Estimating the Daily Vehicle-Miles of Travel in The Chicago and Pittsburgh Metropolitan Areas

LOUIS E. KEEFER, Director, Pittsburgh Area Transportation Study

●ESTIMATING the daily vehicle-miles of travel (DVMT) in a metropolitan area is an uncomplicated matter. One vehicle-mile of travel results from one vehicle traveling one mile, or from two vehicles each traveling one-half mile, or from other obvious combinations. Estimating the DVMT on any particular street requires simply extending its length in miles by its average daily traffic count. Estimating the DVMT in any particular metropolitan area requires only that street lengths and traffic counts be available for the area.

Work of this nature has now been done for at least two different sizes of metropolitan areas, in Chicago by the Chicago Area Transportation Study, and in Pittsburgh by the Pittsburgh Area Transportation Study. In Chicago, it was planned and executed as a minor accuracy check of trip survey data but was finished well after the standard accuracy checks and final trip factoring, based on screen line comparisons, had been completed. In Pittsburgh, as a result of the encouraging results obtained in Chicago, it was planned from the start as the major accuracy check.

This paper reports both the Chicago and the Pittsburgh experiences and makes a general comparison of the two.

ESTIMATING DVMT IN CHICAGO METROPOLITAN AREA

First Estimate

Traffic Counts Program and Analysis.—During the summer of 1957 the Chicago Area Transportation Study (CATS) began planning a traffic counts program designed for estimating the DVMT in its local and arterial street systems. The designation of these systems was according to its own classification criteria and such systems did not, therefore, correspond to any others. CATS arterial system within the city of Chicago, for example, was closely patterned after the "Preferential Street System" designated by the Chicago Planning Commission, but with adaptations to satisfy CATS purposes of traffic assignment analysis. The extent of the CATS arterial street system, which included expressways, is shown in Figure 1.

The program called for one 24-hr machine count on each of four local and two arterial street sections in a sample zone in each of 43 of the 44 districts of the study area. From the variable number of zones within each district, or ring and sector segment of the study area, one sample zone was chosen by a random draw. The district comprising the Chicago Central Business District (CBD) was omitted from the program.

Inasmuch as the sample zones were of two basic sizes (that is, either 1 sq mi or 4 sq mi), there were either four or sixteen ¼ sq mi "grids" in each. Where there were four, it was decided to locate the first local street count in one of the four northwest grids, the second in one of the four northeast, the third in one of the four southeast, and the fourth in one of the four southwest grids. The particular grid in each group of four was chosen randomly.

The next step was to choose the actual local street count location in each grid. For purposes of the 1956 trip survey origin-and-destination coding, each block within each grid had been numbered sequentially in a set of "geographic" coding maps. It was only necessary, then, to draw one block from each chosen grid, randomly, according to its

