STANDARD DEVIATION AND COEFFICIENT OF VARIATION OF AUTOMATIC TRAFFIC RECORDER COUNTS

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SYNOPSIS

The primary function of the fixed automatic traffic recorder is to obtain a complete and continuous record of the number of vehicles passing a given point on a highway network. This record is usually set down on an hourly basis. As a consequence, a large and unwieldy body of data is quickly accummulated even for a single station, and the extraction of all of the useful statistics from this mass of basic data from more than a few stations, is a tedious and costly undertaking. Even such items as the yearly, monthly, weekly, daily and hourly maxima, minima and averages, and the seasonal trends, can only be made available after extensive tabulations and calculations.

During the past two years, the highway planning survey division of the Iowa State Highway Commission has been following a procedure which makes possible a more thorough statistical analysis of these recorder data and continues the computation of the averages without increasing the cost beyond that for these averages alone. This procedure involves the use of automatic electrical calculating and tabulating equipment to eliminate the extensive and tedious manual manipulation of the data required for the extraction of all of these statistics and for the preparation of weekly and monthly reports of the recorder data.

This paper presents a brief description of the data obtained in the operation of fixed automatic traffic recorders, and of the statistics readily derived from these data through simple tabulation and calculation; it describes the procedure used by Iowa State Highway Commission for a more thorough statistical analysis of these data and discusses the significance of the statistics available from this analysis. Emphasis is placed on the significance and utility of the standard deviation and the coefficient of variation of the recorder counts. In this procedure, provision is made for the calculation of the statistics for each hour of the day for the week days of each month of the year. When available for a complete year the statistics reveal the months of the year, the weeks of the month, the days of the week and the hours of the day upon which the least variable and consequently most reliable short counts may be made.

The paper concludes that (1) such knowledge will permit a more accurate determination of the values for average annual daily traffic from data taken in short coverage counts; (2) such knowledge will permit preparation of coverage counting schedules which will provide for more accurate values for average annual traffic than present systems of scheduling; (3) such knowledge will permit the selection of the portion or portions of the day for the coverage counts that may be more reliable as a base for the computation of average annual daily traffic and more comfortable for the manual recording personnel than any of those now generally used in these counts; and (4) these statistics will provide means for evaluating the performance of the recorders themselves.

This paper deals with the standard deviations and coefficients of variation computed for the volume of hourly and daily traffic for the weekdays of each month as obtained in the operation of 26 fixed automatic traffic recorders located on the primary road system in Iowa. The main body of the report is given to the evolution of a procedure for the computation of these two statistics from the recorder data and to the discussion of their significance in traffic survey operations. Emphasis is placed upon the application of the knowledge of certain characteristics of the traffic stream that may be had only from these statistics. Attention is directed to the extension of the utility of the automatic traffic recorder data that becomes possible through the availability of this knowledge. The general conclusion of the paper is that the employment of this knowledge in the design of traffic survey counting and sampling schedules should provide for more efficient conduct of the traffic surveys and for greater accuracy and reliability in their results.

For any road system, the purpose in using automatic traffic recorders is to obtain an intimate, accurate and complete knowledge of the chronological distribution of the traffic passing some point on a given highway system that is representative of other points on the system insofar as this characteristic of the traffic is concerned. For any highway system, enough recorders should be operated for a given traffic condition to obtain a truly representative sample of that condition and enough of such groups of recorders should be used to obtain representation for each condition encountered on the system.

The need for the type of information to be obtained from continuous observations of the traffic at representative points on a given highway became obvious early in modern traffic engineering activities. Many investigators had explored the use and potentialities of such information for increasing the efficiency of traffic survey operations and improving the results. The exorbitant costs of manual operations to obtain this information led others to seek means of obtaining it more easily.

In 1934 the Iowa State Highway Commission became actively interested in this work and started a traffic survey master station which was continued for a period of slightly more than one year, November 1, 1934 to December 31, 1935, on the primary road extending south from Ames. This station was operated manually to obtain a continuous record of the volume and classification of the traffic passing the station. This was the first operation of its kind to be conducted for the period of a whole year. A report on the operation was presented by Mark Morris before the Highway Research Board in December 1935, and this report appears in the *Proceedings* of the Fifteenth Annual meeting of the Board. Mr. J. Gordon McKay of the Bureau of Public Roads, Mr. N. W. Dougherty of the University of Tennessee, Mr. Nathan Cherniack of the Port of New York Authority and a number of others had previously conducted similar studies but for much shorter periods of time. Studies of the data from these investigations quickly established the utility of full-time master station operations and emphasized the need for some means of obtaining at least the data for traffic volume at a number of points representative of the various portions of a given highway system, and at less cost than by manual operations.

In 1935, in the course of the development of plans for the traffic survey divisions of the basic statewide highway planning surveys, the Bureau of Public Roads, in collaboration with the International Business Machines Corporation, devised an instrument for obtaining a continuous hourly record of the number of vehicles passing a given point on a highway. This was the first practical and reliable automatic traffic recorder. Nearly all of the state highway departments installed some of these instruments in connection with the traffic survey work of the planning surveys in 1936 and 1937. Most of the original installations have been in continuous operation since they were first made. Many states have added to the original group of installations to obtain more complete coverage of a given system and to provide more positive assurance that each traffic condition on that system was represented in the collection of automatic traffic recorder data.

During the past fifteen years, occasional meditation upon the original and current uses of the fixed automatic recorder data has raised some doubt in the mind of the author that the potentialities of these data were being fully utilized. During this period, the data have been used principally to determine the annual trends, seasonal variations and daily patterns in traffic. From these statistics, factors have been derived for the conversion of values for traffic volume as obtained in one or more short counts of from 4 to 8 hr. to values for average annual daily traffic and average annual weekday traffic. For this work these factors are valuable tools in general traffic survey operations and as such are undoubtedly worth the cost of the whole automatic recorder operation. But the curious among traffic engineers have long believed that there were other potentialities of the automatic recorder data yet untouched which, if they could be developed, would render a service to traffic survey operations comparable in value to that given by the simple statistics which were being derived from these data and used so effectively during the past fifteen years.

