Volume and Speed Characteristics at Seven Study Locations

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This paper reports on those portions of the research project, "Fundamental Characteristics of Traffic Flow," which pertain to volume and speed characteristics on major urban arterials.

Seven study locations in the vicinity of two Michigan cities, Detroit and Lansing, were representative of a wide variety of urban arterials, ranging from a controlled-access expressway to a surface arterial with heavy parking along commercially developed frontage.

At each of the study locations at least one continuous week of data was successfully collected. This involved: (a) detecting traffic volume, speed, and headway information for each individual lane of the direction being studied; (b) transmitting this information from the detection units to a central office; whereupon (c) the information was summarized on graphical and digital recorders. Various analyses were then performed on the data by manual and mechanical means.

The most important findings with regard to traffic volume were the similarities in certain volume characteristics which were found to exist between the seven arterials studied. Ratios, in percentage form, of shorter peak period volumes to longer peak period volumes were computed, and comparisons between routes revealed surprising similarities. Similarities in the cumulative distribution curves of daily minute traffic volumes permitted devising a method for estimating percentile minute volumes for any of the seven routes.

The distribution of minute volumes, by lane, as related to total minute volume was investigated, and the equation for average minute volume in the middle lane as a function of the total minute volume for three lanes in one direction was formulated. Computations were made of approximate confidence intervals for this relationship.

The variation of 15-min average lane speeds, by time of day, and the distribution of 1-min average lane speeds for the seven study locations were determined, and pertinent observations and comparisons were made. By combining lanes on the facilities and plotting the variation of 15-min average speeds, it was found that during the period from 11 a.m. to 3 p.m. the deviations of individual 15-min average speeds from 24-hr average speed were extremely small — smaller, in fact, than the normal accuracy of the speed detection instruments.

● THE MAJOR OBJECTIVE of the research project was to investigate the fundamental characteristics of traffic flow (volume, speed, density, and headway) and the interrelationships of these characieristics on major urban highways. The design of the experiment permitted a secondary objective, that of relating roadway features, as defined by varying degrees of medial and marginal friction, to the fundamental characteristics of traffic flow.

The design of experiment was based on the four friction concept (5, 6) which, in essence, classifies road and traffic characteristics which resist traffic flow into four types of friction — internal, medial, marginal, and intersectional. Internal friction, defined as that friction which exists between vehicles traveling in the same direction, was present in varying degrees at each of the seven study locations as a result of heavy traffic volumes. Intersectional friction, that friction which exists between vehicles traveling at right angles to one another, was eliminated by selecting study locations away from the influence of intersectional movement. The experiment was designed (Table 1) to include the study of arterials with various degrees of medial friction (occurring between vehicles traveling in opposite directions) and marginal friction (existing along the margin of the road).

TABLE 1

Medial Friction Marginal Friction	None (Wide Median)	Moderate (Narrow Median)	Heavy (No Median)
None (access control)	1	2	3
Moderate (no parking)	4	5	6
Heavy (parking)	7	8	9

Each combination of medial and marginal friction was defined as a "cell", and the cells were assigned numbers one through nine (Table 1). It was originally planned to study nine locations, one for each cell. Locations which fit the definitions of cells one through seven were selected; however, no locations for cells eight and nine could be found which were free from the influence of intersectional friction.

At each study location, a radar speed detector and volume detector were installed for each lane to detect the speed of each vehicle, the time headway between each pair of vehicles, and the volume of traffic for any period of time. In all cases, only one direction of traffic was studied.

The measured traffic characteristics were transmitted to a 17-ft trailer which housed the recording equipment. The volume impulses were channeled to a 20-pen recorder which had four pens operating — one for each lane and a fourth pen with manual control for daily volume checks. The chart speed of the recorder was 6 in. per minute, which permitted measuring time headways directly from the chart to the nearest ¼ sec. The speed impulses were routed to graphical speed recorders, one for each lane, which were operating at 1½ in. per minute. The trailer was located in a position that permitted the person in the trailer to observe the traffic characteristics that were being measured and recorded.

A check of the accuracy of the volume and speed detection equipment was made each morning and afternoon, for each lane, while the station was in operation. The volume check was made by counting vehicles using the manually actuated pen of the 20-pen recorder. The speed checks were made by timing, with a stop watch, vehicles passing through a measured speed trap. These checks indicated that the minute volumes were normally accurate to within ± 0.7 percent and the minute average speeds were normally accurate to within ± 1.5 mph.

VOLUME CHARACTERISTICS

This section presents the results of analyses pertaining to traffic volume characteristics. Not only the characteristics on each of the seven types of facilities are evaluated, but also the similarity and differences in volume characteristics between the various types are discussed.

Comparison of Various Peak Period Traffic Volumes

For each of the seven facilities, the peak 1-min, 5-min, 15-min, and 1-hr periods were determined. The volume during these periods is given in Table 2. The periods indicated are consecutive but do not necessarily start and end on an hour or on an even 5 min. For example, the values given in the 15-min col. are representative of traffic volume during that consecutive 15-min period during which more vehicles were passed than during any other consecutive 15-min periods during the day.

TABLE 2

PEAK PERIOD TRAFFIC VOLUMES

Marginal Friction	Medial Friction	Cell	Route	Traffic Volume 1 Min	 5 Min	 15 Min	 1 Hr	 6a.m.-6p.m.	 6p.m.-6a.m.	 Tot. 24-Hr Vol
None	None	1	Ford Exp.	115	496	1,424	5,268	37,742	11,989	49,731
	Mod	2	Davison Exp.	63	283	775	2,763	18,812	7,887	26,699
	Heavy	3	Schaeffer Road	58	159	351	1,186	10,242	4,218	14,460
Moderate	None	4	Mich. Ave., E. Lansing	27	110	322	1,053	7,160	3,035	10,195
	Mod	5	Mich. Ave., Dearborn	53	237	603	2,172	14,075	4,688	18,763
	Heavy	6	Grand River, E. Lansing	39	157	437	1,423	7,008	3,150	10,158
Heavy	None	7	James Couzens Highway	84	334	878	3,360	21,059	10,014	31,073

Table 2 also gives the daytime (6 a.m. to 6 p.m.), nighttime (6 p.m.-6 a.m.), and total 24-hr volumes. Notice the wide range of 24-hr volumes — from nearly 50,000 vehicles on the Ford Expressway (cell 1) to approximately 10,000 vehicles on the two routes in East Lansing (cells 4 and 6). It is also interesting that cell 7, the James Couzens Highway, which had heavy marginal friction in the form of parking, carried more traffic during the periods shown than did the Davison Expressway.

To determine if patterns exist in the ratios of the volumes between any of the time periods, these ratios, in the percentage form, were computed and are given in Table 3. Shown are the percentages that volumes during the peak periods listed across the top of the table are of the volumes during the peak periods listed along the left side of the table. For example, on the Ford Expressway the peak 1-min volume (115) is 23.2 percent of the peak 5-min volume. For each of the comparisons an average percentage for all seven cells was computed. It can be seen that there does not seem to be large variation of the peak volume ratios between routes, and usually the percentage for any given cell differs very little from the average for all cells. This is of greater significance considering the numerical differences in 24-hr volumes, the wide variety of geometric design features, and the considerable difference in size and character of the areas from which traffic is attracted to the various routes. Another important factor is that two of the routes studied were in East Lansing whereas the remainder were in the Detroit area.

The ratio of 1-min volumes to 5-min volumes, and of 1- and 5-min volumes to 15-min volumes for Schaeffer Road traffic, is much larger than for the six other routes studied. A detailed review of the minute volumes indicates that the maximum minute volume (58 vehicles) is extremely greater than the second highest minute volume of 41

TABLE 3

COMPARISON OF PEAK TRAFFIC VOLUMES

	Cell No.	Study Location	1 Min.	5 Min.	15 Min.	1 Hr	6 a.m. to 6 p.m.	6 p.m. to 6 a.m.
5 Min.	1	Ford	23.2%*					
	2	Davison	22.3					
	3	Schaeffer	36.5					
	4	Mich. Ave., E. Lansing	24.5					
	5	Mich. Ave., Dearborn	22.4					
	6	Grand River, E. Lansing	24.8					
	7	James Couzens	25.1					
		Average	25.5					
15 Min.	1	Ford	8.1	34.8%				
	2	Davison	8.1	36.5				
	3	Schaeffer	16.5	45.3				
	4	Mich. Ave., E. Lansing	8.4	34.2				
	5	Mich. Ave., Dearborn	8.8	39.3				
	6	Grand River, E. Lansing	8.9	35.9				
	7	James Couzens	9.6	38.0				
		Average	9.8	37.7				
1 Hr	1	Ford	2.2	9.4	27.0%			
	2	Davison	2.3	10.2	28.0			
	3	Schaeffer	4.9	13.4	29.6			
	4	Mich. Ave., E. Lansing	2.6	10.4	30.6			
	5	Mich. Ave., Dearborn	2.4	10.9	27.8			
	6	Grand River, E. Lansing	2.7	11.0	30.7			
	7	James Couzens	2.5	9.9	26.1			
		Average	2.8	10.7	28.5			
24 Hr	1	Ford	0.23	1.0	2.4	10.6%	75.9%	24.1%
	2	Davison	0.24	1.1	2.4	10.4	70.5	29.5
	3	Schaeffer	0.40	1.1	2.4	8.2	70.8	29.2
	4	Mich. Ave., E. Lansing	0.26	1.1	3.2	10.3	70.2	29.8
	5	Mich. Ave., Dearborn	0.28	1.3	3.2	11.6	75.0	25.0
	6	Grand River, E. Lansing	0.38	1.5	4.3	14.0	69.0	31.0
	7	James Couzens	0.27	1.1	2.8	10.8	67.8	32.2
		Average	0.29	1.2	2.9	10.8	71.3	28.7

