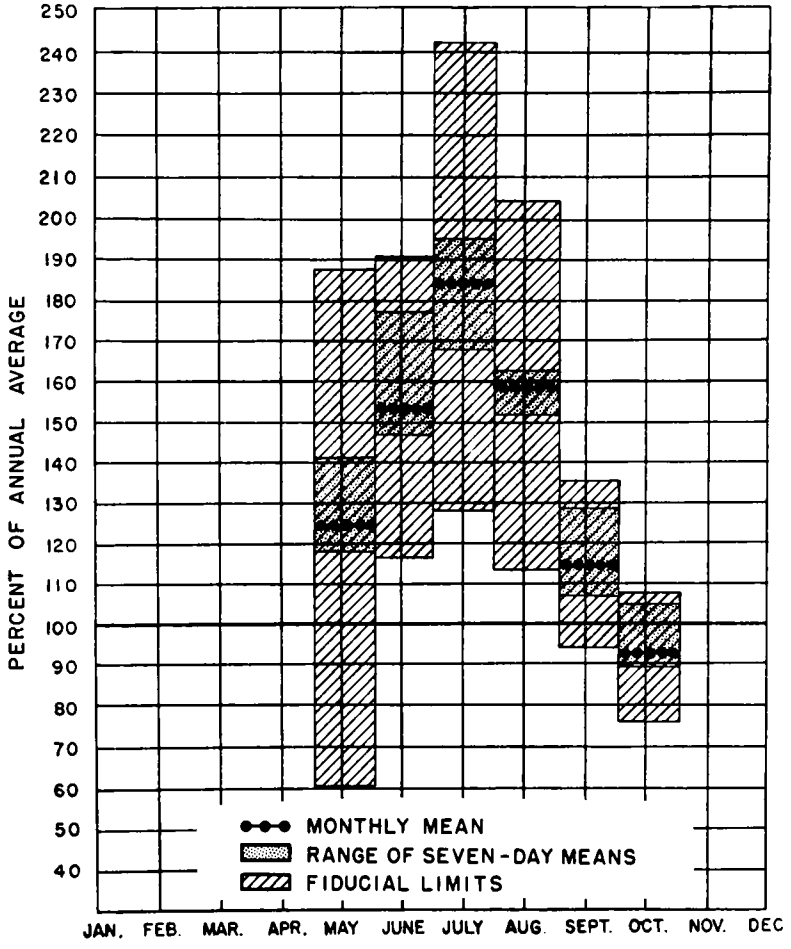

Figure 10. Fiducial limits of "t" test for monthly means of average daily traffic, resort group.

the major differences in month-to-annual relations during June, July, and August, greater accuracy in estimating ADT from sample counts should be expected if farm and resort group patterns are considered separately. During the other three months of the counting period, expansion factors would be quite similar.

Since it is not possible to count all the local rural roads in the state continuously or even for a week each month, it was necessary to find the most efficient method of sampling in terms of reliability and cost. As the ranges of deviation for both the farm and resort group patterns were still large, it was advisable to investigate various methods of sample counting which might further reduce errors in estimating ADT's. Figure 11 shows a comparison of counts of all days in the month to those of weekdays only. The inclusion of weekend travel increased the range of the average daily traffic by as much as 32.4 percent. The inclusion of weekend traffic produced monthly traffic means which were 6.7 to 10.4 percent greater than the monthly means for weekday travel. This increase in average daily traffic must be given consideration when computing factors for adjusting sample counts which include weekend travel. To determine whether weekend travel had greater influence on resort road volumes than on farm road volumes, separate studies were made for stations in each pattern group.

The pattern of average daily travel on farm roads for all days of the month was similar to the pattern of average travel for weekdays only (Fig. 12). The inclusion of weekend volumes in the average traffic for all days in the month produced traffic volumes which were never more than 8.6 percent greater than the average traffic volume for weekdays only. When the 5 farm road stations were considered

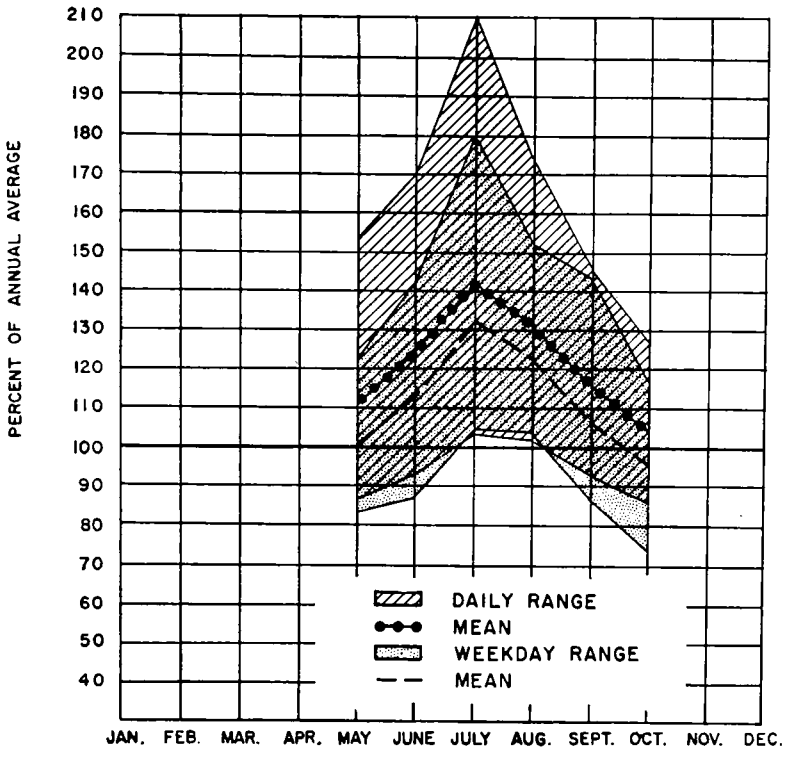

Figure 11. Comparison of monthly average daily traffic and monthly average weekday traffic.