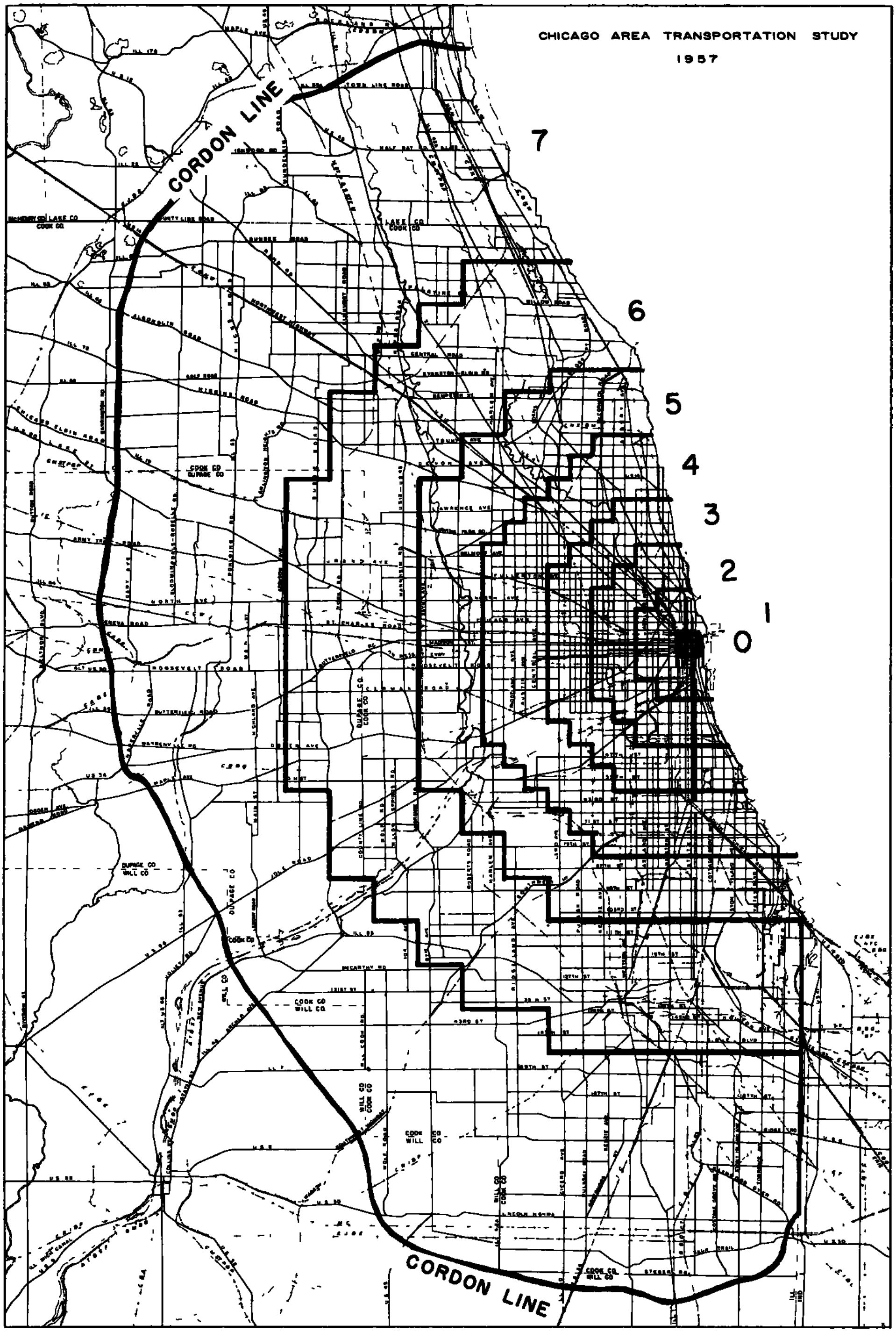

Figure 1. CATS arterial street system and rings.

trip-end coding number. If the block ended with an odd number, the north-south street bounding the eastern edge of the block was programmed for a count; if the block ended with an even number, the east-west street bounding the southern edge of the block was programmed.

There were some exceptions to this technique. Where the programmed street was not a local street a substitution was necessary. Also, it was decided that within a particular sample zone, the same local street would not be programmed twice. This, also, made a substitution necessary on several occasions.

The programming of the arterial streets to be counted in each sample zone was quite arbitrary. It was decided that one north-south and one east-west arterial street would be taken. All the arterial streets in each sample zone were assigned sequential numbers left to right and top to bottom, and one of each grouping chosen by a random draw.

The traffic counts program was started during September and completed during November 1957, by one counter setter using Streeter-Amet-type RC equipment. As the counts were taken, the tapes were edited for completeness and accuracy. If acceptable, they were transmitted to key punchers who prepared a punch card for each hour's count, showing the 15-min totals and the grand total. If unacceptable, recounts were taken. In general, there was no control over when the counts were taken, this being left to the counter setter, nor were the counts factored for daily or monthly variations.

Along with each tape that was sent to the key punchers, went a code sheet containing 40 columns of coded information concerning the street counted and the zone in which it was located. The latter included the total mileage (scaled from aerial photographs) of the local and arterial streets, respectively, in each of the sample zones, and the total land area and street area (taken from land use survey records) in each of the sample zones and the districts represented by these zones.

Following certain machine calculations (for example, the peak hour and peak 15-min percentages) punch card summary listings were made from which the DVMT in the local street system was found for each district as follows: the four local street counts in each sample zone were averaged and the average extended by the local street mileage in the represented district (X), as found through the ratio: local street mileage in the sample zone/X: street area in the sample zone/street area in the represented district. The ratio method was used because time limitations did not permit scaling the exact mileage throughout the study area.