*Example: On the Ford Expressway the peak 1-min volume (115) is 23.2 percent of the peak 5-min volume (496).

vehicles. On the other hand the peak 5-min volume is relatively small because it includes minute volumes as low as 12 and 13 vehicles per minute. The net result is a high 1-min to 5-min volume ratio and 1-min to 15-min volume ratio. The proximity of the Ford Motor River Rouge plant may be partially the reason for the abnormal 1-min and 5-min peak volume periods.

Although not absolutely true in all cases, it may be generally observed that the higher volume routes (cells 1, 2, and 7) are characterized by lower percentages in the table. This indicates that on the higher volume routes the demand is spread out over longer periods — that is, the peak periods are less accentuated than on the lower volume routes. It is felt, however, that the importance of this presentation lies in the close agreement of the percentages rather than in the explanation of the relatively minor differences.

The practical use of these results is for estimating any of the peak period volumes. By entering the table with any of the listed peak period traffic volumes, any other peak period volume may be estimated.

Hourly Variations of Traffic Volume

To obtain a pictorial view of the variations of traffic volume during the day in each of the cells, and to compare the cells with each other, a plot was made of hourly volume — as a percentage of 24-hr volume (one direction) — versus time of day. This plot is shown in Figure 1. The hourly variation for each of the seven cells is shown by a different type of line as indicated by the key. Before discussing the variations, it should once again be noted that traffic in one direction only was observed. Consequently, it can be seen that some of the facilities depicted have peak periods during the morning, while others have their peaks during the afternoon. Regardless of this fact, there is recognizable similarity in the traffic volume variations from cell to cell. The cell which seems to deviate farthest from the general pattern is cell 4 (Michigan Avenue, East Lansing). The hourly volumes during early afternoon on this facility are a considerably higher percentage of 24-hr volume than on the other facilities. Notice, also, the sharp evening peak for cell 4 reaching a maximum of 7.0 percent of the 24-hr volume between 9 and 10 p.m. Much of the traffic contributing to this peak originated from a nearby shopping center which remained open until 9 p.m.

It can be generally observed in the figure that those routes with comparatively high peaks in the morning had comparatively low peaks during the afternoon and vice versa. There is nothing startling about this, but the results do follow an expected pattern.

One result which was being sought from this analysis was to determine whether some period during the day was particularly well suited as a volume estimating period. In other words, it would be desirable to select a period when the percentage of the hour

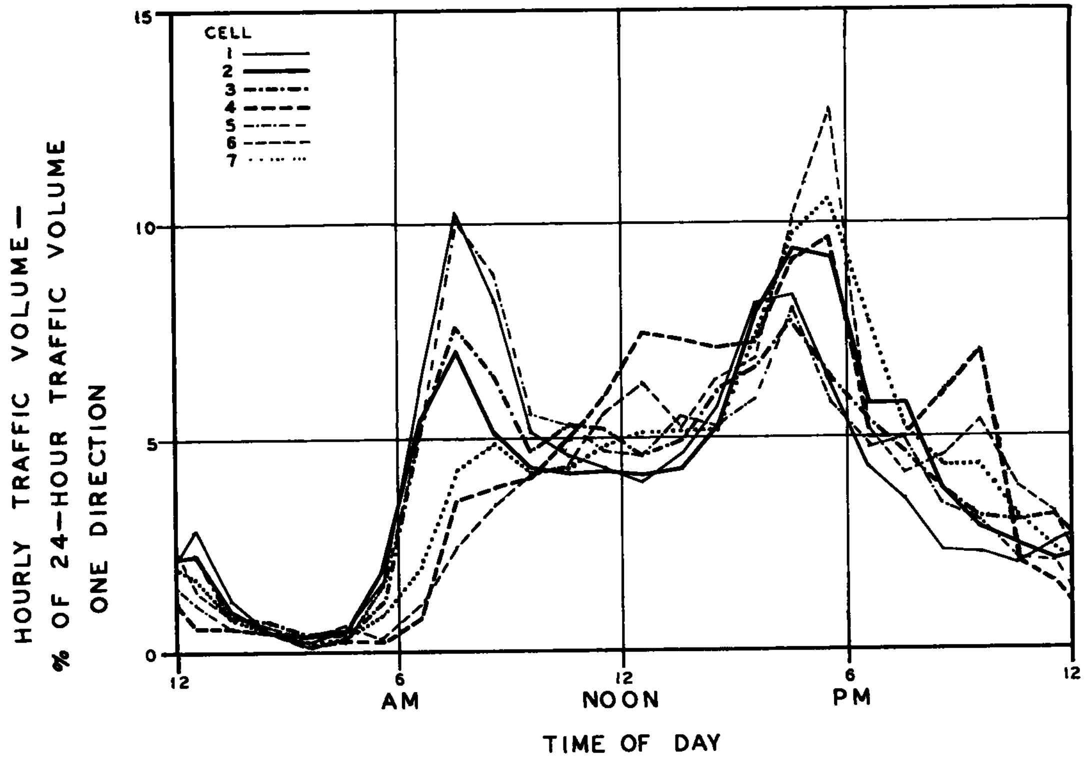

Figure 1. Hourly traffic volume fluctuations.

volume to the 24-hr volume was relatively uniform for all the cells studied. By inspecting Figure 1 it seems that the most uniform period is from 10 to 11 a.m. For this hour the range of values for the seven cells is from 4.2 to 5.3 percent of 24-hr volume, and the average value is 4.73 percent. If, then, it is desired to make an hour directional volume count and to estimate the 24-hr directional volume, the data indicate that the best period for the short count would be from 10 to 11 a.m. For the data presented, an estimate based on the 10 to 11 a.m. volume will yield a smaller range of percent differences from the actual 24-hr volume than will estimates based on any other 1-hr period.

The figure also reveals that the peak hour expressed as a percentage of the 24-hr volume for the seven cells was 10.3, 9.3, 7.8, 9.6, 10.2, 12.7, and 10.7 percent. The hour volumes selected in computing the percentages began on the hour and consequently are slightly lower than similar percentages given in Table 3.

Distribution of Daily Minute Traffic Volume

Traffic volume for each minute of the selected 24-hr period was measured; therefore, it was possible to determine the distribution of the minute volumes for each cell. Because volume is more commonly expressed in terms of 24 hours rather than as minute volumes, it was felt desirable, in this case, to do so.

The procedure used was to plot 24-hr percentile minute volume versus the percent that these minute volumes were of the 24-hr volume. Two such graphs are shown in Figure 2 — the upper graph indicating the accumulative minute volume distribution for each of the cells, and the lower graph with an "average" curve representing the distribution of minute volume for all seven cells. It is of significant value to note the high degree of similarity between the cells, and it was for this reason that the average distribution was plotted.

The legend of Figure 2, "Method of Estimating Various Percentile Minute Volumes," implies the usefulness of the relationship. That is, by entering the lower graph with any desired percentile minute volume, the percent that volume is of the 24-hr volume can be determined. As an example, consider a study of traffic flow on an urban arterial highway where the 24-hr traffic volume was determined to be 20,000 vehicles. Suppose it is desired to determine the value of the 24-hr, 90-percentile minute volume (that volume which is exceeded by 10 percent of the minutes during the day and is greater than the remaining 90 percent of the minutes). Entering the graph with 90-percentile minute volume enables determination that it is 0.135 percent of the 24-hr volume. Hence, the 90-percentile minute volume equals 0.00135 x 20,000, or 27 vehicles per minute. When the percent that a certain minute is of 24-hr volume is known, the percentile rank of that minute volume can be determined from the graph.