The function of the automatic traffic recorder is to obtain a continuous record of the number of vehicles passing a given point on a system of highways and to set down that record in a form which will best serve the purposes for the operation of these recorders. Generally, this record consists of entries of the total traffic accumulated to the end of each hour. From this record, hourly values are obtained by subtraction of each entry from its successor. Normally, the record is allowed to accumulate in the machine for one week, at the end of which it is removed and forwarded to a central office for calculation and tabulation.

The recorders produce a large mass of data consisting of the hourly record of traffic at a given location for an entire year and eventually for a period of years. Treatment of these data has been limited generally to the calculations and tabulations necessary for the determination of the characteristics of traffic volume that are essential for the derivation of factors for converting the values from short counts to values for average annual daily traffic. These are: (1) the hourly, (2) the daily, and, (3) the seasonal variation in the volume of traffic; (4) the value for the average annual daily traffic; (5) the value for the average weekday traffic; and (6) the value of the portion of the total traffic for the weekday found for the period of the day used in making the short counts.

In Iowa, the manual work involved in these calculations and tabulations of the data from 26 recorders on the primary roads and 12 on the secondary roads, and the preparation of the weekly and monthly reports of the data for the Bureau of Public Roads, required the full time of three employees. This work is monotonous and tedious; it has been difficult to keep a crew permanently engaged upon it. Any attempt to extract additional statistics from the data by manual methods would require a much larger force and thus increase the personnel and space problems.

As a consequence, the search for a procedure for extracting additional statistics has had the objectives of doing all the calculating and tabulating with automatic mechanical equipment and of extending the mechanical operation to provide additional statistics to extend the utility of the recorder data. In 1948, after a number of years of experimentation, both objectives were attained by the planning survey division of the Iowa State Highway Commission and, since that time, all operations for the calculation and the tabulation (except the subtractions on the original record and the entry of hourly values on tabulation cards) have been performed with International Business Machines Corporation automatic calculating and tabulating equipment. For this procedure, a key punch, calculating punch, tabulating machine, card sorter, and summary punch are required. A sixth item, the collator, is useful in reducing the sorting. All of this equipment is on hand in Iowa principally for other purposes and is used incidentally for this work. The availability of the equipment, some of it idle at some period during each month, was an added incentive to the development of

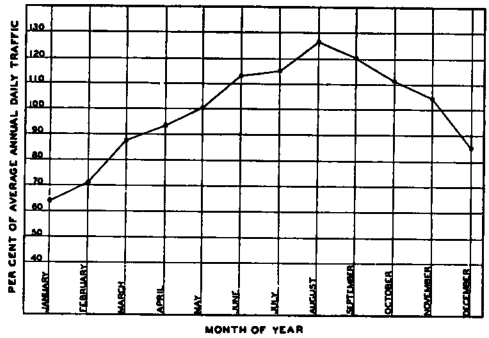

Figure 1. Seasonal Variation in Daily Traffic

the procedure for treating the automatic traffic recorder data. It would be impractical to install it for this work only. Thus, a third objective was attained, a more efficient use of costly equipment.

The current calculations and tabulations under this procedure include all of those previously made manually with the exceptions heretofore noted, and in addition include those for the standard deviation and coefficient of variation for the hourly and daily values for volume of traffic for the weekdays of each month. These are the statistics sought for extending the usefulness of the recorder data. The entire procedure occupies the full time of the equivalent number of employees required for the manual operations, although three to five times as much work is involved in the extraction of the additional statistics alone.

Figure 1 contains data showing the monthly or seasonal variation in the values for average daily traffic for all recorders for each month of the calendar year 1949, presented as a percentage of the average annual daily traffic for that year for all of the 26 recorders located on the primary road system in Iowa. From these data, it may be observed that the volume of traffic in May at any point on that system may be expected to be about the average for the year and that the peak may be expected in August. The low value was found to occur in January. From these data, it may be deduced that a 24-hr. traffic count made on any day would require the application of a factor, which may be derived from Figure 1, to convert the value obtained in that count to that for the average annual daily traffic, or that to be expected as the average for any other month of the year. Such a factor would, of course, be one of the components of a composite factor for converting values obtained in less than 24 hr. to these values.

Figure 2 shows the data for the monthly or seasonal variation in average week day traffic for the calendar year 1949 for the same stations used for Figure 1. As most traffic counts are made on weekdays these data are those most generally used for the derivation of the conversion factors for values obtained in short counts.

Figure 3 contains the data for the same stations showing the hourly variation in daily traffic for the average annual daily traffic. The same type of data for the average annual weekday traffic are shown in Figure 4. Factors for converting results of short counts to values for the 24-hr. day are derived from these data. These factors, combined with those derived from data for seasonal variation, are used to obtain values for average annual daily traffic from values obtained in one or more short counts of 8 hr. When the greatest accuracy is sought for the conversion factors, the hourly variation pattern for the average weekday for the month in which the count is made should be used. Generally this is unnecessary, since