The DVMT in the arterial street system was found in a different way. For every route section in the system there was already on hand (as a result of the previously completed arterial street inventory) a punch card showing the route length in tenths of miles and the 1953 annual average daily traffic (among other items). These were extended for every route section and the resulting 1953 DVMT summarized by ring. The 1957 arterial street sample counts were totaled and compared, by ring, with the 1953 counts at identical locations, to obtain 1953 to 1957 factors. These ring factors, given in Table 1, were used to convert the DVMT for 1953 to a 1957 basis.

Findings.—There were 38.0 million DVMT traveled on a typical weekday during September-November 1957, in the study area. Of this total, 82.6 percent, or 31.4 million DVMT were traveled over 2,921 miles of arterial streets, representing 25.2 percent of the total of 11,614 miles of streets in the study area. The remaining 17.4 percent, or 6.6 million DVMT, were traveled on 8,693 miles of local streets, or 74.8 percent of the total street mileage. The travel by system by ring is given in Table 1.

The average local street count, as calculated from the sample of 167 count locations, was highest in ring 1. Except for ring 2, the average count fell off successively through ring 7. The average local street count for all rings, excluding ring 0 for which no counts were made, was 1,046.

The average arterial street count, as calculated from the sample of 86 count locations, was highest in ring 3 and fell off successively through adjoining rings, with an abrupt drop in ring 7. The average arterial street count for all rings, excluding ring 0, was 15,650.

As expected, the proportion of travel occurring in the peak traffic hour decreased with increasing volume. The average peak hour percentage was comparatively constant for local streets throughout all rings, decreasing slightly toward the CBD as volume increased. The over-all weighted peak hour percentage on local streets was 13.7 percent. The average peak hour percentage for arterial streets was almost equally constant. Note, however, that while the local peaks ranged from 11.3 to 14.8 percent, the arterial peaks ranged only from 7.5 to 9.7 percent.

TABLE 1

DAILY VEHICLE-MILES OF TRAVEL (IN THOUSANDS) IN THE STUDY AREA ON A TYPICAL WEEKDAY DURING OCTOBER-NOVEMBER 1957, WITH OTHER PERTINENT DATA, BY ANALYSIS RING

Item	Analysis Ring 0	1	2	3	4	5	6	7	Total All Rings
Local streets									
Number of local counts	0	4	26	28	26	27	28	28	167 [1]
Average local count	5,000 [2]	3,223	1,430	2,230	1,160	544	412	228	1,046 [1]
Average peak hour percent	10.0 [2]	11.3	12.2	14.0	14.2	14.2	14.8	14.0	13.7 [1]
Number of miles Local streets	2.0 [3]	226.7	472.6	719.4	1,338.0	1,754.5	1,868.8	2,310.7	8,692.7
1957 vehicle-miles in thousands	10 [2]	731	646	1,529	1,580	859	750	523	6,628
Arterial streets									
Number of arterial counts	0	2	14	14	14	14	14	14	86
Average arterial count	16,000 [2]	14,340	16,236	23,068	19,271	17,232	12,507	5,731	15,650 [1]
Average peak hour percent	7.0 [2]	7.5	8.3	7.6	8.1	9.4	8.9	9.7	8.7 [1]
Number of miles Arterial streets [5]	14.1 [4]	92.5 [4]	138.9	191.4	305.4	393.4	687.3	1,098.3	2,921.3
1953 vehicle-miles in thousands	292	2,054	2,879	3,827	4,859	4,398	3,977	3,311	25,597
1953 to 1957 count ratio	1.00 [2]	0.92	1.10	1.09	1.05	1.19	1.58	1.58	1.16 [1]
1957 vehicle-miles in thousands	292	1,890	3,167	4,171	5,102	5,234	6,284	5,231	31,371
All streets 1957 vehicle-miles in thousands	302	2,621	3,813	5,700	6,682	6,093	7,034	5,754	37,999

[1] Excluding ring 0.
[2] Estimated.
[3] Scaled from USGS maps.
[4] Known to be low because of combining route sections in coding network.
[5] From network punch cards.