A number of interesting observations concerning the differences in the accumulated distributions of minute volume can be made from the upper graph in Figure 2. In the middle percentile range the seven distribution curves form a very narrow band. However, the curves spread out considerably in the lower and higher percentile ranges. There does seem to be a pattern in the way in which the curves spread out. First, remember that the two lowest volume routes were cells 4 and 6 (Michigan Avenue and Grand River in East Lansing, respectively), and the three highest routes were cells 1, 2, and 7 (Ford, Davison, and James Couzens). Then note that in the low percentile ranges the curves for cells 4 and 6 are lowest; and, in the upper percentile ranges, the cells 1, 2, and 7 curves are among the lowest four. This indicates that the low 24-hr volume routes have a greater number of minutes whose volumes are a small percentage of 24-hr volume than do the higher 24-hr volume routes. The 95- to 100-percentile minute volumes on the high volume routes are not generally as large a percent of the 24-hr volume as on the lower volume routes. More simply stated, it was generally the case on the routes studied that the lower volume routes had a higher number of low minute volumes and also had relatively larger peak minute volumes. This observation reinforces the statements and observations made earlier. The 100-percentile minute volumes are the same as that indicated in Table 3 relating the peak minute to the 24-hr volume.

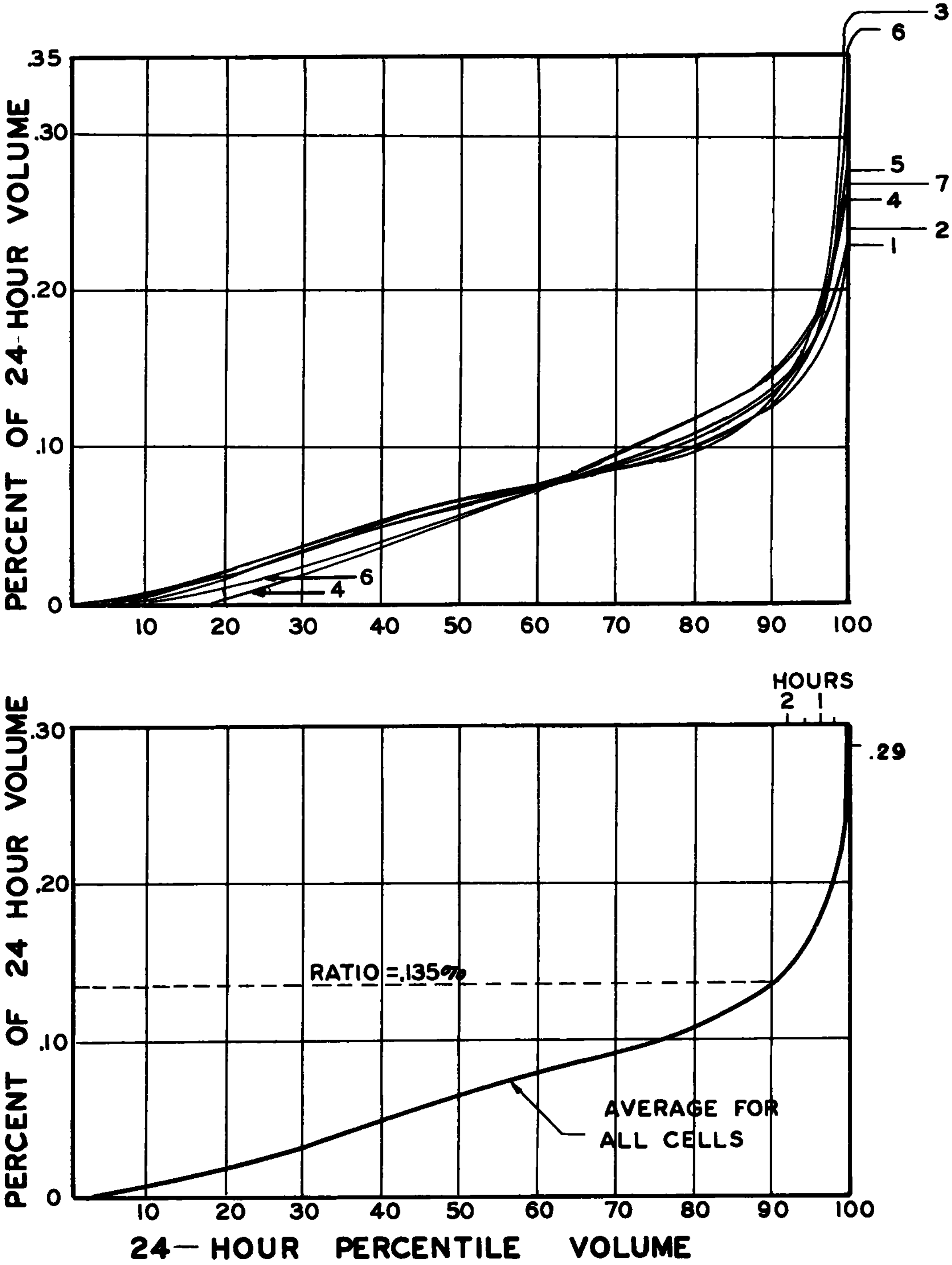

Figure 2. Method of estimating various percentile minute volumes.

An analysis was made to determine where each distribution curve departs from the approximately linear path that it follows in the lower percentile ranges. It is felt that this point demarks what can be considered as the separation between peak minute volumes and non-peak minute volumes. Finding this point on each of the curves then was a matter of determining the point following which an increased rate of change (or slope) occurs. The rate of change is determined on the basis of the ratio of vertical to horizontal rate of growth

$$\left(\frac{\Delta V}{\Delta H}\right)$$

which is the tangent of the angle between the curve segment and the horizontal axis. To determine the point following which a rapid increase in slope is noticeable, attention was also given to the rate of change of this ratio. Based on both of these considerations, the points were found after which a departure from the linear rate of growth occurs, and these are listed, as follows:

Cell	Cumulative Percentage
1 — Ford Expressway	84
2 — Davison Expressway	82
3 — Schaeffer	92
4 — Michigan (East Lansing)	88
5 — Michigan (Dearborn)	89
6 — Grand River (East Lansing)	82
7 — James Couzens	80
Average	85.3

The 85.3 percent indicates that the peak minute volumes extend for about 3 hours and 32 minutes. Again the fair degree of similarity between cells with regard to the location of this point is noticed. This analysis also indicates that, generally speaking, the peak periods last longer on the high volume routes (cells 1, 2, and 7) than on the lower volume routes.

There also seems to be a point higher up on each of the distribution curves where another rapid rate of change of slope occurs and the curves become nearly perpendicular. Using the same technique, the following points were found after which the most rapid rate of change occurs:

Cell	Cumulative Percentage
1 — Ford Expressway	98.9
2 — Davison Expressway	97.6
3 — Schaeffer	99.4
4 — Michigan (East Lansing)	98.9
5 — Michigan (Dearborn)	98.0
6 — Grand River (East Lansing)	98.4
7 — James Couzens	95.6
Average	98.1

The 98.1 percent indicates that this minute volume level is exceeded approximately 27 min per day. These percentiles are analogous to the 30th highest hourly volume in that they have a possible use as design volumes. It is economically unfeasible to design the road so that it will have sufficient capacity during every single minute. It can be seen on the lower graph of Figure 2 that 98 percentile corresponds to a minute volume which is approximately 0.20 percent of 24-hr volume. The 100 percentile minute volume is approximately 0.29 percent of 24-hr volume. Consequently, if the road is to satisfy the requirements of the highest 2 percentile of the 24-hr period (in other words the highest 29 min), it must be designed to carry nearly 50 percent more traffic.

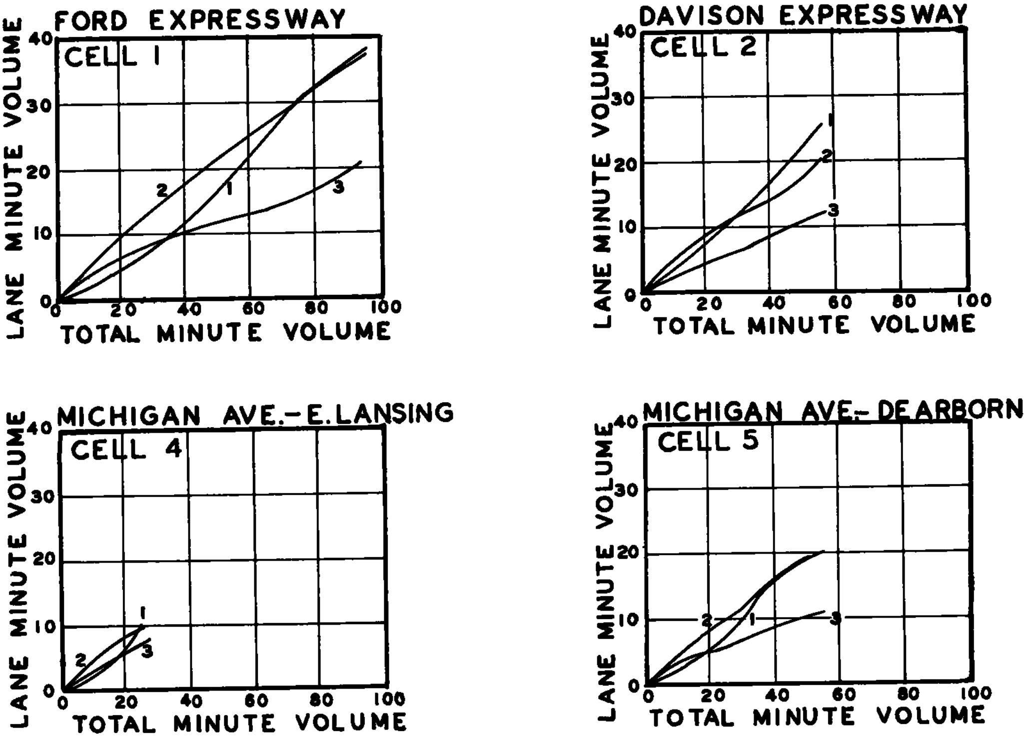

Figure 3. Lane use on test routes.