TABLE 1
AVERAGE 24-HR. DAILY TRAFFIC AT EACH OF THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH, 1949

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Avg.
601	3,363	3,883	4,584	4,937	5,201	5,467	5,090	5,519	5,455	5,353	5,408	4,503	4,897
604	2,045	2,440	2,947	3,131	3,344	3,494	3,396	3,556	3,365	3,162	3,500	2,801	3,098
605	948	864	1,087	1,177	1,310	1,426	1,351	1,399	1,668	1,460	1,557	1,223	1,289
607	469	521	639	695	805	967	984	1,091	979	929	792	661	794
614	2,316	2,509	3,258	3,251	3,589	4,058	4,116	5,229	5,438	5,247	4,210	3,112	3,861
615	2,078	2,121	2,416	2,405	2,344	3,083	3,250	3,334	3,006	2,871	2,621	2,383	2,659
616	1,330	1,565	1,897	1,837	2,081	2,486	2,551	2,758	2,714	2,381	2,252	1,869	2,143
617	1,324	1,252	1,665	1,765	1,711	1,964	1,901	—	2,015	1,967	2,057	1,735	1,760
618	1,713	1,842	2,083	2,258	2,378	2,621	2,710	2,938	2,677	2,469	2,314	2,082	2,340
619	990	1,019	1,456	1,519	1,545	1,733	1,818	1,848	1,846	1,882	1,647	1,351	1,554
620	1,129	1,350	1,581	1,639	1,656	2,033	2,155	2,306	2,304	1,909	1,766	1,441	1,772
621	1,333	1,540	1,578	2,011	1,992	2,221	2,278	2,425	2,176	2,110	2,039	1,737	1,953
622	819	1,054	1,257	1,389	1,478	1,888	1,984	2,152	1,854	1,771	1,560	1,355	1,547
623	839	1,270	1,649	1,750	1,834	2,089	2,090	2,334	2,120	1,982	1,841	1,660	1,788
624	1,482	1,747	2,087	2,352	2,404	2,778	2,777	2,774	2,611	2,400	2,417	2,109	2,328
625	1,032	1,149	1,502	1,657	1,831	1,991	1,934	2,141	2,169	1,976	1,891	1,605	1,740
626	686	713	905	1,043	1,116	1,362	1,417	1,635	1,502	1,326	1,309	902	1,160
627	1,357	1,415	1,777	1,943	2,033	2,646	2,722	3,037	2,738	2,732	2,522	2,143	2,255
628	1,462	1,716	2,029	2,432	3,288	4,528	4,997	4,990	3,932	2,796	2,448	2,075	3,058
629	816	1,023	1,059	1,150	1,222	1,374	1,392	1,516	1,437	1,398	1,375	1,158	1,243
630	792	887	1,048	1,099	1,186	1,353	1,443	1,590	1,456	1,301	1,216	1,071	1,203
631	710	834	1,007	1,051	1,200	1,327	1,375	1,618	1,498	1,339	1,210	1,042	1,184
632	2,256	2,201	3,826	3,398	3,763	3,812	3,692	4,450	4,601	4,582	4,247	3,203	3,669
633	334	413	541	485	480	485	530	572	544	536	503	533	496
635	2,390	2,995	3,534	3,627	3,903	4,156	4,105	4,437	4,460	4,632	4,058	1,857	3,679
636	618	669	856	873	932	972	1,072	1,108	1,058	1,008	1,051	882	925

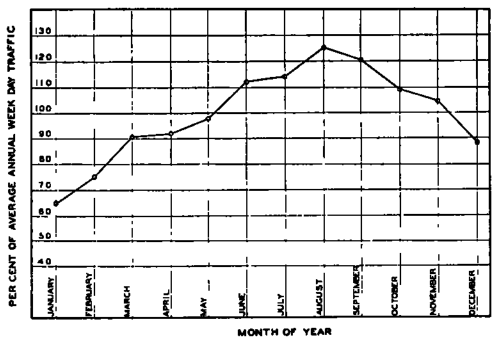

Figure 2. Seasonal Variation in Weekday Traffic

the factors derived from the pattern for average annual weekday are sufficiently accurate for all practical purposes.

Figure 5 contains data showing the standard deviations of the values for weekday traffic from the average weekday for the month.

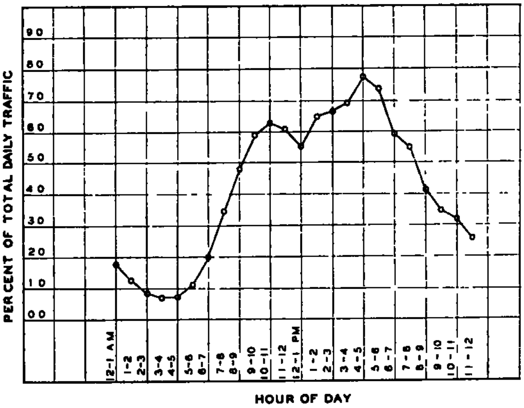

Figure 3. Hourly Variation in Daily Traffic

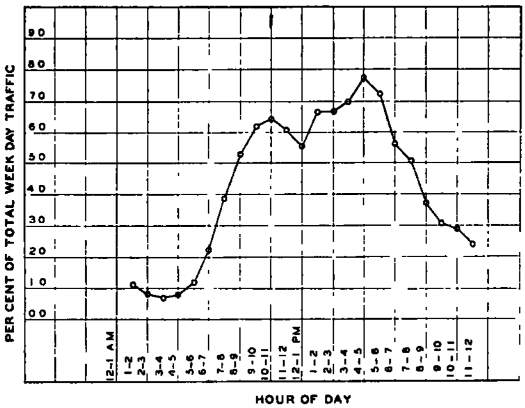

Figure 4. Hourly variation in Weekday Traffic

Each plotted point represents the values for standard deviation and the mean for one recorder for one month. All months of the year are represented in this figure. The relationship, if any, between the standard deviation and the mean are obscured by the eccentricities of the data for the year as a whole. The figure is without significance except that of showing the effect of these eccentricities.

Figure 6 contains data showing the coefficient of variation for the data shown in Figure 5. Each plotted point represents the values for coefficient of variation and the mean for one recorder for one month. Here again the eccentricities serve to conceal the significance of this statistic.

Figure 7 contains data showing the average coefficient of variation of the weekday values for each month of the year for the 26 recorders. As might be expected, because of climatic conditions in Iowa during the winter months the coefficient of variation is large in January and February. Large values may be expected also in December and March. In 1949 the weather was unusually mild in December and March. In that year the usual March weather came in April and the usual April weather came in March. The abnormality of the weather in these months affected the hourly variations more than it did the daily variations as will be noted in comparing the data in Figures 7 and 10.

From Figure 7 it is evident that the most stable values for volume of weekday traffic may be expected in the months of April, May, June, July, August and October. The record for other years than 1949 may indicate that September should be included in this list. With this possible exception these are the months of the year in which a single 24-hr. weekday count may be made with the least probability of a large variation from the average volume of traffic for the month in which the count is taken, provided of course the count was not on a holiday.