Based on the sample of 86 counts, the growth of travel on arterial streets between 1953 and 1957 (the 1953 to 1957 count ratio) was most rapid in the outlying areas. The increase, while modest in rings 2 through 5, was a resounding 58 percent in rings 6 and 7. Somewhat surprisingly, there was an apparent decrease in ring 1. The overall weighted increase of 16 percent for all rings represented an average annual increase of four percent.

The growth of travel on local streets during a similar duration cannot be found for lack of comparable counts. It is interesting to speculate that, while arterial street counts were decreasing in ring 1 and increasing but little in rings 2 through 4, local counts may have increased considerably in the same rings. Thus, arterial streets in the highly built-up inner rings might be thought of as operating near capacity, so that additional traffic would be diverted to local streets for greater portions of trips.

Although existing traffic counts were not a determining factor in CATS street classification, the results of the traffic counts program, nevertheless, showed a rather consistent relationship between CATS street classification and existing traffic counts. The principal finding was that the streets in the CATS area might well have been classed as arterial or local, according to whether they carried more or less than 3,000 vehicles per day.

Only 11 of the 167 local streets counted had traffic exceeding 3,000 vehicles during the 24-hr count period, six exceeding 5,000 vehicles, but none exceeding 10,000 vehicles. On the other hand, only nine of 86 arterials had less than 3,000 vehicles, and seven of these were in rings 6 and 7 where arterial counts might be expected to be lower.

The 11 local streets having counts greater than 3,000 were examined to find reasons for the high counts. Several emerged: the particular street was a short-cut path between two arterial streets, often avoiding a turn prohibition or traffic signal or providing a slightly shorter travel distance; it was heavily enough traveled but of insufficient length to be classed as arterial for CATS purposes; or it was located in a manufacturing area near a large traffic generator such as Goose Island or the Union Stock Yards.

The nine arterial streets having counts less than 3,000 were similarly examined. Generally, these proved to be in the outer rings, linking small towns and villages, but of a low type, occasionally even metal-surfaced, and simply lacking a higher count.

Second Estimate

Traffic Counts Program and Analysis.—As a result of the considerable interest generated by the first estimate of the DVMT in the Chicago metropolitan area, a second traffic counts program was planned and executed. To distinguish them, the former was called sample A and the latter, sample B.

The two samples were drawn in the same manner, but involved entirely different count locations. Randomly located 24-hr weekday traffic counts were taken during April through July 1958, in a randomly selected analysis zone in each of the 44 districts in the study area. The schedule called for four counts on local streets (except in the district constituting the Chicago CBD) and two counts on arterial streets in each sample zone. The same general method of finding the local and arterial street DVMT was used as for sample A, except that the counter tapes were not key punched as previously.

Findings.—There were 36.5 million DVMT traveled on a typical weekday during April-July 1958, in the study area. Of this total, 30.0 million vehicle-miles, or 82.2 percent, were traveled on 2,921 miles of arterial streets, representing 28.3 percent of the 10,314 miles of streets estimated in the study area. The remaining 6.5 million vehicle-miles, or 17.8 percent, were traveled on 7,393 miles of local streets, or 71.7 percent of the total street mileage estimated in the study area. The travel by system by ring is given in Table 2.

The results compared closely with those from Sample A. Calculation of the local street mileage by district, by the ratio described previously, yielded lower totals than before, but because the average local street counts were slightly higher, the total DVMT in the local street system was almost the same (6.4 to 6.6 million).

The sample A vs sample B comparison of the DVMT in the arterial street system was nearly as good (31.4 to 30.0 million). The variations in ring totals resulted from the calculation of new expansion factors by which the known 1953 totals were updated.

The average local street count, as calculated from the sample of 167 count locations, was highest in ring 1 and decreased successively through ring 7. The average local street count for all rings, excluding ring 0 for which no local counts were taken (there were only two miles of local streets in ring 0) was 1,166 vehicles. This compared closely with the average of 1,046 vehicles derived from sample A.