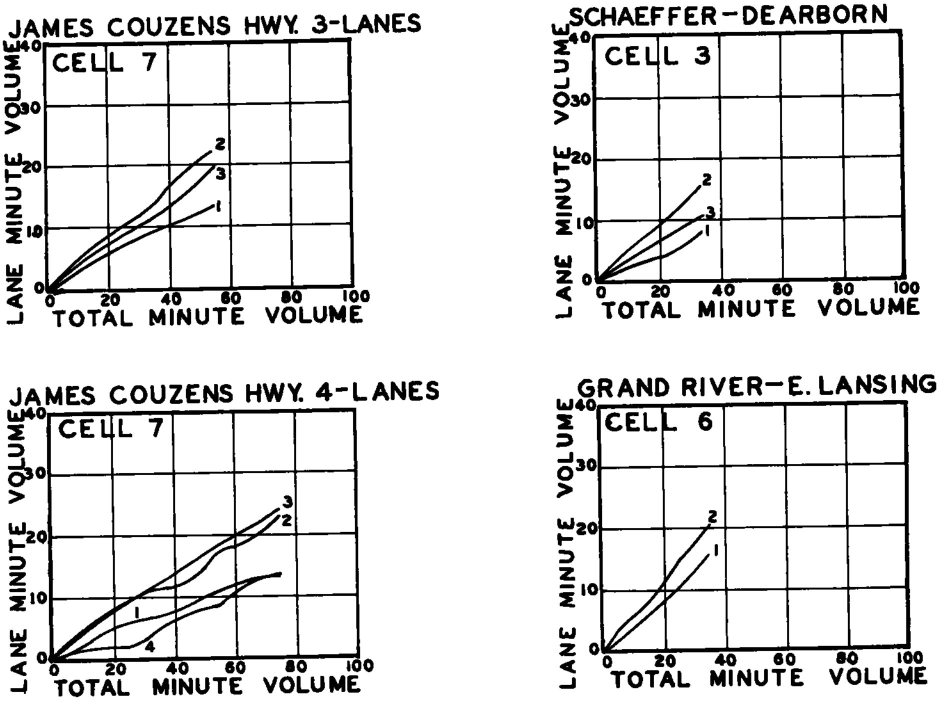

Figure 4. Lane use on test routes.

The Effect of Traffic Volume on Lane Distribution

For an analysis of the relationship between total volume and lane use for each of the cells, the graphs shown in Figures 3 and 4 were constructed. On each of the graphs the vertical scale is lane minute volume, and the horizontal scale is total minute volume. There is one graph for each cell, with the exception of cell 7, the James Couzens Highway, which is depicted in two graphs – one for the normal periods when there are three moving traffic lanes, and one for the period from 4 to 7 p. m. when parking is prohibited and there are four moving traffic lanes. The graphs are constructed in such a way that a point on a curve represents the average minute lane volume for a given total minute volume.

A definite pattern exists between lane use and traffic volume and can be seen from Figures 3 and 4. In each of the seven graphs, beginning with the lowest minute volume and proceeding to the largest minute volume, there is an apparent interplay between the use of the lanes. First, lane 2 (middle lane) carries the greatest lane volume with lane 3 (curb lane) carrying the second highest lane volume. As the minute volume increases, lane 2 continues to carry the highest lane volume, while the use of lane 1 increases faster than lane 3, and in several of the cells lane 1 begins to exceed lane 3. At the highest minute volume ranges the volumes in lane 1 approach or, in several cases, exceed the volume in lane 2 while the volume in lane 3 is approximately only one-half as great as in either lanes 1 or 2.

There are two additional observations that can be made in regard to the general pattern of volume distribution between lanes: (1) For any total minute volume, the average minute volume in lane 3 is never greatest; and (2) for any total minute volume, the average minute volume in lane 2 is never smallest. Another factor which is apparent in Figure 3 is that when total volume is high, lane 3 is carrying a considerably lower volume than either of the other two lanes. In other words, when it is really needed, the lane next to the shoulder is not carrying its share of the load.

To be able to better compare cells with each other, the curves were plotted in a slightly different manner as is shown in Figure 5. Each lane was plotted separately so there are three graphs, and the lane volume curve for the cells is shown on each graph. Cell 6 (Grand River in East Lansing) was omitted in this case because it has only two lanes in the direction studied, whereas all the other cells had three lanes.

Note the very narrow band formed by the cell curves in the lane 2 graph, and also that the slopes of the curves are relatively constant. The lane 3 and particularly lane 1 curves, however, are decidedly more spread out and have more fluctuating slopes. Because of the close agreement of the lane 2 curves, a statistical analysis was performed to determine an average line for all six cells.

The average volume for lane 2 of all six cells under scrutiny, and for total minute volumes varying from 0 to 60, is represented by a nearly straight line. The equation

$$\bar{\bar{V}}_2 = 0.415\, V_t$$

representing a straight line passing through the origin closely approximates the values determined from the collected data. The constant 0.415 implies that 41.5 percent of the total minute volume uses lane 2. In this equation V_t = total minute volume, and $\bar{\bar{V}}_2$ = the mean of the average lane 2-min volumes.

Assuming that the average volumes for the individual facilities represented a random sample from a population of such facilities, and assuming that the variables are normally distributed, 95 percent confidence intervals for the mean were computed for certain levels of the traffic volume. These confidence intervals lie in the range as indicated in the following table:

Range of V_t	Range of 95 Percent Confidence Interval
5 - 25	$\bar{\bar{V}}_2 \pm 0.5$
25 - 45	$\bar{\bar{V}}_2 \pm 1.5$

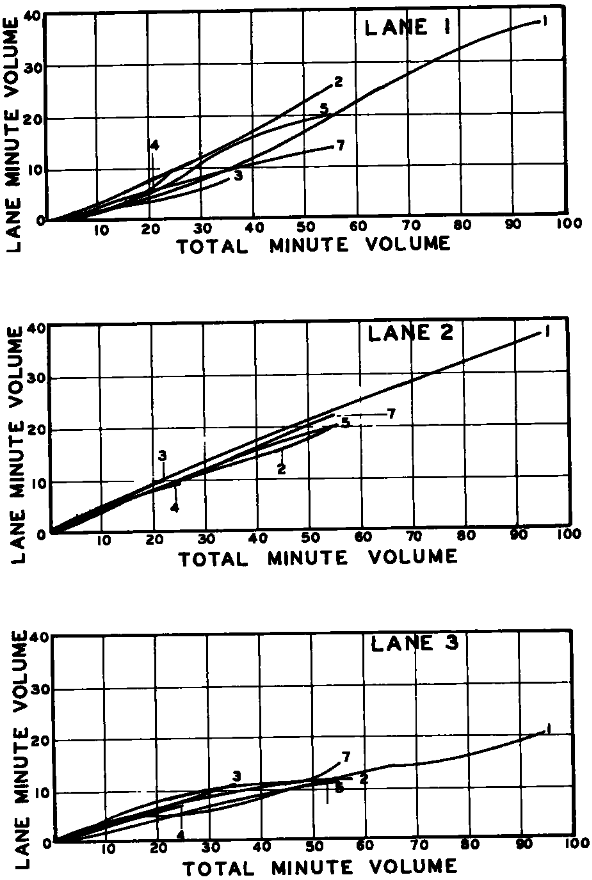

Figure 5. Comparison of lane use by lane.

For V_t's higher than 45 vehicles per minute, the 95 percent confidence interval is considerably wider. For example, when $V_t = 53$, the 95 percent confidence interval on $\bar{V}_2$ is ± 4.19.

For a given lane 2 average minute volume, $\bar{V}_2$, between 1 and 10, a reasonable estimate of the total minute volume, based on the present data, is

$$V_t = \frac{\bar{V}_2}{0.415} \pm 2.$$

For values of $\bar{V}_2$ between 11 and 15 inclusive, the estimated total minute volume is

$$V_t = \frac{\bar{V}_2}{0.415} \pm 3.$$

Beyond a value for $\bar{V}_2$ of 15, the spread is considerably wider.