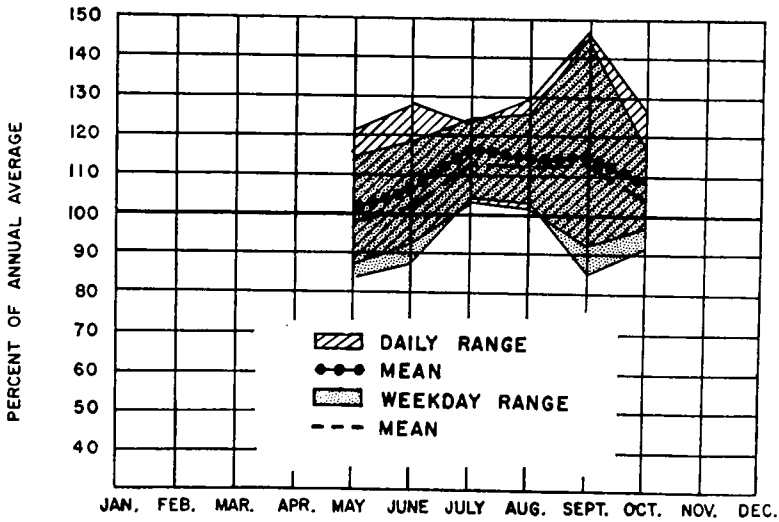

Figure 12. Comparison of monthly average daily traffic and monthly average weekday traffic, farm group.

as a group, the means of the average traffic for all days in the month were always within 5 percent of the means of the average travel on weekdays only.

On resort roads, the average daily travel for all days in the month was consistently greater than the volume of average travel on weekdays only. The inclusion of weekend travel in the computation of average travel for the month produced volumes which, in some months, were as much as 32.4 percent greater than the volumes of average travel on weekdays only (Fig. 13). In fact, in the resort group Saturday and Sunday traffic was often double the volume of weekday traffic. The mean of the average traffic for all days in the month was consistently greater than that of weekdays only. The differences ranged from 12.7 to 22.5 percent each month.

Thus, it appeared important to avoid sample counting on resort roads on Saturdays and Sundays and not so important to avoid weekend counting on farm roads. However, since the inclusion of weekend volumes on resort roads indicated a possibility for extreme deviations, it was concluded that, for consistency, sampling on both farm-to-market and resort roads should be restricted to weekdays only. The inclusion of weekend variations must then be taken care of in the computation of the adjustment factors.

After concluding that a reduction in errors of estimate might be achieved by restricting sample counting to weekdays, the possibility of abnormal variations resulting from the inclusion of holiday counts in the sample was next considered. An investigation of the influence of the three major holidays, Memorial Day, the Fourth of July, and Labor Day, showed that the effect of holidays was even more extreme than that of weekends. Whereas, at times, the deviation of the holiday volumes from their respective monthly mean was small, variations as large as 175 percent above the monthly mean merited the exclusion of holiday travel from sample counts.

Factors to adjust the sample counts to estimated average annual daily traffic volumes were derived from means of weekday travel on farm-to-market and resort roads. However, it was considered possible to use factors obtained from ATR data for travel on primary roads. If this proved to be correct, the expense and effort involved in taking counts of local rural roads to produce expansion factors would be eliminated.

The seasonal patterns and group means of the farm-to-market and resort roads

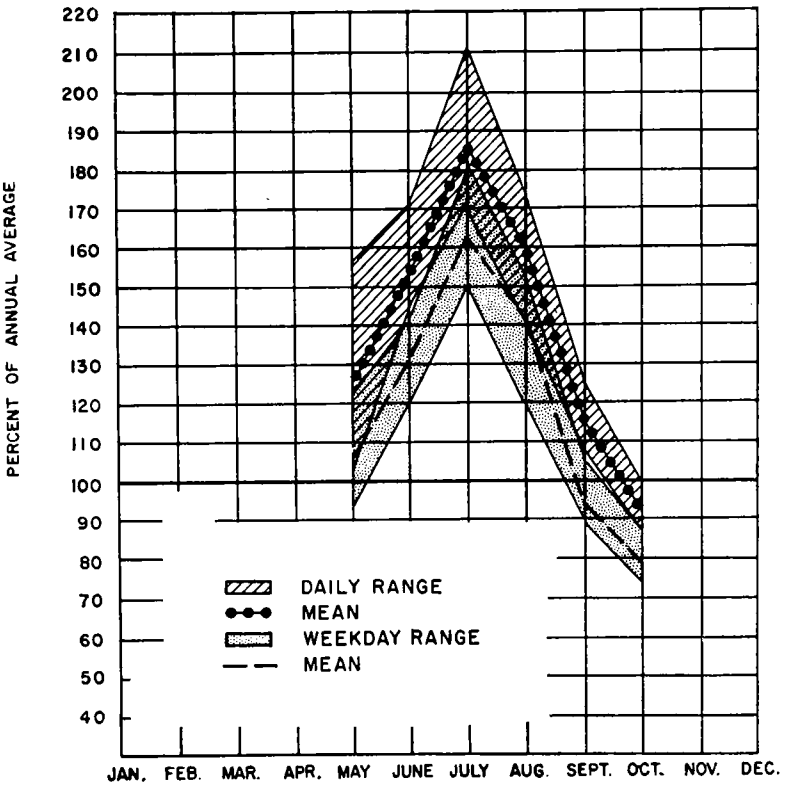

Figure 13. Comparison of monthly average daily traffic and monthly average weekday traffic, resort group.

were compared to the seasonal pattern of the four ATR group means of the primary roads (Fig. 14). Data for ATR group Ib produced the best fit. The farm group could have been matched more closely using composite patterns for other ATR groups, but the problem of deciding which group factor to use on which farm-to-market road in later application made this method seem impractical. The resort local road data were compared to ATR data for primary road group IV (Fig. 15). The group patterns were not as closely associated as were the two farm group patterns shown in Figure 14. However, ATR group IV showed the best fit available. The differences between the month group mean factors of the local road stations and the ATR group mean factors was from 9.4 to 16.2 percent in the case of the resort group and under 5 percent for the farm group, except for a 8.9 percent difference in June.