Hence, through this statistic a powerful new tool is provided in the knowledge of the behavior that should aid in designing traffic counting schedules which will give more reliable values for either average annual daily or average annual weekday traffic. The extraction of this statistic from the fixed automatic traffic recorder data provides a means for greatly extending the utility of these data in general traffic survey operations.

Figure 8 contains the standard deviations and their means for each of the 26 recorders for the weekday traffic for the months of April through October. These data show a relationship between the standard deviations and their means that may be expected, that is, the standard deviation varies as the mean. This indicates the possibility of constant value for the coefficient of variation for these data and that the months represented are relatively free from the disturbances causing the ab- days and other special occasions occurring in these months.

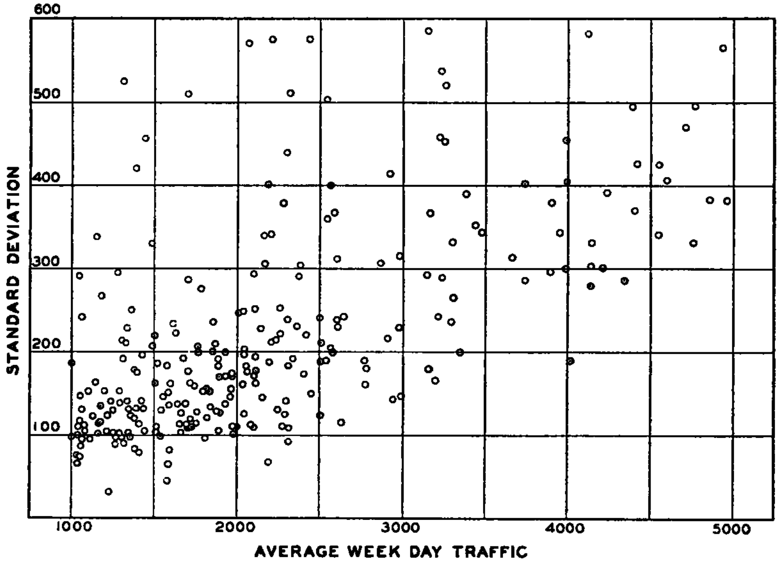

Figure 5. Relation between Standard Deviation and Average Weekday Traffic

TABLE 2

AVERAGE 24-HR. WEEK DAY TRAFFIC AT EACH OF THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH 1949

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Avg.
601	3,258	3,835	4,397	4,622	4,958	5,510	4,755	5,259	5,255	4,867	4,934	4,557	4,684
604	2,077	2,541	2,908	2,971	3,247	3,354	3,297	3,303	3,294	2,972	3,242	2,859	3,005
605	886	893	1,066	1,103	1,219	1,337	1,291	1,319	1,583	1,359	1,490	1,249	1,233
607	482	536	641	663	764	909	952	1,042	939	863	791	673	771
614	2,330	2,567	3,226	3,148	3,378	3,910	4,008	5,059	5,292	4,711	4,124	3,217	3,747
615	2,094	2,159	2,402	2,330	2,306	2,991	3,155	3,208	2,939	2,758	2,568	2,503	2,618
616	1,299	1,575	1,842	1,704	1,890	2,229	2,371	2,502	2,596	2,267	2,054	1,866	2,016
617	1,239	1,274	1,636	1,723	1,658	1,886	1,895	—	1,968	1,892	2,029	1,768	1,724
618	1,690	1,888	2,068	2,197	2,255	2,505	2,597	2,779	2,599	2,364	2,254	2,110	2,275
619	999	1,048	1,341	1,355	1,382	1,583	1,669	1,680	1,686	1,659	1,539	1,351	1,441
620	1,176	1,388	1,605	1,583	1,580	1,962	2,111	2,245	2,307	1,881	1,763	1,499	1,758
621	1,324	1,589	1,550	1,935	1,922	2,127	2,191	2,321	2,120	2,030	1,976	1,750	1,903
622	804	1,079	1,248	1,345	1,442	1,815	1,926	2,107	1,816	1,686	1,512	1,383	1,514
623	860	1,299	1,656	1,717	1,769	1,997	2,040	2,275	2,093	1,963	1,838	1,714	1,768
624	1,482	1,778	2,044	2,206	2,306	2,579	2,641	2,624	2,501	2,293	2,302	2,102	2,238
625	1,050	1,190	1,497	1,587	1,702	1,891	1,876	2,039	2,132	1,822	1,847	1,631	1,689
626	666	728	886	997	1,059	1,233	1,294	1,501	1,432	1,232	1,309	895	1,103
627	1,389	1,402	1,670	1,795	1,852	2,420	2,502	2,769	2,579	2,436	2,377	2,146	2,111
628	1,478	1,736	1,976	2,187	2,929	3,906	4,393	4,363	3,737	2,537	2,285	2,098	2,802
629	834	1,063	1,067	1,113	1,179	1,311	1,340	1,450	1,409	1,373	1,353	1,164	1,221
630	812	908	1,036	1,050	1,128	1,274	1,413	1,529	1,430	1,260	1,171	1,109	1,177
631	715	840	977	978	1,074	1,207	1,291	1,513	1,423	1,263	1,147	1,061	1,124
632	2,211	2,192	3,656	3,168	3,476	3,668	3,444	4,214	4,246	3,948	3,996	3,151	3,447
633	329	409	514	453	445	445	508	569	528	512	479	446	470
635	2,544	3,244	3,731	3,742	3,985	4,133	4,140	4,416	4,594	4,767	4,142	2,001	3,787
636	637	671	810	843	883	912	1,053	1,061	1,043	970	1,030	889	900

normal variations encountered for the more unstable months. Such eccentricities as are found are due principally to the effect of holi-

Figure 9 contains the coefficients of variation and the means for the weekday traffic for the same months considered in Figure 8. Here, the

TABLE 3

STANDARD DEVIATION OF THE 24-HR. WEEK DAY TRAFFIC AT EACH OF THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH. 1949