A few more interesting observations may be made from the lane 3 and lane 1 graphs of Figure 5. It appears that for a total volume of from 0 to 30 vehicles per minute, lane 3 carries on the average of 30.5 percent of the total volume. For a total volume of 30 to 50, lane 3 carries on the average only 23.5 percent of the total volume, and, furthermore, the percentage decreases even more with larger total minute volume. Conversely, inasmuch as the proportion carried by lane 2 remains relatively constant, the percentage of vehicles carried by lane 1 increases with increased total minute volume. Using the aforementioned percentages for lanes 2 and 3, and knowing the total volume, the amount of traffic using lane 1 can be estimated.

SPEED CHARACTERISTICS

This section presents the results pertaining to the speed characteristics on the seven facilities which were studied. First comparisons are made within each individual cell, and then the results of investigations of similarities and differences between cells are discussed.

Variation of Average Speed by Time of Day

For all seven facilities studied, at least 24 consecutive hours of individual vehicle speed detection in each lane were recorded. The individual speeds were averaged for 1- and 15-min intervals. Because of the small number of vehicles during the 1-min intervals, rather large fluctuations occur from minute to minute (particularly during early morning hours), and it was decided not to attempt to plot the minute-to-minute variation in average speed for the 24-hr period, but rather to plot 15-min average speeds.

Figures 6 and 7 include the variation of 15-min average speed, by lane, for each of the seven cells. For four of the cells (1, 2, 4, and 6) the 15-min average speeds for the total 24-hr period were computed and plotted on the graphs shown. Notice the relatively large fluctuations which occur during the early morning hours, mainly a result of the low volumes during these periods. Because the analysis of individual speeds from the graphical recorder tape is so time consuming (5 minutes of analysis for each 1 minute of data per lane), it was necessary to eliminate those analyses which were felt to be relatively unimportant. Consequently, for the remaining cells (3, 5, and 7) only the

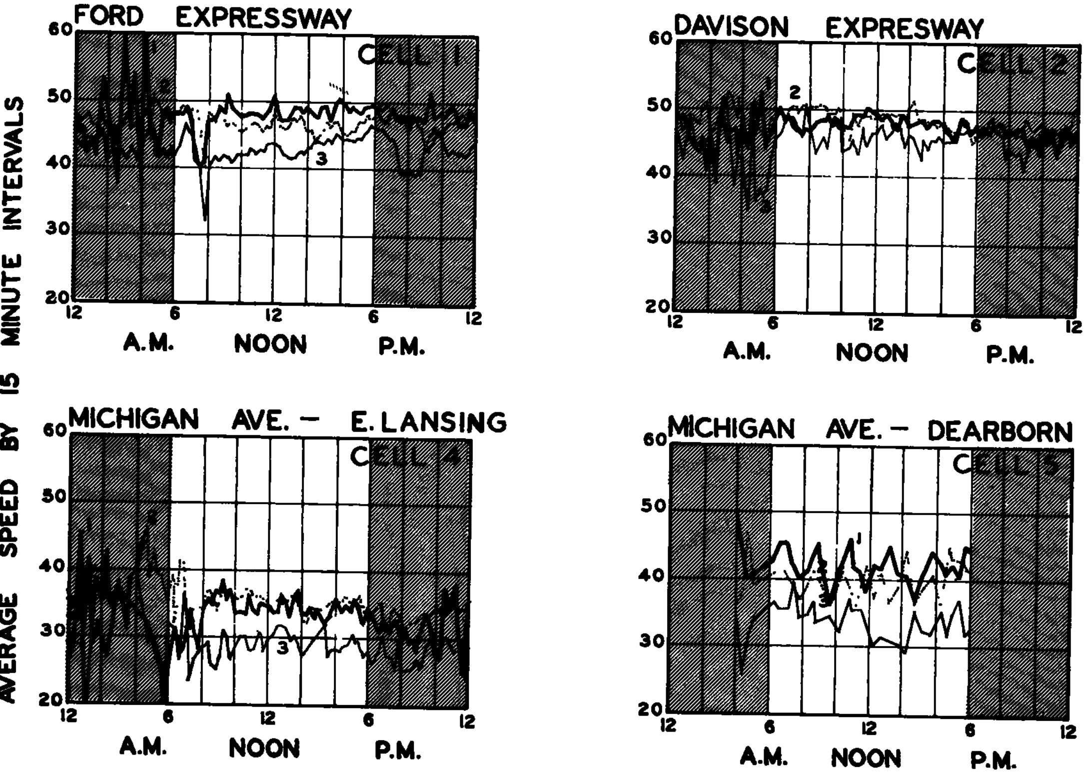

Figure 6. Variation of average lane speed by time of day.

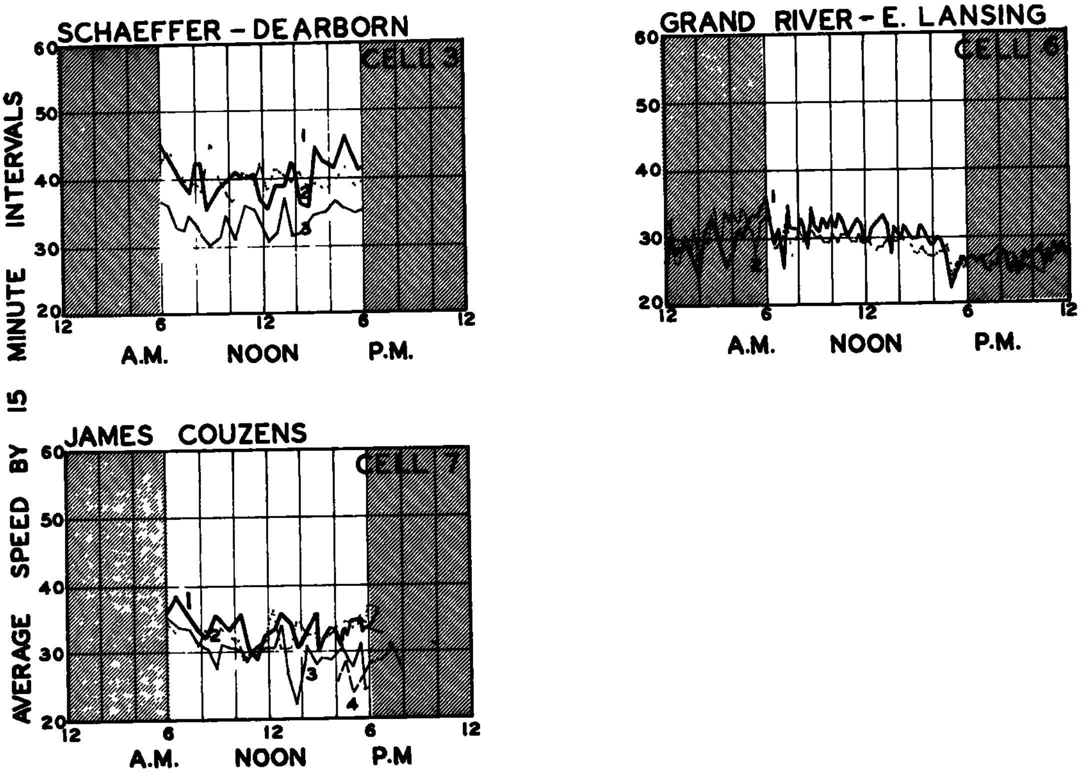

Figure 7. Variation of average lane speed by time of day.

periods from 6 a.m. to 6 p.m. have been analyzed. For these three cells, additional time-saving procedures were employed. First, five 30-min periods were selected, and these were completely analyzed — every individual speed observation being considered. Then, for the remaining 30-min periods, a sampling technique (1-min sample for each 30-min period) was used to compute estimates of average speed. If the average speeds computed from the 1-min samples were 5 percent greater or less than the composite average obtained from the five 30-min samples, a second 1-min sample was taken and considered in computing the average speed.

More careful scrutiny of each of the graphs allows a number of observations to be made. Notice, for example, the magnitude of the fluctuations in 15-min average speed for the daytime period (6 a.m. to 6 p.m.). Particularly in cells 1, 2, 4, and 6 these fluctuations are very small for all lanes of the facilities. Note in cell 1 (Ford Expressway) the one large drop in average speed between 7 and 8 a.m., which, unlike the very early morning fluctuations, is caused by an excessive volume. For cells 3, 5, and 7 the average speeds plotted have slightly greater fluctuations from period to period. This was expected, however, because of the sampling procedure which was used to analyze the data.

Another interesting observation which can be made is a comparison of the average speeds between lanes for a given cell. Notice, for all cells, that lane 3 is characterized by lowest average speed, and lane 1 is generally characterized by highest average speed. The mean average lane speed for the total period analyzed was computed for each cell, and it was found that: (a) in all cases, without exception, lane 3 had the lowest mean average speed; and (b) in nearly all cases (excluding cells 2 and 4) lane 1 had the highest mean average speed.