To test the accuracy of average ADT's produced by ATR group factors, 54 samples of 48-hour weekday counts were randomly selected from data for each of the 8 stations having continuous counts. In selecting the samples the summer holiday weeks were excluded. The 48-hour samples were then grouped as to farm and resort group patterns. Each randomly selected 48-hour count was divided by two to procure an average weekday value and then expanded by the respective ATR factors to produce estimated ADT's. The Chi Square Test was then applied to determine the "goodness of fit."

Table 1 shows the computations for the Chi Square Test for the farm group samples. With 5 stations in the group, the

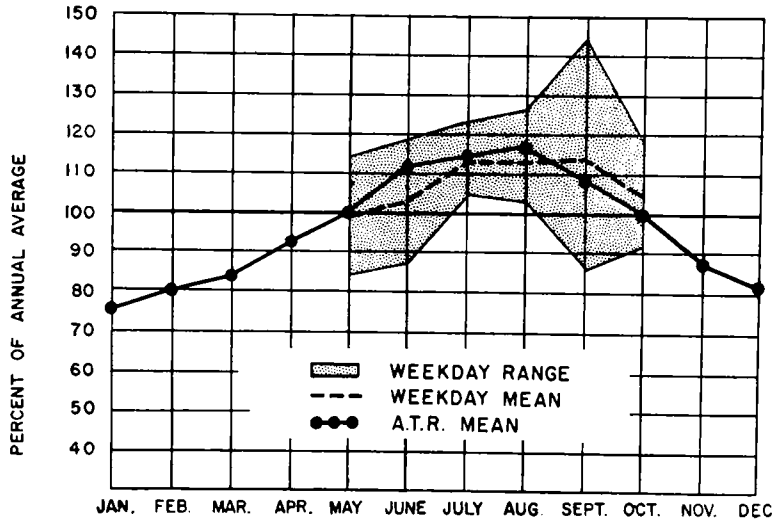

Figure 14. Monthly mean of average weekday traffic on farm roads compared to ATR group Ib mean.

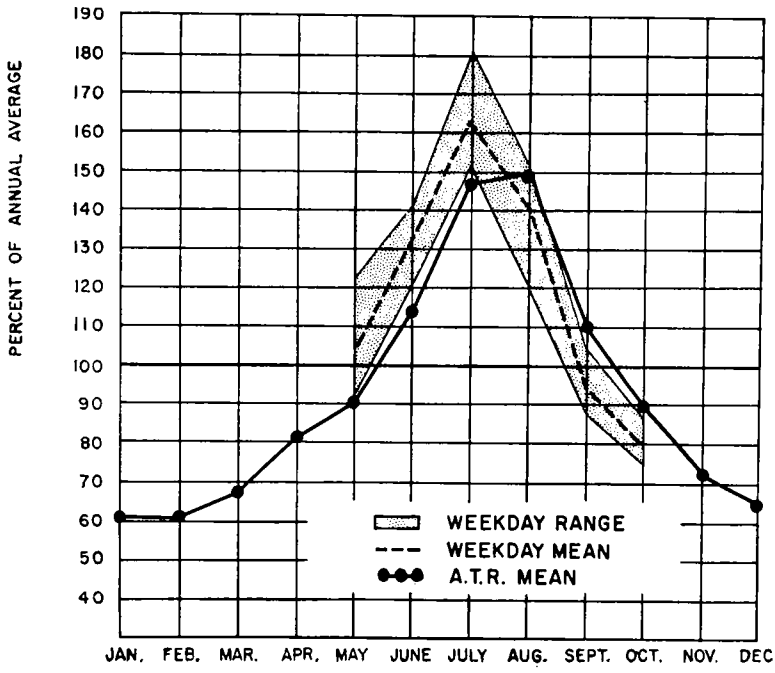

Figure 15. Monthly mean of average weekday traffic on resort roads compared to ATR group IV mean.

TABLE 1

CHI SQUARE TEST FOR PERCENTAGE DEVIATIONS OF ESTIMATED ADT'S BASED ON 48-HR WEEKDAY OBSERVATIONS FROM TRUE ADT'S [1]

Class Interval, % Deviation [2]	$1/S = 0.0642$ $S = 15.57$	Theoretical Cumulative Frequency	Theoretical, f_t	Observed, f_o	$f_o - f_t$	$(f_o - f_t)^2$	$\frac{(f_o - f_t)^2}{f_t}$
0.0 to 0.9	0.0578	12.4	12.4	18	5.6	31.36	2.529
1.0 to 1.9	0.1220	26.2	13.8	10	−3.8	14.44	1.046
2.0 to 2.9	0.1862	39.9	13.7	17	3.3	10.89	0.795
3.0 to 3.9	0.2504	53.4	13.5	14	0.5	0.25	0.019
4.0 to 4.9	0.3146	66.7	13.3	12	−1.3	1.69	0.127
5.0 to 5.9	0.3788	79.7	13.0	13	0	0	0
6.0 to 6.9	0.4430	92.4	12.7	12	−0.7	0.49	0.039
7.0 to 7.9	0.5072	104.8	12.4	14	1.6	2.56	0.206
8.0 to 8.9	0.5714	116.7	11.9	8	−3.9	15.21	1.278
9.0 to 9.9	0.6356	128.2	11.5	11	−0.5	0.25	0.022
10.0 to 10.9	0.6998	139.3	11.1	13	1.9	3.61	0.325
11.0 to 11.9	0.7640	149.9	10.6	7	−3.6	12.96	1.223
12.0 to 12.9	0.8282	159.9	10.0	13	3.0	9.0	0.900
13.0 to 14.9	0.9566	178.5	18.6	19	0.4	0.16	0.009
15.0 to 16.9	1.0850	194.9	16.4	16	−0.4	0.16	0.010
17.0 to 18.9	1.2134	209.3	14.4	10	−4.4	19.36	1.344
19.0 to 20.9	1.3418	221.5	12.2	11	−1.2	1.44	0.118
21.0 to 23.9	1.5344	236.3	14.8	16	1.2	1.44	0.097
24.0 to 26.9	1.7270	247.3	11.0	14	3.0	9.0	0.818
27.0 to 31.9	2.0480	259.0	11.7	14	2.3	5.29	0.452
32.0 and above	5.0000	270.0	11.0	8	−3.0	9.0	0.818

Degrees of freedom $= 21 - 3 = 18$; $\chi^2 = 12.175$; $P = 0.83$.