TABLE 2

DAILY VEHICLE-MILES OF TRAVEL (IN THOUSANDS) IN THE STUDY AREA ON A TYPICAL WEEKDAY DURING APRIL-JULY 1958, WITH OTHER PERTINENT DATA, BY ANALYSIS RING

Item	Analysis Ring 0	1	2	3	4	5	6	7	Total All Rings
Local streets									
Number of local counts	0	4	27	27	28	28	26	27	167 [1]
Average local count	5,000 [2]	2,505	2,114	1,645	1,409	664	584	370	1,166 [1]
Miles local streets (calc.)	2.0 [3]	201.6	322.6	566.5	1,229.7	1,327.1	1,622.0	2,121.8	7,393.3
1958 vehicle-miles in thousands	10	505	682	932	1,733	881	947	785	6,475
Arterial streets									
Number of arterial counts	2	14	14	14	13	14	13	13	97
Average									
Arterial count	13,436	16,507	15,533	14,609	14,723	10,789	7,383	3,339	11,976
Average peak hour percent	8.1	8.4	8.7	8.4	8.8	9.3	9.6	9.7	8.8
Miles arterial streets[5]	14.1 [4]	92.5 [4]	138.9	191.4	305.4	393.4	687.3	1,098.3	2,921.3
1953 vehicle-miles in thousands	292	2,054	2,879	3,827	4,859	4,398	3,977	3,311	25,597
1958/1953 Ratio	0.96	1.12	0.92	1.06	1.09	1.29	1.45	1.20	1.10
1958 vehicle-miles in thousands	280	2,300	2,649	4,057	5,296	5,673	5,767	3,973	29,995
All streets 1958 Vehicle-miles in thousands	290	2,805	3,331	4,989	7,029	6,554	6,714	4,758	36,470

[1]Excluding ring 0.
[2]Estimated.
[3]Scaled from network maps.
[4]Known to be low because of combining route sections in network coding.
[5]From network punch cards.

A similar pattern was disclosed for arterial streets; the highest average count, as calculated from the sample of 97 count locations, found in ring 1, and decreasing successively through ring 7. This contrasts with sample A where the highest count was found in ring 3, decreasing successively in both higher and lower adjacent rings. The average arterial street count for all rings was 11, 976 vehicles. Both the ring averages and the over-all average were lower for sample B than for sample A. This indicated only that different samples were taken.

As a matter of curiosity, the average count on all arterial street sections was calculated from the arterial street inventory punch cards, by ring, as given in Table 3. Comparison of the averages shown in Tables 2 and 3 indicate that the arterial streets chosen for counts in sample B had lower counts, on the average, than did the universe of arterial streets, in rings 0 through 4.

TABLE 3

AVERAGE ARTERIAL STREET SECTION TRAFFIC COUNTS, BY RING, CALCULATED FROM THE ARTERIAL STREET INVENTORY PUNCH CARDS

Ring	Number of Sections Averaged	Average Arterial Traffic Count
0	112	20, 783
1	248	23, 720
2	401	18, 629
3	485	20, 000
4	675	15, 977
5	701	10, 715
6	954	6, 120
7	1, 113	2, 488
Total all rings	4, 689	11, 157

The average peak hour percent for arterial streets increased from ring 0 outward, just as it did for sample A, ranging from 8. 1 to 9. 7 percent. The over-all weighted peak hour was 8. 8 percent for 97 counts, while sample A was 8. 7 percent for 86 counts. No record of peak hour counts on local streets was obtained for sample B because of the type of equipment used. (Streeter-Amet "Junior" instead of "RC" counters were used for local counts, as a matter of convenience in handling and operation.)

The growth of travel on arterial streets between 1953 and 1958 was most pronounced in the outer rings. Not all arterial street counts in sample B had a 1953 or 1955 counterpart. (The 1953 flow maps did not show every street on the CATS arterial street system, and thus no direct comparison was possible.) Only those that did were used to derive the 1953 to 1958 expansion factor used in Table 2. Based on this comparison, the factors ranged from 0. 92 for ring 2 to 1. 45 for ring 6. While there was rough correspondence of factors between samples A and B, those of sample B were lower generally, as reflected by the over-all weighted factors of 1. 16 and 1. 10, respectively. No attempt was made to correct the 1958 counts to 1958 ADT by the use of daily and monthly factors.