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
601	520.8	454.8	370.7	407.9	383.2	411.4	333.5	425.7	347.1	368.5	564.6	424.6
604	570.3	360.9	218.1	314.6	453.8	200.6	266.1	305.9	241.8	228.9	538.1	307.5
605	201.6	198.1	98.9	153.6	104.2	228.5	135.8	98.7	147.8	122.3	207.6	131.2
607	106 2	81.0	46 4	81.2	85.8	89.5	127.8	111.6	133.1	129.3	119.4	67.1
614	439.0	400 9	459.1	292.9	389.6	288.2	189.3	405.2	428.6	470.3	581.0	242.5
615	296 0	339.5	172.4	191.4	92.4	144.7	178.7	164 8	144.4	188.6	206.5	240.6
616	357.6	254.3	135.2	285.7	190.5	218.4	303.4	186.1	312.5	379.3	177.8	211.5
617	143.0	294.1	138 0	110.7	233.6	105.7	170.1	—	172.0	120.1	250.4	206.8
618	510.5	195.4	177 4	212.5	222.2	151.4	239.9	177.6	229.9	231.1	253.7	177.1
619	186 1	148 0	103.3	97.4	81.8	66.5	103.8	108 9	137.1	127.3	98.6	252.1
620	268 8	177.7	137.2	182.0	45 1	163.0	195 4	131.1	519 6	182.0	114.8	220.3
621	211.2	82.6	147.7	170.5	137.1	139.7	183 6	118.3	163.8	160.3	170.6	127.9
622	204.5	106.4	103.2	131.8	131.6	158.7	198.8	117.1	95.9	112.3	110.7	130.4
623	336 6	214 4	114.1	162 0	198.5	110.7	125.5	118.3	112 5	145.3	152.6	119.9
624	457 2	276.4	203.9	342 7	183.3	199.2	241.1	116.9	124.3	141.8	223.9	171.0
625	292.3	154.2	162.2	161.9	175.3	126.2	127.6	194 5	305.0	121 0	237.9	222.9
626	126.8	65.6	77.8	97.9	116.4	32.9	101.8	101.3	140.7	123.8	525.5	139.3
627	419.6	177.4	192.1	153.6	201.2	219.9	212.9	161.6	367.9	574.8	291.6	228.8
628	330.7	160 0	101.4	67.9	415 9	380.8	491.8	286.2	1100.9	188.0	125.9	257.4
629	191.2	234 3	87.6	89 6	134 5	89.2	139.6	103.1	114.3	120.1	131.1	118.7
630	203 5	120 7	66.4	72 8	121.9	96.4	77.8	120.8	722.5	86.9	116.1	101.7
631	229.0	130.8	81.0	193.3	112 8	117.3	152.8	186 7	194.6	190.6	163.7	131.7
632	576.2	401.1	640.5	367.7	344.0	314.8	354.3	299 7	390.6	342.6	406.4	584.4
633	120.1	53.1	68.2	52.6	55.4	53.8	84.3	169.0	271.9	84.6	63.0	42.7
635	503.2	289.6	286 2	401.3	298 5	304.6	330.3	428.0	339.4	494.6	279.2	247.2
636	117.1	91.3	122.9	70 7	83 5	77.4	109.0	94.4	99.2	68.8	74.3	107.4

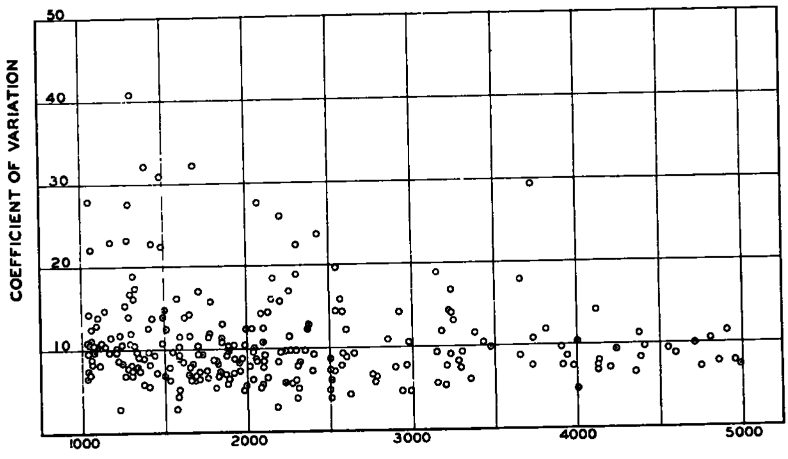

Figure 6. Relation between Coefficient of Variation and Average Weekday Traffic

coefficient of variation is, as predicted from the data in Figure 8, practically constant for all volumes of traffic. This signifies relatively stable values for volume of traffic in each of the months included in the sample.

Figure 10 contains the average coefficients of variation for all recorders for each of the hours for the weekday of each month for the entire year. These statistics indicate the hours of the weekday having the least variation in values from their respective averages for the year. Examination of this figure shows that the hours 7 to 8 and 8 to 10 in the morning

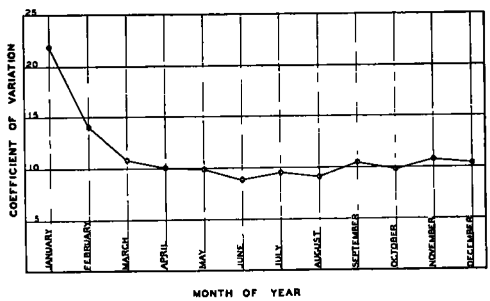

Figure 7. Seasonal Variation in Coefficient of Variation

have a considerable variation in all months of the year. The same is true for the hours before 7 in the morning and after 6 in the afternoon. Data for these hours has been omitted for the sake of simplicity in presentation. The coefficients of variation for the hours for which data are shown are closely grouped for each month with the lowest values occurring during the months of May to October, incl. These data indicate the hours for which a single count may be expected to have the least departure from the average for that hour for