[1] Estimated ADT's based on 270 random 48-hr observations from 5 experimental local rural road stations in primarily farm-to-market areas. Stations 106, 301, 302, 304 and 305. 1956 volumes from May through October. (Expanded by ATR group Ib factors — weekday/ADT.)

[2] All cells with f_t less than 10 were previously grouped.

total number of samples was 270. The range of deviations was 53 percent and the standard deviation was 15.57. A frequency of 10 was the minimum value required for each class interval cell. The probability value of 0.83 indicated a good fit. The cumulative frequencies for the theoretical and observed values are compared in Figure 16. About 69 percent of the estimated ADT's were within 15.57 percent of the true ADT and 90 percent of the estimates were within 25 percent of the true ADT. Only 3.3 percent of the estimates produced ADT's which varied from the true ADT by 30 percent or more. However, because the variations in daily travel on low-volume roads cause substantial errors in the computation of the ADT, it may be expected that the larger errors will occur on the lower volume roads. To achieve the accuracy of a 24-hour count taken on a road with a volume of 1,000 vehicles, the period of the counting on lower-volume roads must increase as the volume of daily travel decreases. Because the need for accuracy on low-volume roads is not as critical as the need on high-volume roads and because lengthening the period of counting will increase the cost of field operations, larger errors between estimated and true ADT's on low-volume roads are considered acceptable.

The results of the Chi Square Test for the resort group are shown in Table 2. The probability value of 0.16 for the resort group also showed a good fit. With three stations in this group, the total sample was 162. The range of deviations was 42 percent and the standard deviation was 15.48. Figure 17 shows the theoretical and observed frequencies again to be quite similar. In this case the third standard deviation fell outside the percent deviation range of the sample; therefore, extreme deviations should be readily noticed as being atypical.

Another investigation was made to determine whether 7-consecutive-day count samples would give estimated ADT's of greater accuracy than the 48-hr weekday samples did, still using the same ATR group data. Since travel on weekends was included in the sample count, the in-

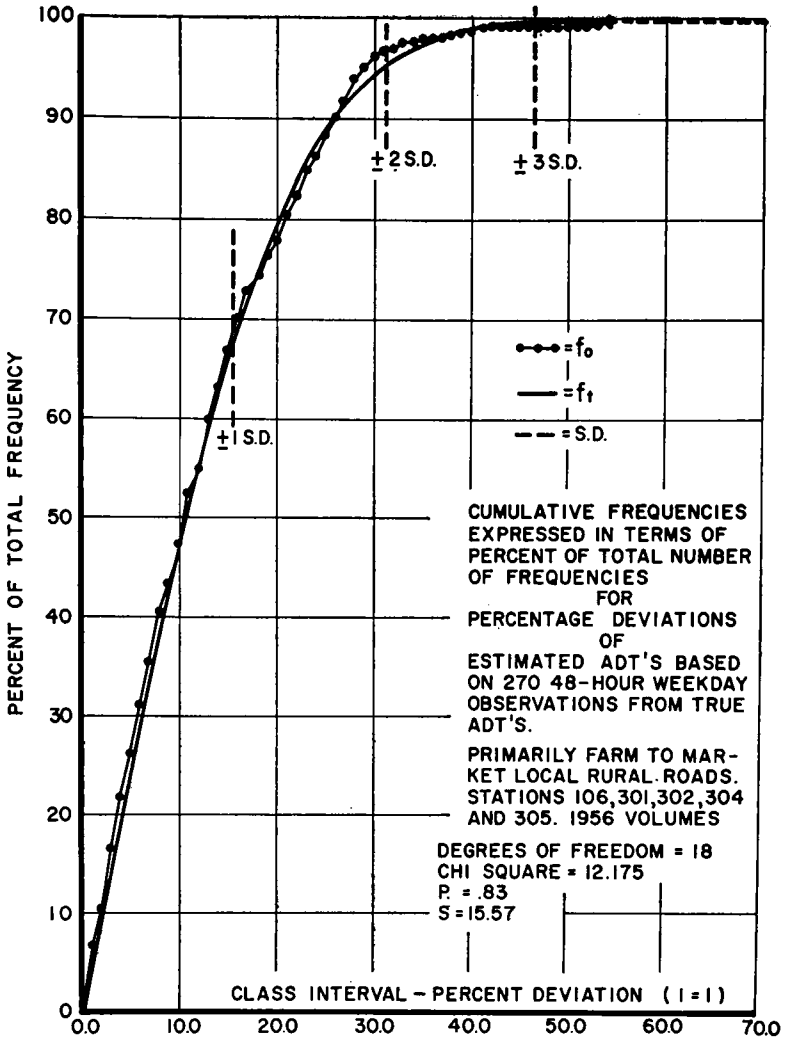

Figure 16.