As a way of verifying the accuracy of such factors, a comparison was made between the 1953 and 1956 editions of the Chicago Metropolitan Area Traffic Map prepared by the Illinois Division of Highways. An expansion factor was calculated for each matching route section in rings 6 and 7. The unweighted average of 137 factors for ring 6 was 1. 37; of 266 factors for ring 7, 1. 39. This indicated that the sample B factor of 1. 45 for ring 6 was approximately correct, but that the factor of 1. 20 for ring 7 was possibly too low. Table 2 was prepared without regard to this additional evidence.

Again it appeared that the classification of streets in the CATS area could have been accomplished, in large measure, by the use of traffic count criteria. Only 15 of the 167 local street counts analyzed exceeded 3, 000 vehicles during the 24-hr count period, two exceeding 5,000, but none exceeding 6,000 vehicles, and these, generally, for the reasons previously cited. Only 15 of the 97 arterial street counts analyzed were less than 3,000 vehicles, and 10 of these were in rings 6 and 7 where arterial street counts were expected to be lower.

Comparison With Trip Survey Data

Two estimates of the total DVMT in the study area were now available. The first for September-November 1957; the second for April-July 1958. The estimates were 38.0 and 36.5 million vehicle-miles, respectively. These represented excellent sources of independent data with which to check with the total DVMT calculated from the CATS trip surveys of April-October 1956. While the data did not correspond time-wise, an approximate check was expected to be interesting, nevertheless.

The screenline-factored results of the internal (or home-interview) trip survey were converted to vehicle-miles of travel by taking the 'L' distance trip frequency distribution, multiplying by the average distance for each distance range, and totaling, as given in Table 4. The total was factored by 0.493 to rēduce person-trips to automobile trips, and by 1.20 to account for truck, taxi, and external trips. The resulting total of approximately 34.0 million vehicle-miles (57,792,000 x 0.49 x 1.20) comes out close to, but under, estimates from samples A and B.

ESTIMATING THE DAILY VEHICLE-MILES OF TRAVEL IN THE PITTSBURGH METROPOLITAN AREA

Traffic Counts Program, Analysis, and Findings

Arterial Street System DVMT.—From the beginning, the Pittsburgh Area Transportation Study (PATS) planned for a traffic counts program for estimating the DVMT in its local and arterial street systems.

As in Chicago, the designation of these systems was determined by the purposes of traffic assignment analysis. The reasoning behind this might be explained as follows: Transportation planning for the future starts with a comparison of present total travel supply (streets) and future total travel demand (trips). If demand is expressed as trips between pairs of analysis zones (zonal interchange), then supply must be expressed

TABLE 4

ESTIMATED PERSON-MILES OF TRAVEL IN THE STUDY AREA DURING AN AVERAGE WEEKDAY IN APRIL-NOVEMBER, 1956, FROM RESULTS OF THE CATS TRIP SURVEYS

Right-Angle Trip Distances (in miles)	% Distribution of Auto Driver Trips	Median Distance for Each Distance Range	Person Miles of Travel
0.0 - 0.9	2.7	0.6	162,000
1.0 - 1.9	23.6	1.5	3,550,000
2.0 - 3.9	25.1	3.0	7,550,000
4.0 - 5.9	15.8	5.0	7,900,000
6.0 - 7.9	7.7	7.0	5,400,000
8.0 - 9.9	7.4	9.0	6,650,000
10.0 - 11.9	4.8	11.0	5,300,000
12.0 - 13.9	4.8	13.0	6,250,000
14.0 - 15.9	3.5	15.0	5,250,000
16.0 - 17.9	1.3	17.0	2,200,000
18.0 - 19.9	1.1	19.0	2,080,000
20.0 +	2.3	24.0	5,500,000
Total	100		57,792,000

as streets connecting pairs of analysis zones. But how many streets? The technique of comparison determines this. Assuming that traffic assignment, or allocation of trips to specific streets, is the technique chose, then the method of assignment used is the determining factor. At PATS the minimum travel time path "all or nothing" method of assignment will be used. This means that all trips between a pair of zones are allocated to the minimum path connecting them. The path may consist of only one street (later referred to as a route section) if the zones are contiguous, or of many streets with turns at intersections if the zones are distant. Thus there need be only enough streets to interconnect all pairs of zones, but these must provide the minimum path leading from every zone center, preferably in at least four directions. Hence, the working definition of an arterial street as used at PATS: "An arterial street is a street having significant capacity for interzonal trip movement as a link in an anticipated minimum travel time path." Expressways are self-defining and local streets are the residua