To better compare the magnitude and variability of 15-min average lane speed between cells, three graphs were plotted (Fig. 8), one for each lane. On each graph all

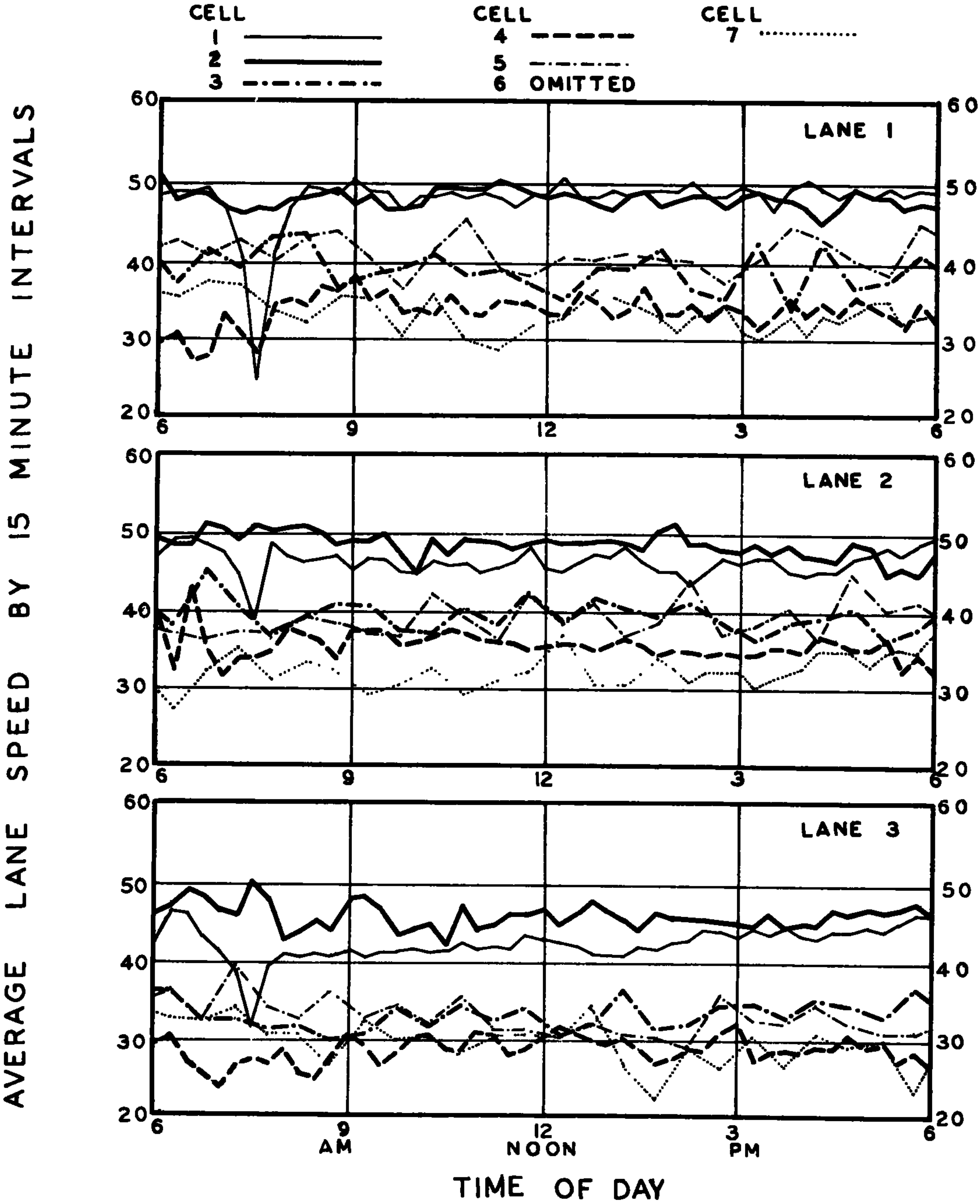

Figure 8. Variation of average lane speed by time of day for all cells.

the cells with the exception of cell 6 were plotted as indicated by the key at the top of the figure. The reason for not plotting cell 6 on this figure was that it had only two traffic lanes in the direction studied while all the other cells had three lanes. Because of the less important random fluctuations during much of the low volume "nighttime" period, only the period of 6 a.m. to 6 p.m. is shown on the graphs.

It seems that the most important observation to be derived from Figure 8 is that for all cells, and for each lane, the 15-min average speed variations generally form a series of parallel, horizontal lines. This is especially noticeable from 9 a.m. to 6 p.m. Of course, there are upward and downward fluctuations from period to period, but the magnitude of the fluctuations seems to be fairly constant from 9 a.m. to 6 p.m. For those cells (1, 2, 4, and 6) in which every individual speed observation was included in the analysis the lines appear to be extremely horizontal; whereas, for the cells which were analyzed on a sampling basis, the fluctuations are slightly larger as would be expected.

For the period from 6 a.m. to 9 a.m. most of the lines still appear to be of the same character as for the rest of the day. As discussed previously, the only major exception seems to be the Ford Expressway (cell 1) which has a large drop in average speed in all three lanes caused by congestion of traffic during the morning peak period (7 to 8 a.m.).

The last investigation in regard to speed variations was an attempt to determine if there were small intervals of time during which speeds could be measured, and this average speed thus computed to estimate the 24-hr average speed. To perform this investigation, lane speeds were averaged for 15-min periods and then lane average speeds were combined resulting in 15-min average speeds for each of the facilities. Only those facilities (cells 1, 2, 4, and 6) where the speed of each vehicle was determined are included in this analysis and only the period from 6 a.m. to 6 p.m. was studied.

The results of this investigation are shown in Figure 9. It is observed that averaging the lane speeds has the effect of eliminating incidental variations which were very pronounced in the graphs of average 15-min speeds for each lane separately. As a result, it is noted that there are several long periods during which the variation in 3-lane, 15-min average speed does not differ from the over-all 24-hr average by more than ± 1 mph. The period between 11 a.m. and 3 p.m. seems to be especially well suited to

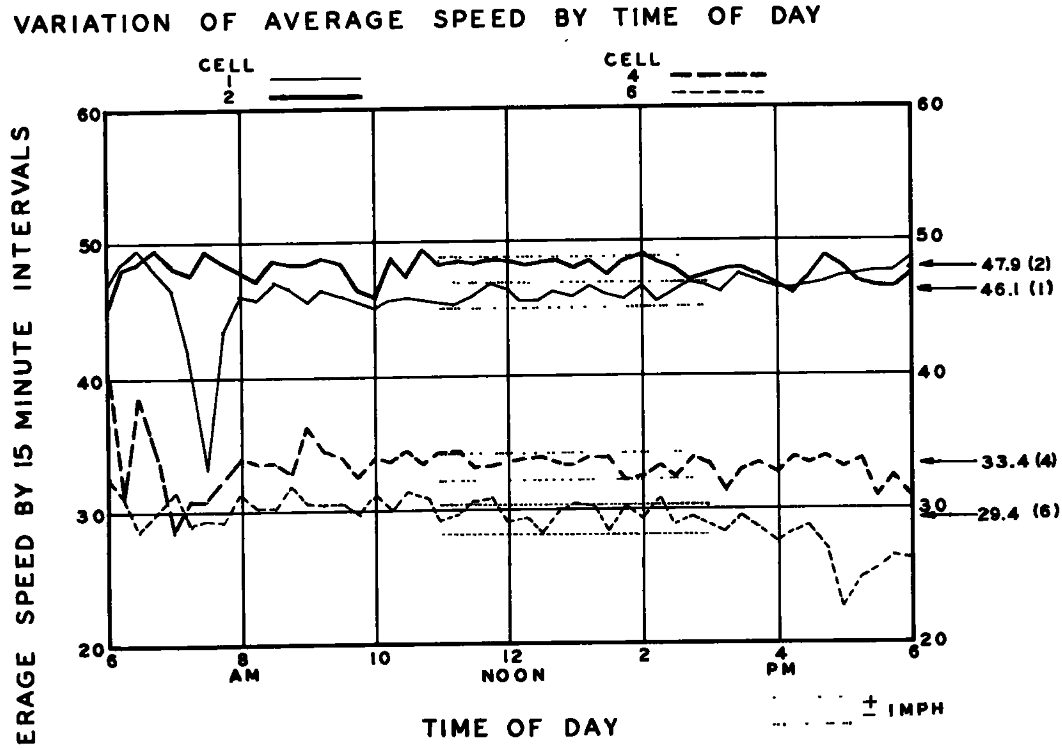

Figure 9. Variation of average speed by time of day.

the determination of the daily average speed. The ± 1 mph confidence limits for each of the four facilities from 11 a.m. to 3 p.m. are indicated on the figure. The practical significance of this result is that by measuring the speeds for any period of 15 minutes between 11 a.m. and 3 p.m. an estimate of the 24-hr average speed can be made, and it would be accurate to within ± 1 mph.