TABLE 4
COEFFICENT OF VARIATION OF THE 24-HR. WEEK DAY TRAFFIC AT EACH OF THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH 1949

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
601	15.99	11.86	8.43	8 83	7.73	7.47	7.01	8.09	6.61	7.57	11.44	9.32
604	27.46	14.20	7.50	10 59	13.98	5.98	8.07	9.26	7.34	7.70	16.60	10.76
605	22.75	22.18	9.28	13.93	8.55	17.09	10.52	7.48	9.34	9.00	13.93	10.50
607	22.03	15.11	7.24	12.25	11.23	9.85	13.42	10.71	14.17	14.98	15.09	9.97
614	18.84	15.62	14.23	9.30	11.53	7.37	4.72	8.01	8.10	9 98	14.09	7.54
615	14.14	15.72	7.18	8.21	4.01	4.84	5.66	5.14	4.91	6.84	8.04	3.85
616	27.53	16.15	7.34	16.77	10.08	9.80	12.80	7.44	12.04	16.73	8.66	11.33
617	11.54	23.08	8.44	6.42	14.09	5.60	8.98	—	8.74	6.35	12.34	11.70
618	30.21	10.35	8.58	9.67	9.85	6.04	9.24	6.39	8.85	9.78	11.26	8.39
619	18.63	14.12	7.70	7.19	5.92	4.20	6.22	6.48	8.13	7.67	6.41	18.66
620	22.86	12.80	8.55	11.50	2.85	8.31	9.26	5.84	22.52	9.68	6.51	14.70
621	15.95	5.20	9.53	8.81	7.13	6.57	8.38	5.10	7.73	7.90	8.63	7.31
622	25.44	9.86	8.27	9.80	9.13	8.74	10.32	5.56	5.28	6.66	7.32	9.43
623	39.14	16.51	6.89	9.44	11.22	5.54	6.15	5.20	5.38	7.40	8.30	7.00
624	30.85	15.55	9.98	15.53	7.95	7.72	9.13	4.46	4.97	6.18	9.73	8.14
625	27.84	12.96	10.84	10.20	10.30	6.67	6.80	9.54	14.31	6.64	12.88	13.67
626	19.04	9.01	8.78	9.82	10.99	2.67	7.87	6.75	9.83	10.05	40.15	15.56
627	30.21	12.65	11.50	8.56	10.86	9.09	8.51	5.84	14.27	23.60	12.27	10.66
628	22.37	9.22	5.13	3.10	14.20	9.75	11.20	6.56	29.46	7.41	5.51	12.27
629	22.93	22.04	8.21	8.05	11.41	6.80	10.42	7.11	8.11	8.75	9.69	10.20
630	25.06	13.29	6.41	6.93	10.81	7.57	5.51	7.90	22.53	6.90	9.91	9.17
631	32.03	15 57	8.29	19.76	10.50	9.72	11.84	12.34	13.68	15.09	14.27	12.41
632	26.06	18.30	17.52	11.61	9.90	8.58	10.29	7.11	9.20	8.68	10.17	18.55
633	36.50	12.98	13.27	11.61	12.45	12.09	16.59	29.70	14.20	16.52	13.15	9.57
635	19.78	8.93	7.67	10.72	7.49	7.37	7.98	9.69	7.39	10.38	6.74	12.35
636	18.38	13.61	15.17	8.39	9.46	8.49	10.35	8.90	9.51	7.09	7.21	12.08

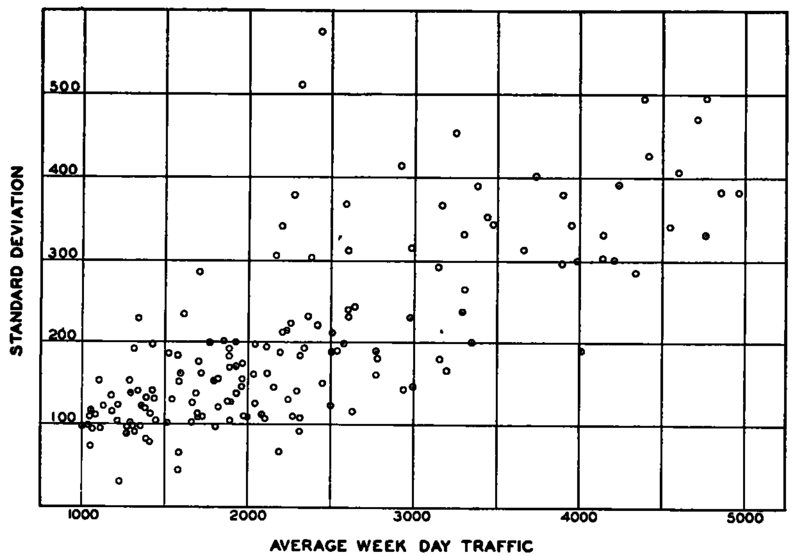

Figure 8. Relation between Standard Deviation and Average Weekday Traffic, April to October, incl.

each month during the year. The afternoon hours are slightly more constant than the morning hours.

to any grouping of the hours between 9 and 6. This fact permits the selection of the portion of the day for the most accurate results from

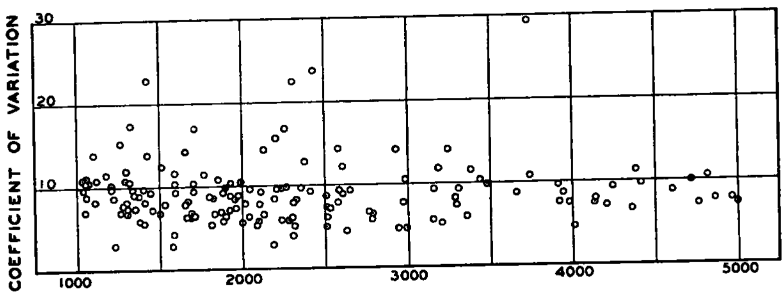

Figure 9. Relation between Coefficient of Variation and Average Weekday Traffic, April to October, incl.