It should be added, however, lest the arterial street system seem too circumscribed, that experience has demonstrated this specialized method of street classification virtually assures inclusion of all streets which by the criteria of other methods would be included. On the other hand, a number of streets may be included which would not otherwise qualify as arterials. In outlying portions of the study area, for example, an unpaved road between adjoining zones may be designated as an "arterial" for lack of any other connecting link.

As part of the arterial street inventory, but primarily in connection with the development of an area-wide traffic flow map, 1958 traffic counts were obtained at the mid-points of most of the limited access and arterial street sections (Fig. 2). The type of counts obtained are given in Table 5.

TABLE 5

NUMBER OF TRAFFIC COUNTS OF DIFFERENT TYPES MADE FOR THE PATS ARTERIAL STREET INVENTORY

Type of Count	Number
24-hr manual classification	95
8-hr manual classification, expanded to 24 hr by an area factor	529
24-hr machine	789
24-hr machine, from a previous year factored to 1958	189
Estimated	14
Total	1,616

Most of the manual counts were made during July through September 1958; most of the machine counts were made during August through November 1958. No attempt was made to factor the counts to the average annual daily traffic for 1958, or to the average daily traffic for the fall quarter of 1958.

These 24-hr counts, the peak hour percents, the light, medium, and heavy commercial vehicle percents, and the lengths in hundredths of miles, along with other inventory data, were punched into an inventory card for each street section. After checking for accuracy, the total DVMT for each section was machine-calculated, and the peak hour and commercial vehicle DVMT machine-calculated in turn. A machine summary of the calculated values, by ring within type of street, produced the values in Table 6.

Several interesting features emerge in Table 6. It can be seen that the average traffic count on arterial street sections decreases more or less regularly with increasing distance from the CBD, but that due to the increasing arterial street mileage of the outer rings, the total DVMT by ring increases rapidly. Ring 7, of course, is an incomplete ring, accounting for the decrease in that ring. The percent of travel occurring in the peak hour increases from inner to outer rings, as it did in Chicago. The percent of travel by light commercial vehicles (panel and pickup trucks and other 4-wheel types) likewise increases from inner to outer rings. This may be partly explained by the frequent substitution of pickup trucks for personal automobiles in the outlying and