TABLE 2

CHI SQUARE TEST FOR PERCENTAGE DEVIATIONS OF ESTIMATED ADT'S BASED ON 48-HR WEEKDAY OBSERVATIONS FROM TRUE ADT'S [1]

Class Interval, % Deviation [2]	$1/S = 0.0646$ $S = 15.48$	Theoretical Cumulative Frequency	Theoretical, f_t	Observed, f_o	$f_o - f_t$	$(f_o - f_t)^2$	$\frac{(f_o - f_t)^2}{f_t}$
0.0 to 1.9	0.1227	15.8	15.8	13	−2.8	7.84	0.496
2.0 to 3.9	0.2519	32.2	16.4	16	−0.4	0.16	0.010
4.0 to 5.9	0.3811	48.1	15.9	9	−6.9	47.61	2.994
6.0 to 7.9	0.5103	63.2	15.1	16	0.9	0.81	0.054
8.0 to 9.9	0.6395	77.4	14.2	16	1.8	3.24	0.228
10.0 to 11.9	0.7687	90.4	13.0	11	−2.0	4.0	0.308
12.0 to 13.9	0.8979	102.2	11.8	13	1.2	1.44	0.122
14.0 to 15.9	1.0271	112.7	10.5	19	8.5	72.25	6.881
16.0 to 18.9	1.2209	126.0	13.3	11	−2.3	5.29	0.398
19.0 to 22.9	1.4793	139.5	13.5	15	1.5	2.25	0.167
23.0 to 27.9	1.8023	150.4	10.9	14	3.1	9.61	0.882
28.0 and above	5.0000	162.0	11.6	9	−2.6	6.76	0.583

Degrees of freedom $= 12 - 3 = 9$; $\chi^2 = 13.123$; $P = 0.16$.

[1] Estimated ADT's based on 162 random 48-hr observations from 3 experimental local rural road stations in primarily resort areas. Stations 102, 103, and 105. 1956 volumes from May through October. (Expanded by ATR group IV factors — weekday/ADT.)

[2] All cells with f_t less than 10 were previously grouped.

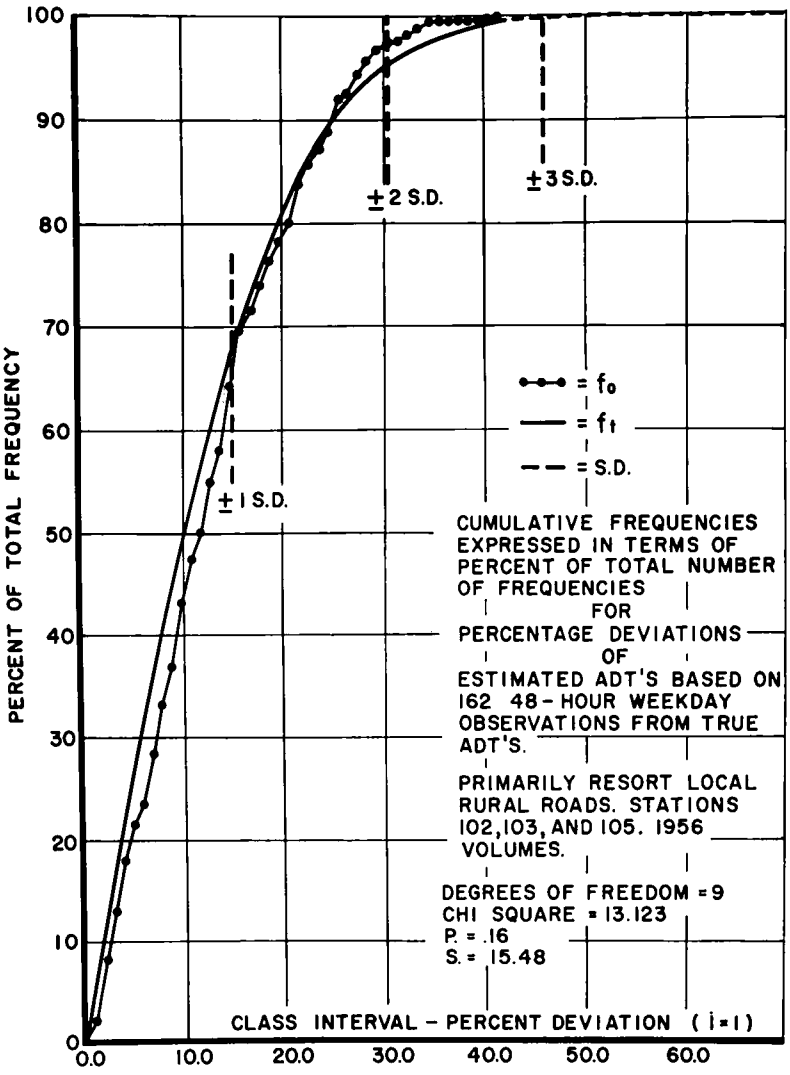

Figure 17.

fluence of such travel was eliminated from the factor computation. Figures 18 and 19 show the fit achieved.

In the farm group these adjusted means were closer to the group means in September and October than in the case of the weekday comparisons (Fig. 14). However, they were further from the group means in the remaining four months. The means of the 7-day counts deviated from the true monthly means by 30.4 percent in total. In contrast, the means of the 48-hr counts deviated from the true monthly means by 24.5 percent in total.

In the resort group the means to be used for computing factors for adjusting the 7-day samples deviated as much as 26.9 percent from true monthly means. This deviation was 10.7 percent greater than the deviation of the means used to compute factors for adjusting 48-hr sample counts. In August, September, and October the means for adjusting 7-day

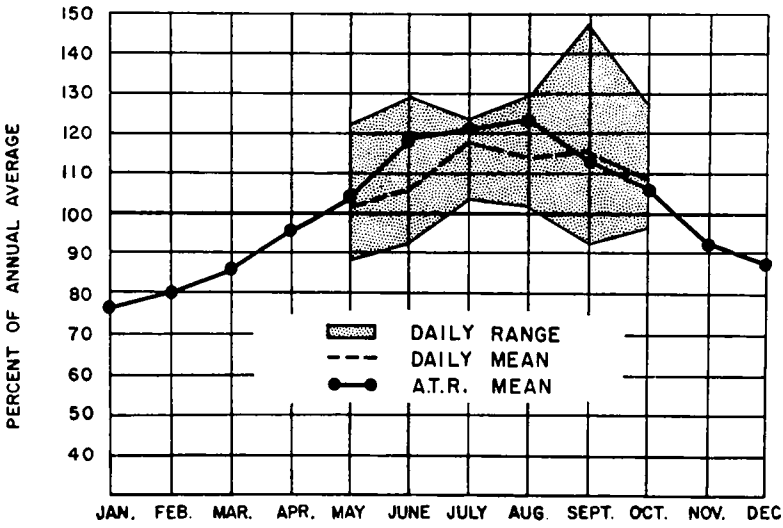

Figure 18. Monthly mean of average daily traffic on farm roads compared to ATR group Ib mean.