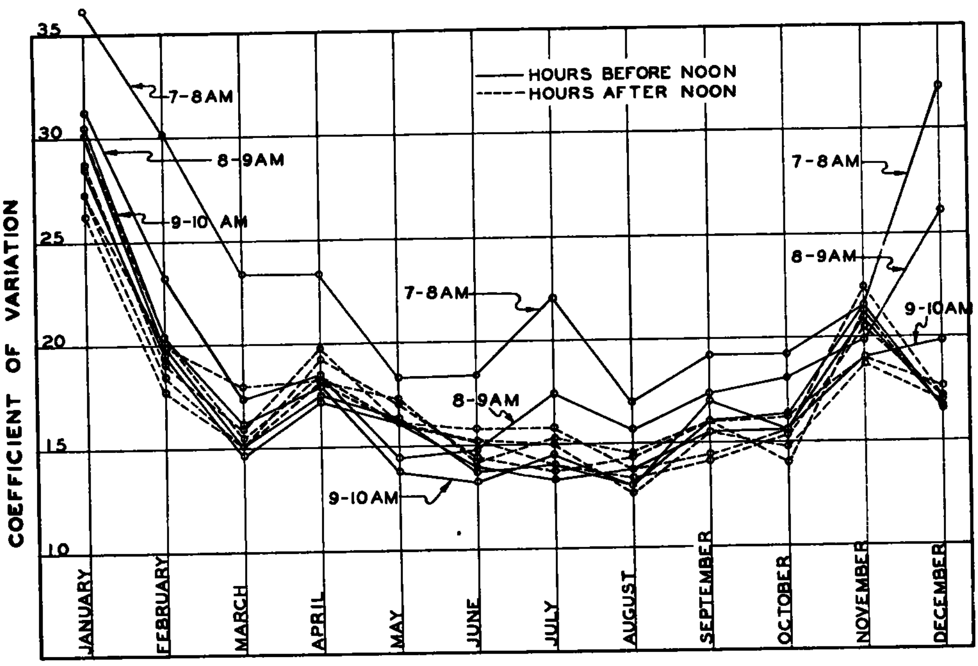

Figure 10. Seasonal Variation in Coefficient of Variation for Different Hours of the Weekday

These statistics indicate that traffic counts made between 9 in the morning and 6 in the afternoon may be expected to give more reliable results than those including any of the other hours of the day. This statement applies short counts, and permits the design of a more convenient counting schedule for such counts than has been used generally. In these short count operations, counting is usually continuous through a given period, say eight hours, of the day. From the data in Figure 10, it is apparent that a schedule involving count- to 4 P.M. at that point, as is generally done. Such a schedule would be more confortable

TABLE 5

AVERAGE HOURLY COEFFICIENT OF VARIATION OF THE WEEK DAY TRAFFIC AT THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH FOR EACH OF THE HOURS FROM 7 A.M. TO 7 P.M., AND FOR THE 24-HR. TOTAL

Hour Period	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
7- 8 A.M.	37.37	30 24	23.35	23.32	18.30	18.14	22.09	17.00	19.28	19.16	21.63	32.02
8- 9 A.M.	31.32	23.31	17.43	18.62	14.47	14.72	17.41	15.72	17.34	18.00	19.89	26.03
9-10 A.M.	30 53	20.31	16.04	18.10	14.84	13.25	14.63	12.97	17.05	15.54	19.12	19.74
10-11 A.M.	30.10	20.07	15.06	17.52	16.35	13.77	14.04	13.00	15.94	16.33	21.57	16.67
11-12 A.M.	28 46	19.68	14 74	17.27	16.18	13.96	13.32	13.77	15.66	15.47	20.97	16.59
12- 1 P.M.	27.28	19.94	17.98	18.42	17.35	14.29	15.30	14.67	15.98	16.27	19.15	17.59
1- 2 P.M.	27.22	18.65	15.19	19.30	17.06	14.62	13.70	14.38	16.12	14.00	21.25	16.73
2- 3 P.M.	26.38	17.52	15.17	18.26	16.16	15.23	14.06	13.36	14.25	15.57	22.47	17.17
3- 4 P M	28.79	19.15	15.96	19.72	16.05	15.80	15.86	13.70	14.50	15.31	20.57	17.23
4- 5 P.M.	30.13	20.47	15.65	18.66	15.96	15.18	15.14	13.72	15.63	14.75	18.76	17.02
5- 6 P.M.	32.79	23.03	17.93	18.64	17.15	16.10	15.91	14.37	16.86	15.65	18.81	18.40
6- 7 P.M.	37.70	27.02	22.29	21.92	18.72	17.77	21.14	15.82	21.63	23.42	23.26	22.76
24-hr. Total ..	23.98	14.11	11.74	10.27	9.75	7.84	9.12	8.26	11.02	9.83	11.55	10.97

TABLE 6

AVERAGE HOURLY STANDARD DEVIATION OF THE HOURLY PERCENTAGE OF THE 24-HR. WEEK DAY TRAFFIC AT THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH FOR EACH OF THE HOURS FROM 7 A.M. TO 7 P.M.

Hour	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
7-8 A.M.	1.13	0.97	0.87	1.10	0.90	0.83	0.99	0.83	0.89	1.33	1.14	0.84
8-9 A.M.	1.55	1.23	1.05	1.78	0.96	0.82	1.02	0.88	1.02	0.92	1.37	1.02
9-10 A.M.	1.59	1.32	1.13	1.19	0.91	0.83	0.97	0.92	1.03	0.93	1.51	0.99
10-11 A.M.	1.78	1.35	1.58	1.12	0.93	0.83	0.90	0.76	0.90	0.93	1.55	0.89
11-12 A.M.	1.74	1.30	1.04	1.05	0.88	0.80	0.82	0.80	0.85	0.84	1.45	0.83
12-1 P.M.	1.52	1.20	1.11	1.00	0.84	0.69	0.82	0.79	0.83	0.83	1.24	0.86
1-2 P.M.	1.88	1.32	1.19	1.07	0.93	0.91	0.95	0.87	0.92	0.84	1.54	0.97
2-3 P.M.	1.80	1.34	1.17	1.04	0.88	0.91	0.96	0.89	0.93	0.86	1.58	0.89
3-4 P.M.	1.98	1.43	1.25	1.16	0.95	0.90	1.00	0.86	0.94	0.89	1.53	0.96
4-5 P.M.	1.99	1.61	1.43	1.17	1.03	0.99	1.04	0.95	1.07	0.99	1.67	1.08
5-6 P.M.	1.95	1.52	1.35	1.11	1.10	1.04	1.06	0.97	1.02	0.94	1.53	0.97
6-7 P.M.	1.61	1 37	1.15	1.09	1.02	0.94	1.07	0.89	1.08	1.05	1.17	0.96