Distribution of Minute Average Speeds

The distribution of minute average speeds at each of the seven locations was determined and is presented in Figures 10 and 11. Cells 1, 2, 4, and 5 are depicted in Figure 10, while cells 3, 6, and 7 are included in Figure 11. The horizontal scale of each graph is 1-min average speed while the vertical scale is an accumulative percent of minutes with average speeds less than indicated on horizontal scale. First comparisons between lanes on the same facility are discussed, followed by a discussion comparing similar lanes of all the cells.

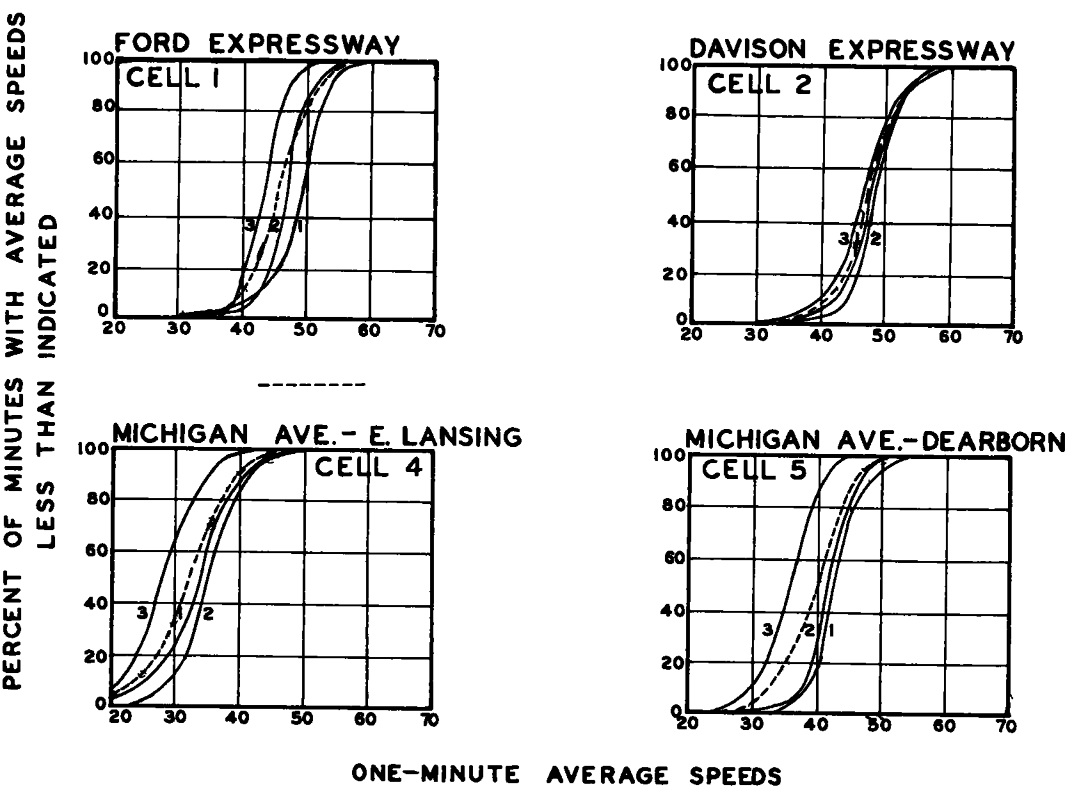

Figure 10. Distribution of minute average speeds.

In each of the graphs depicted in Figures 10 and 11, the distribution curve of minute average speeds for lane 3 for all cells is offset to the left 2 to 7 mph, while the distribution curves for lanes 1 and 2 for each of the cells are quite similar. For five of the cells (excluding Davison Expressway and Michigan Avenue in East Lansing), the distribution curve for lane 1 is offset to the right indicating a higher average speed. The distribution curves for the lanes for Davison Expressway and Grand River are close together indicating little difference in speed distributions between lanes.

The construction of such graphs permits the measurement of certain statistical characteristics, such as the median, 15 percentile, 85 percentile, 15-85 percentile

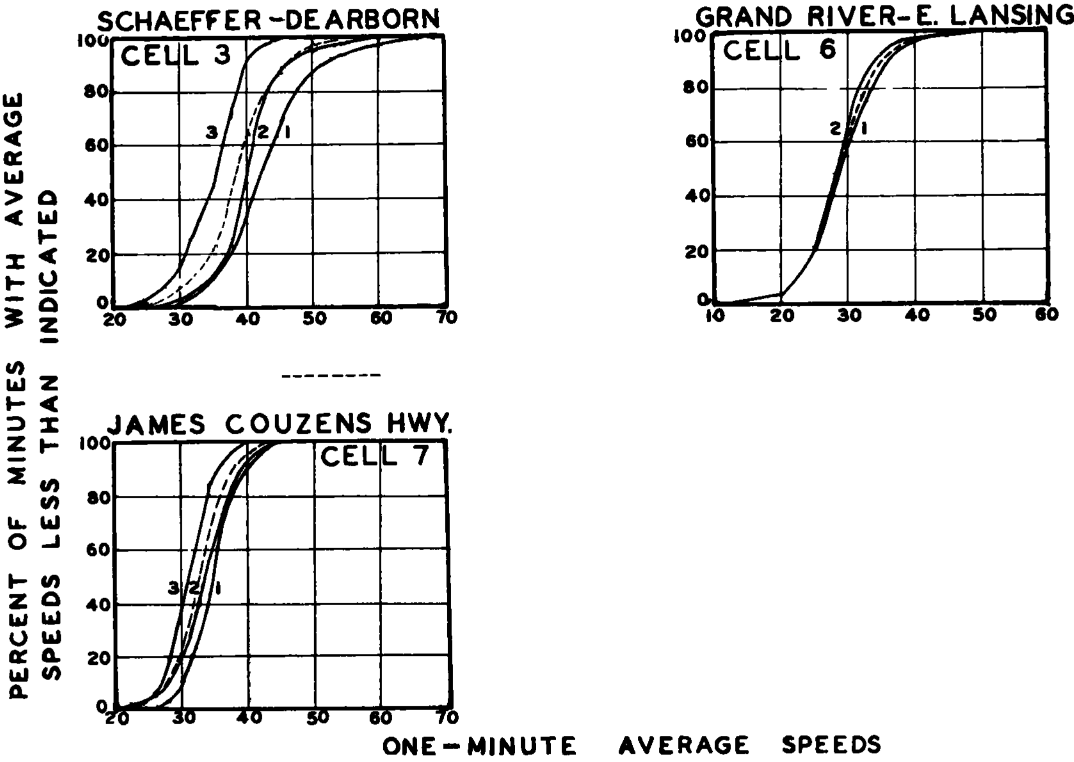

Figure 11. Distribution of minute average speeds.

range, 10-mph pace, and percent of vehicles within the 10-mph pace. These statistical characteristics are summarized in Table 4. Additional analyses were made in order to summarize the speed distributions for daytime (6 a. m. to 6 p. m.) and nighttime (6 p. m. to 6 a. m.) for the Ford and Davison Expressways. The minute average speed distributions at the James Couzens location were determined for the period when three lanes are used for traffic movement and also for the period (4 to 7 p. m.) when four lanes are used for traffic movement.

Although there is little difference between daytime and nighttime average speeds (45.3 and 45.4 mph on the Ford Expressway; and 47.4 and 46.3 mph on the Davison Expressway), the daytime minute average speeds are much more uniform. For example, the 15-85 percentile range on the Ford and Davison Expressways during the daytime was 5 to 6 and 6 to 9 mph, whereas during the nighttime the 15-85 percentile range was 8 to 11 and 9 to 13 mph. Another method that can be used to show the difference between speed distributions is to compare the percent of vehicles included within the 10-mph pace. This percent on the Ford and Lodge Expressways during the daytime was 89 to 93 and 77 to 88 percent whereas the similar percent for nighttime was 68 to 80 and 60 to 72 percent.

In comparing the speed distributions of the seven cells many similarities exist. Note in Table 4 that the average median and mode for each lane for all seven facilities are within 2 mph of one another. The 15-85 range for each lane for all seven facilities is always between 7 and 13 mph. This means that 70 percent of the minutes have an average speed never greater than ± 6.5 mph from the 24-hr average speed and on some lanes of some facilities never greater than ± 3.5 mph. A review of the percent of vehicles included in the 10-mph pace indicates that the percent varies from 58 to 88 which means that the average speed during 58 to 88 percent of minutes during the 24-hr period is never greater than ± 5.0 mph from the 24-hr average speed.