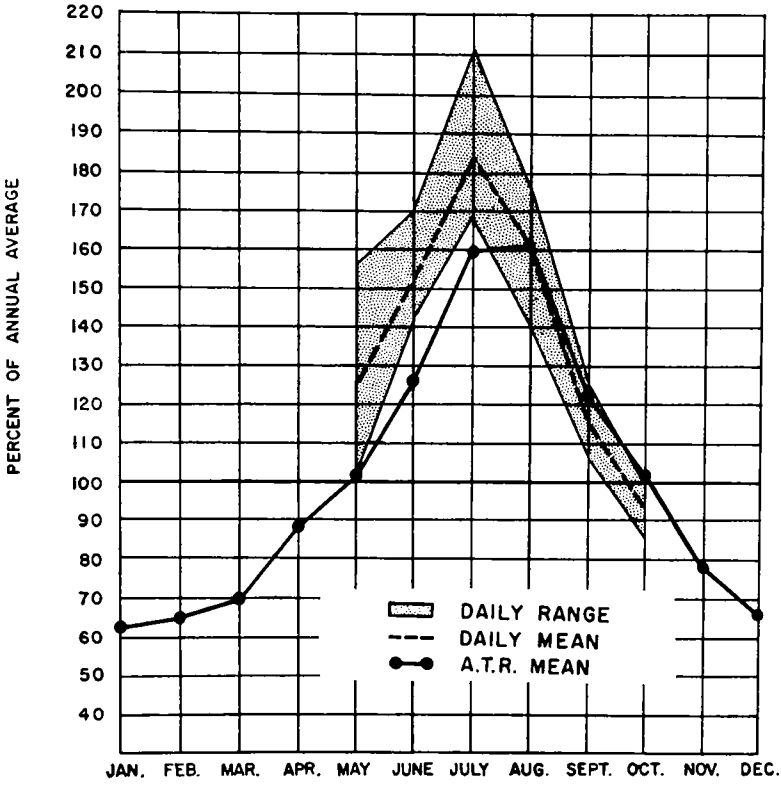

Figure 19. Monthly mean of average daily traffic on resort roads compared to ATR group IV mean.

TABLE 3

CHI SQUARE TEST FOR PERCENTAGE DEVIATIONS OF ESTIMATED ADT'S BASED ON 7-CONSECUTIVE-DAY OBSERVATIONS FROM TRUE ADT'S [1]

Class Interval, % Deviation [2]	$1/S = 0.0672$ $S = 14.87$	Theoretical Cumulative Frequency	Theoretical, f_t	Observed, f_o	$f_o - f_t$	$(f_o - f_t)^2$	$\frac{(f_o - f_t)^2}{f_t}$
0.0 to 1.9	0.1277	18.3	18.3	12	−6.3	39.69	2.169
2.0 to 3.9	0.2621	37.2	18.9	19	0.1	0.01	0.001
4.0 to 5.9	0.3965	55.5	18.3	15	−3.3	10.89	0.595
6.0 to 7.9	0.5309	72.8	17.3	26	8.7	75.69	4.375
8.0 to 9.9	0.6653	89.0	16.2	19	2.8	7.84	0.484
10.0 to 11.9	0.7997	103.7	14.7	9	−5.7	32.49	2.210
12.0 to 13.9	0.9341	117.0	13.3	14	0.7	0.49	0.037
14.0 to 15.9	1.0685	128.6	11.6	14	2.4	5.76	0.497
16.0 to 17.9	1.2029	138.8	10.2	11	0.8	0.64	0.063
18.0 to 20.9	1.4045	151.2	12.4	14	1.6	2.56	0.206
21.0 to 25.9	1.7405	165.3	14.1	18	3.9	15.21	1.079
26.0 and above	5.0000	180.0	14.7	9	−5.7	32.49	2.210

Degrees of freedom $= 12 - 3 = 9$; $\chi^2 = 13.926$; $P = 0.13$.

[1] Estimated ADT's based on 180 random 7-consecutive-day observations from 5 experimental local rural road stations in primarily farm to market areas. Stations 106, 301, 302, 304, and 305. 1956 volumes from May through October. (Expanded by ATR group Ib factors — all days/ADT.)

[2] All cells with f_t less than 10 were previously grouped.

counts were closer to the true monthly mean than were means for adjusting the 48-hr counts. With a range of deviations from 1.3 percent to 26.9 percent, the 7-day count means had an 11.9 percent increase of total deviations from the ATR means over the 48-hr weekday count means.

Six random samples of 7 consecutive day volumes were also selected from each farm and each resort group for each month. This gave the farm group a sample of 180, the resort group a sample of 108. The Chi Square Test was again applied.

Table 3 shows the Chi Square Test of normality for the farm group. The standard deviation of 14.87 was slightly lower than that of the 48-hr sample, as was the range of 47 percent. This test had a probability of 0.13, which was still acceptable. Figure 20 shows the cumulative frequencies for both the theoretical and observed frequencies for this test. Whereas 89 percent of the estimates based on 48-hr samples were within 25 percent of the true ADT, 93 percent of the estimates based on 7-day samples were within 25 percent of the true ADT. However, both tests showed 96.7 percent of each sample was within 30 percent of the true ADT.

A Chi Square Test comparing the percentages of errors in estimated ADT's for farm group samples showed that estimated ADT's based on the 48-hr samples and the 7-day samples were not significantly different. The probability value was 0.76 (Table 4). From this evidence it was concluded that the 7-day count sample would not appreciably increase the accuracy of estimating the ADT on farm-to-market roads.