TABLE 7

AVERAGE HOURLY COEFFICIENT OF VARIATION OF THE HOURLY PERCENTAGE OF THE 24-HR. WEEK DAY TRAFFIC AT THE 26 PRIMARY ROAD AUTOMATIC RECORDER STATIONS IN IOWA CLASSIFIED BY MONTH FOR EACH OF THE HOURS FROM 7 A.M. TO 7 P.M.

Hour	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
7-8 A.M.	41.32	32.27	26.73	26.78	22.00	19.91	23.19	19.54	21.89	31.92	28.46	29.62
8-9 A.M.	32.34	25.41	20.30	30.43	17.16	15.40	19.41	16.52	17.93	16.52	24.64	23.48
9-10 A.M.	26.08	22.15	17.97	18.49	14.80	13.56	16.19	14.71	16.51	15.06	23.55	17.51
10-11 A.M.	25.58	19.96	23.98	17.81	15.37	13.55	14.86	12.07	14.19	14.70	23.36	13.48
11-12 A.M.	25.38	19.18	16.35	17.87	15.61	13.63	14.48	13.32	14.37	14.19	23.33	12.94
12-1 P.M.	23.38	19.69	18.69	18.32	16.49	13.18	15.98	15.11	15.26	15.09	22.90	14.18
1-2 P.M.	24.17	18.12	16.56	16.23	14.77	14.57	15.43	14.46	14.94	13.00	23.33	13.47
2-3 P.M.	23.63	18.77	16.47	15.94	13.96	14.48	15.26	14.22	14.32	13.10	23.41	12.21
3-4 P.M.	24.50	19.04	17.19	17.22	14.74	14.33	15.92	13.86	14.37	13.23	21.41	12.25
4-5 P.M.	23.05	18.83	16.80	15.37	14.05	14.51	15.54	13.90	13.93	12.90	20.92	12.43
5-6 P.M.	27.72	20.09	17.76	15.01	15.32	15.07	15.80	14.80	13.53	12.61	20.37	13.63
6-7 P.M.	31.61	24.62	20.95	18.81	17.50	16.45	18.80	16.09	17.80	18.26	22.31	17.91

ing from 9 A.M. to 1 P.M. and from 2 P.M. to 6 P.M. at a given point would give better results than continuous counting from 8 A.M. for the recorder than the schedule generally used, since it would provide for an hour for rest and relief.

CONCLUSIONS

The conclusions drawn from this study of the standard deviations and coefficients of variation of the fixed automatic traffic recorder data are:

1. The extraction of the standard deviation and coefficient of variation of the fixed automatic traffic recorder data makes available knowledge which greatly extends the utilities of these data.

2. The use of these statistics will permit the design of more efficient traffic counting schedules for either short manual counts or short portable recorder operations.

3. The schedules designed with the aid of the knowledge of traffic behavior provided by these statistics will produce more accurate and more reliable estimates for either average annual daily traffic or average annual weekday traffic.

ACKNOWLEDGEMENT

Many people have contributed their ideas and time in the development of the procedure for obtaining the standard deviations and coefficients of variation of the fixed automatic traffic recorder data through the employment of automatic electrical equipment. Credit is due to all of the employees of the highway planning division of the Iowa State Highway Commission who have a part in that endeavor for their cooperation in the development of this procedure. Particular credit should be given to Mr. Carl F. Schach, Assistant Traffic Engineer, who was responsible for the details of the procedure for calculating and tabulating the data, and to Mr. Thomas L. Healy, Statistician, who aided in the adaptation of the statistical calculations for performance in automatic electrical equipment and reviewed the mathematical features of the procedure as a whole. Acknowledgement is also made of the cooperation of the Bureau of Public Roads in encouraging the investigations and in approving them as a part of the several planning survey projects in which they were made.

EFFECTS OF REVERSIBLE LANE MOVEMENT SIGNALIZATION OF THREE LANE HIGHWAYS

M. Mansfield Todd, *Virginia Department of Highways*

SYNOPSIS

There is a 1½-mi. section of 28-ft. width 3-lane State Highway numbered as US Routes 29 and 211 extending westward from the District of Columbia line at the Francis Scott Key Bridge into Arlington County, Virginia. This stretch of highway carried in 1949 in excess of 20,000 vehicles per day, and traffic was expected to be materially increased upon completion by the District of the Whitehurst Freeway on the east side of the river. The highway is intersected by numerous lateral streets serving local residential areas. While there were no really large volumes on any of these intersecting streets, they were sufficiently large to result in considerable accumulated delay to side street traffic, so that the situation was regarded as intolerable by nearly all users of the side streets. There were no funds for additional construction, so it was agreed that the artery must be signalized to apportion some of the side street delay to the artery by giving side street traffic more opportunity for entrance. Since the arterial, directional movements during peak hours were found to be exceptionally unbalanced, it was decided that greatest efficiency would result from a plan of off-center lane, or reversible center lane movement, signalization. Accordingly, 11 intersections were signalized and controlled by master equipment to provide two inbound lanes during morning peak, two outbound lanes during afternoon peak, and two-way center lane use between unbalanced flows.

A comprehensive study of lane use, travel time, capacity, over-all volumes, parallel route use, and delay was made three months before signals were installed. A similar follow-up study was made nine months after signals began operation.