Another area in the investigation of speed distributions was to compare the minute

TABLE 4

SUMMARY OF MINUTE AVERAGE SPEED DISTRIBUTIONS

Facility	Test Period	Lane	Speed Characteristics								
			Speed (mph)			15 Pctl.	85 Pctl.	15-85 Pctl. Range	10-Mph Pace	Included in 10-Mph Pace (%)	Over-all Average (mph)
			Avg.	Med.	Mode						
Ford Exp., cell 1	Day	1	47.7	48	50	45	50	5	44-53	89.5	45.3
		2	46.0	45	46	43	48	5	42-51	93.3	
		3	42.4	42	41	39	45	6	38-47	90.5	
	Night	1	47.0	47	48	41	52	11	44-53	68.4	45.4
		2	46.6	46	48	42	51	9	42-51	74.5	
		3	42.6	42	41	38	46	8	38-47	80.4	
	24 Hr	1	47.4	48	50	48	51	8	44-53	80.7	45.4
		2	46.3	46	46	46	49	7	42-51	85.3	
		3	42.5	42	41	42	46	7	38-47	85.5	
Davison Exp., cell 2	Day	1	47.9	47	48	43	51	8	44-53	88.4	47.4
		2	48.3	48	49	45	51	6	44-53	90.6	
		3	46.1	46	45	41	50	9	41-50	77.0	
	Night	1	46.1	46	47	40	51	11	41-50	66.5	46.3
		2	47.8	47	47	43	52	9	42-51	72.6	
		3	45.0	45	46	38	51	13	42-51	60.8	
	24 Hr	1	47.1	47	47	43	51	8	43-52	78.0	46.9
		2	48.2	48	49	44	51	7	44-53	84.5	
		3	45.5	45	45	40	50	10	42-51	70.5	
Shaeffer Rd. cell 3	-	1	42.8	43	41	37	49	12	38-47	58.9	39.1
		2	40.0	40	42	37	44	7	35-44	80.2	
		3	34.5	35	34	30	39	9	32-41	74.3	
Michigan Ave., E. Lansing cell 4	-	1	33.1	34	34	27	40	13	30-39	62.2	32.5
		2	35.3	35	34	31	41	10	31-40	70.9	
		3	29.1	29	30	23	34	11	25-34	64.9	
Michigan Ave., Detroit cell 5	-	1	42.3	42	42	38	47	9	38-47	77.0	39.4
		2	41.6	42	43	38	45	7	36-45	88.6	
		3	35.1	35	34	31	40	9	31-40	78.8	
Grand River, E. Lansing, cell 6	-	1	28.8	29	28	24	35	11	23-32	64.3	28.3
		2	27.9	28	27	24	33	9	23-32	74.8	
James Couzens (3 lane) cell 7	-	1	34.1	34	34	31	38	7	29-38	86.3	32.5
		2	32.9	33	32	29	38	9	29-38	76.8	
		3	30.5	31	31	27	35	8	26-35	84.4	
James Couzens (4 lane) cell 7	-	1	34.2	35	37	32	37	5	29-38	96.7	31.4
		2	34.7	35	37	31	40	9	29-38	75.0	
		3	30.8	32	31	28	34	6	26-35	86.7	
		4	26.0	26	26	23	30	7	22-31	85.0	

average speed distributions of similar lanes on the seven different facilities (Fig. 12). Again the horizontal scale is minute average speed, and the vertical scale is percent of minutes with average speeds less than indicated minute average speed. The numbers (1 through 7) positioned near each curve refer to the cell number. The top diagram is for lane 1, the middle diagram for lane 2, and the lower diagram for lane 3.

The lane speed distributions of the seven facilities appear to be in pairs from left to right: cells 4 and 7, cells 3 and 5, and cells 1 and 2. The speed distribution curves for cell 6 (Grand River in East Lansing) only appear in the upper two diagrams because there are only two lanes. The curves in the lower diagram are positioned slightly to the left indicating a lower average speed in lane 3. Note the parallel position of the curves for lane 2 which implies that the 15-85 percentile ranges are approximately equal. The curves in the two top diagrams have steep slopes indicating greater uniformity in speed.

In summary, those cells with a combination of minimum marginal and median friction (cells 1 and 2) have distribution curves farthest to the right and have steep slopes. Those facilities (cells 6 and 7) with the combination of greatest median and marginal friction have distribution curves farthest to the left and have relatively flat slopes. It would appear from the study data that as traffic friction increases, average speed decreases and the speeds become less uniform.

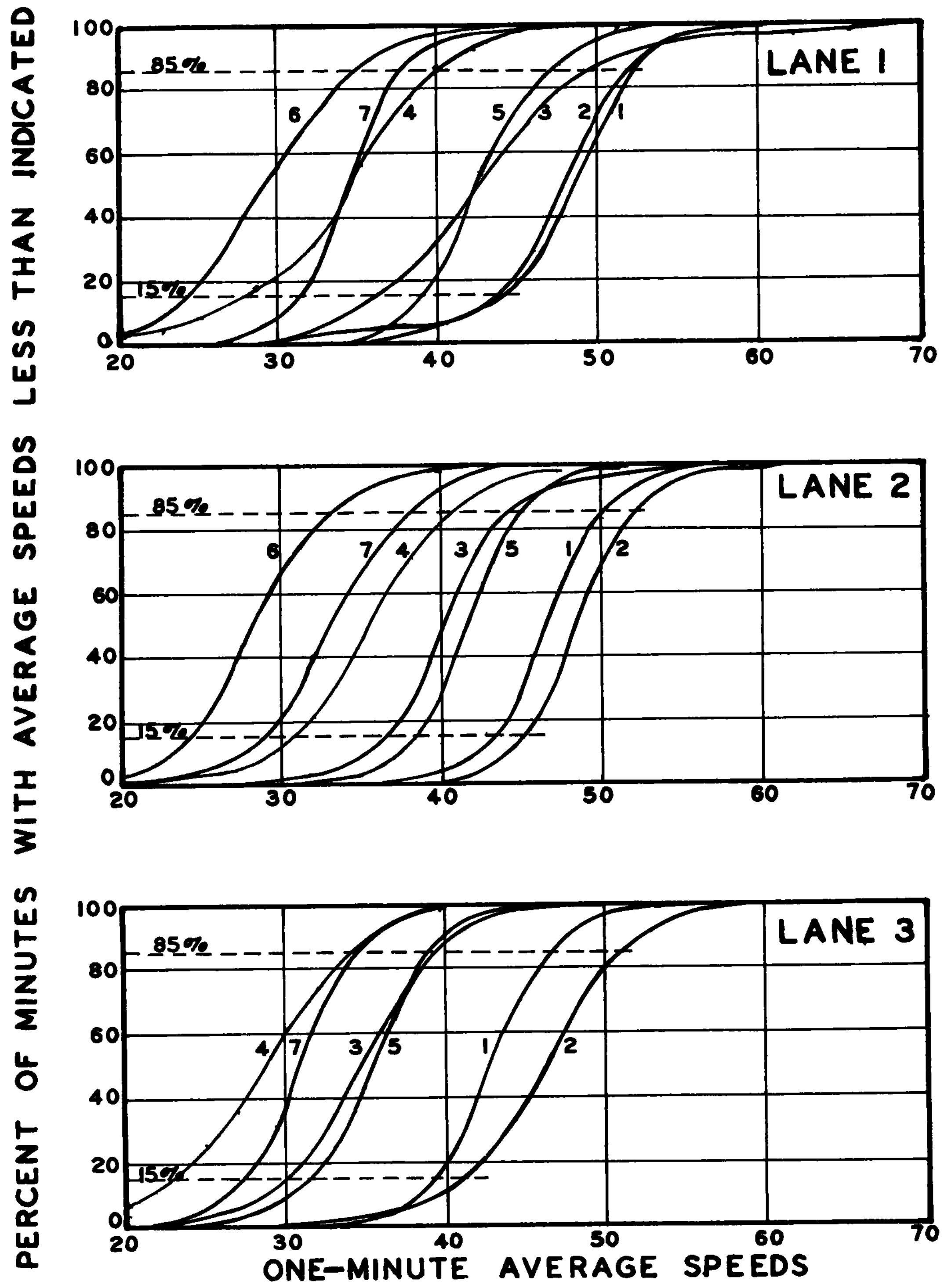

Figure 12. Distribution of minute average speeds by lane.

SUMMARY

The more important findings pertaining to the volume and speed characteristics of the seven locations on major urban arterials are summarized, as follows:

1. The ratio of various peak traffic volumes for different intervals of time for the seven locations are similar.
2. A method of estimating various 24-hr percentile minute volumes when applied to the seven locations give similar satisfactory results.
3. Traffic volume affects lane use and distribution of traffic volume between lanes follows very definite patterns.
4. The shoulder lane (lane 3) at each of the seven locations had the lowest average lane speed, whereas the median lane (lane 1) at five of the seven locations had the highest average lane speed.
5. The variations in average lane speeds between 9 a.m. and 4 p.m. at the seven locations were extremely small.
6. The average speed determined for any 15-min period between 11 a.m. and 3 p.m. was within ± 1 mph of the 24-hr average speed.
7. There was no significant difference between daytime and nighttime average speeds at the locations on the Ford and Davison Expressways. Nighttime average speeds were more dispersed.
8. The average minute lane speeds are quite uniform throughout the 24-hr period with 70 percent of the minutes having average speeds within ± 3.5 to ± 6.5 mph of the 24-hr average speed.
9. Routes having greater medial and marginal friction generally have lower average speed and speeds which are less uniform.

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