Table 5 shows the Chi Square Test of normality for the resort group 7-day count samples. Both the standard devi-

TABLE 4

CHI SQUARE TEST FARM-TO-MARKET LOCAL RURAL ROAD ADT ESTIMATES [1]

f Within S.D. Range	0.0000-0.4999	0.5000-0.9999	1.0000-1.4999	1.5000-1.9999	2.0000-3.9999	Total
F_1 (48-hr sample)	106	78	48	30	8	270
F_2 (7-day sample)	61	60	35	18	6	180
Total	167	138	83	48	14	450

[1] Testing the significance of differences between frequencies of errors of estimated ADT's in terms of standard deviations from true ADT's for 48-hr weekday and 7-consecutive-day random samples.

f_o	f_e	$f_o - f_e$	$(f_o - f_e)^2$	$\frac{(f_o - f_e)^2}{f_e}$
106	100.2	5.8	33.64	0.336
78	82.8	−4.8	23.04	0.278
48	49.8	−1.8	3.24	0.065
30	28.8	1.2	1.44	0.050
8	8.4	−0.4	0.16	0.019
61	66.8	−5.8	33.64	0.504
60	55.2	4.8	23.04	0.417
35	33.2	1.8	3.24	0.098
18	19.2	−1.2	1.44	0.075
6	5.6	0.4	0.16	0.029

Degrees of freedom $= (r - 1)(k - 1) = (2 - 1)(5 - 1) = 4$; $\chi^2 = 1.871$; $P = 0.76$.

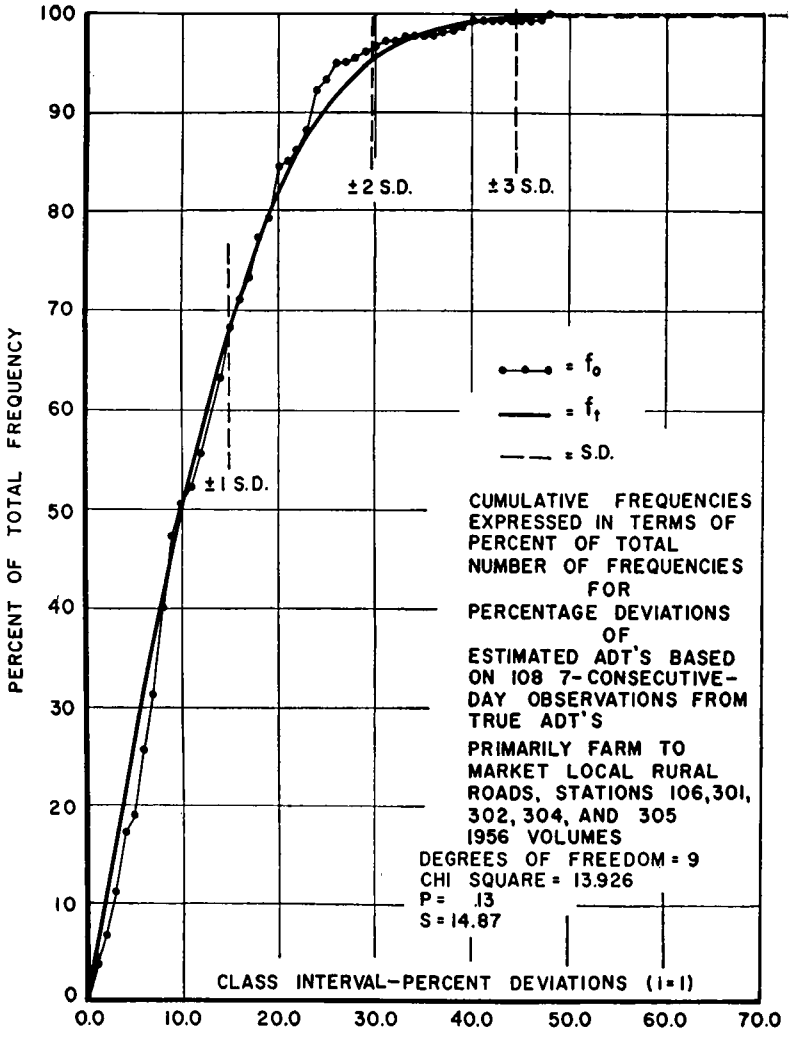

Figure 20.

TABLE 5

CHI SQUARE TEST FOR PERCENTAGE DEVIATIONS OF ESTIMATED ADT'S BASED ON 7-CONSECUTIVE-DAY OBSERVATIONS FROM TRUE ADT'S [1]

Class Interval, % Deviation [2]	$1/S = 0.0514$ $S = 19.46$	Theoretical Cumulative Frequency	Theoretical, f_t	Observed, f_o	$f_o - f_t$	$(f_o - f_t)^2$	$\frac{(f_o - f_t)^2}{f_t}$
0.0 to 2.9	0.1491	12.8	12.8	8	−4.8	23.04	1.800
3.0 to 5.9	0.3033	25.7	12.9	9	−3.9	15.21	1.179
6.0 to 8.9	0.4575	38.1	12.4	14	1.6	2.56	0.206
9.0 to 11.9	0.6117	49.6	11.5	20	8.5	72.25	6.283
12.0 to 14.9	0.7659	60.1	10.5	15	4.5	20.25	1.929
15.0 to 18.9	0.9715	72.2	12.1	16	3.9	15.21	1.257
19.0 to 23.9	1.2285	84.3	12.1	11	−1.1	1.21	0.100
24.0 to 30.9	1.5883	95.9	11.6	3	−8.6	73.96	6.376
31.0 and above	5.0000	108.0	12.1	12	−0.1	0.01	0.001

Degrees of freedom = 9 − 3 = 6; $\chi^2 = 19.131$; $P = 0.006$.

[1] Estimated ADT's based on 108 random 7-consecutive-day observations from 3 experimental local rural road stations in primarily resort areas. Stations 102, 103, and 105, 1956 volumes from May through October. (Expanded by ATR group IV factors — all days/ADT.)

[2] All cells with f_t less than 10 were previously grouped.

ation of 19.46 and the range of 69 percent were larger than those produced by the 48-hr sample. The "goodness of fit" was below the level of acceptance, with a probability value of 0.006. The large difference between the theoretical and observed frequencies are shown in Figure 21. Whereas 89 percent of the estimates were within 25 percent of the true ADT in the 48-hr sample, it was necessary to extend the deviation to 30 percent to include 89 percent of the estimates procured from 7-day samples. In the case of the 48-hr sample test, 3.1 percent of the estimates exceeded 30 percent, whereas 11.1 percent of the estimates exceeded 30 percent in the 7-consecutive-day sample test.

Although the deviations of estimates based on 7-day sample counts were significantly different from normal, it does not necessarily follow that estimates based on 7-day samples were significantly different from estimates based on 48-hr weekday samples. A Chi Square Test was again applied to determine

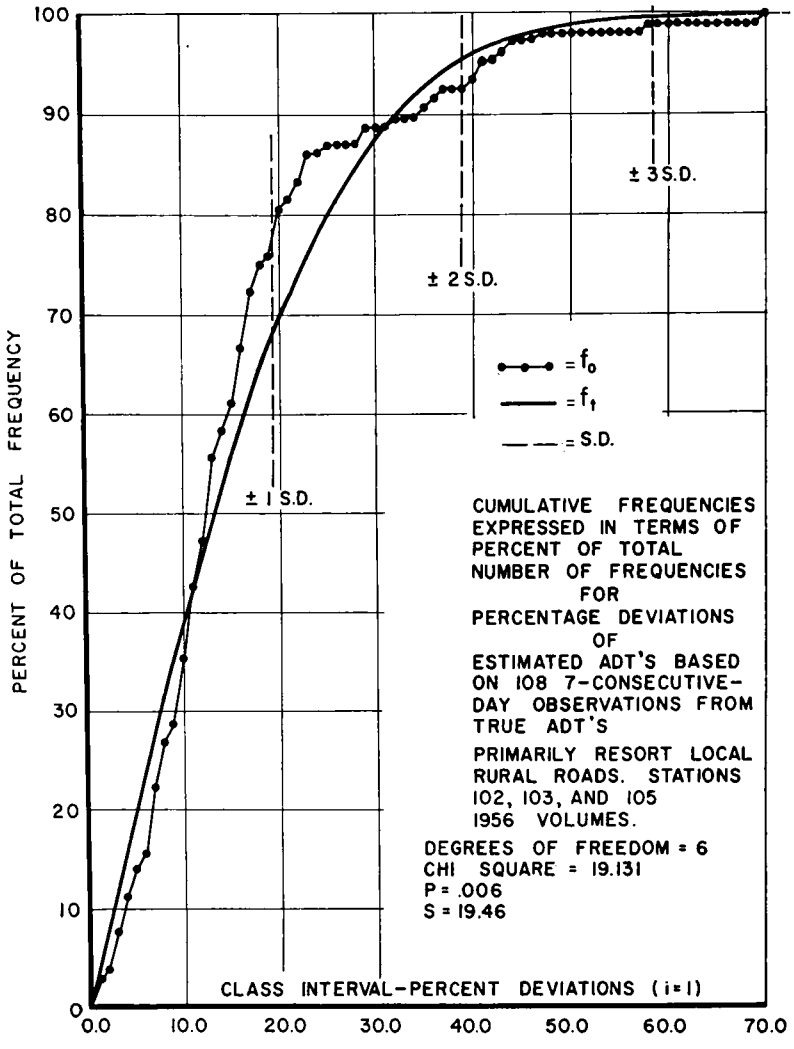

Figure 21.

whether estimates based on 7-day counts and 48-hr counts were significantly different. The resulting probability value of 0.019 (Table 6) proved that the two types of counts were significantly different from each other at the 2 percent level of significance. Estimated ADT's based on 48-hr samples produced the more accurate approximation of the true ADT's for the resort roads than did the 7-day sample.

Thus, the results of the preceding Chi Square Tests showed that, at least with the use of the trunk highway ATR data for expansion purposes, the 48-hr weekday counts gave an estimate of the ADT as good as or better than the 7 consecutive day counts. This is due in part to the extreme variations in weekend travel on resort roads and the noticable lack of variations in weekend travel on farm-to-market roads. These tests have indicated that the variations between weekday and weekend travel are more pronounced on local rural roads than on primary roads under study.

As a result of this study, it has been decided sample counts will be of 48-hr duration. Those on roads having farm-to-market characteristics will be expanded by the group mean factors for ATR group Ib, and those on roads having resort characteristics will be expanded by ATR group IV factors.

The adoption of this procedure eliminates the need for special control counts on local rural roads and accomplishes a considerable saving in the cost of estimating travel on low-volume roads.

TABLE 6

CHI SQUARE TEST RESORT LOCAL RURAL ROAD ADT ESTIMATES [1]

f Within S.D. Range	0.0000-0.4999	0.5000-0.9999	1.0000-1.4999	1.5000-1.9999	2.0000-3.9999	Total
R_1 (48-hr sample)	50	59	31	18	4	162
R_2 (7-day sample)	35	49	12	4	8	108
Total	85	108	43	22	12	270

[1] Testing the significance of differences between frequencies of errors and estimated ADT's in terms of standard deviations from true ADT's for 48-hr weekday and 7-consecutive-day random samples.

f_o	f_e	$f_o - f_e$	$(f_o - f_e)^2$	$\frac{(f_o - f_e)^2}{f_e}$
50	51.0	−1.0	1.0	0.020
59	64.8	−5.8	33.64	0.519
31	25.8	5.2	27.04	1.048
18	13.2	4.8	23.04	1.745
4	7.2	−3.2	10.24	1.422
35	34.0	1.0	1.0	0.029
49	43.2	5.8	33.64	0.779
12	17.2	−5.2	27.04	1.572
4	8.8	−4.8	23.04	2.618
8	4.8	3.2	10.24	2.133

Degrees of freedom $= (r - 1)\quad (k - 1) = (2 - 1)(5 - 1) = 4$; $\chi^2 = 11.885$; $P = 0.019$.

REFERENCE

1. PETROFF, BORIS, AND BLENSLY, ROBERT, "Improving Traffic-Count Procedures by Application of Statistical Method." *Proc. H.R.B.*, Vol. 33 (1954).