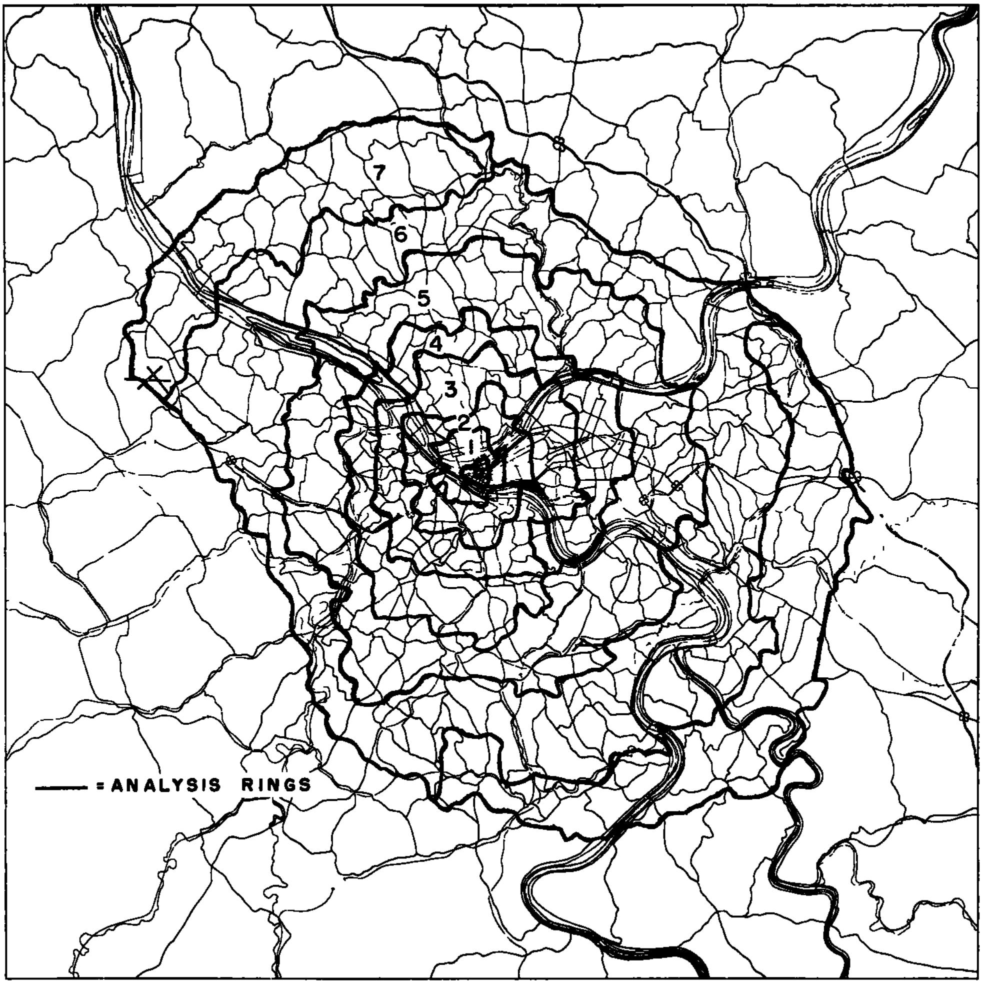

Figure 2. PATS arterial street system and rings.

rural areas. The percents of medium (straight body types with 6 or more wheels) and heavy commercial vehicles (all combination units plus buses) show no definite tendency.

In many respects these facts correspond closely with the experience in Chicago. An interesting difference lies in the more narrow range of values found. For example, the peak hour percents ranged from 8.1 to 9.7 in Chicago; the average arterial count ranged from about 16,507 to 3,339. This is probably a function of the type of study area. In Chicago, there was a rather regular thinning out of the concentration of population with increasing distance from the CBD. In Pittsburgh population concentrations exist along the river valleys as far out as the cordon line. The same narrowing of value ranges is reflected in the local street DVMT information described next.

Local Street System DVMT.—By definition, all streets in the study area that were not included in the arterial street system were local streets. No detailed inventory of these was made, although in mileage the system of local streets was about four times as long as the arterial street system. To get a complete picture of the total DVMT within the study area, of course, the travel on this system was also measured.

Inasmuch as it was impractical to obtain a 24-hr count on every section, a random sample of local streets was chosen for counting. The purpose was to obtain an average count applicable to all streets in an analysis ring. At the time these counts were

TABLE 6

DAILY VEHICLE-MILES OF TRAVEL (IN THOUSANDS) IN THE ARTERIAL STREET SYSTEM IN THE STUDY AREA ON A TYPICAL WEEKDAY DURING JULY-NOVEMBER 1958, WITH OTHER PERTINENT DATA, BY ANALYSIS RING

Item	Analysis Ring								Total All Rings
	0	1	2	3	4	5	6	7	
Number of counts	178	87	94	191	191	313	362	196	1,612
Average count	10,693	13,208	12,263	10,916	11,003	8,300	6,229	4,761	8,796
Arterial mileage	17.39	31.83	56.18	96.50	113.22	233.29	344.88	196.16	1,089.45
Total VMT	208.7	454.1	706.7	1,143.6	1,133.6	1,777.7	1,814.8	790.4	8,029.6
Peak hour VMT	16.8	37.9	57.3	93.6	95.7	158.7	167.2	73.4	700.6
Percent	8.0	8.3	8.1	8.2	8.4	8.9	9.2	9.3	8.7
Light Commercial									
VMT	11.0	27.5	45.4	76.7	77.5	124.3	126.4	55.8	544.6
Percent	5.3	6.1	6.4	6.7	6.8	7.0	7.0	7.1	6.8
Medium Commercial									
VMT	12.9	35.6	49.3	72.8	70.0	121.6	119.5	41.2	522.9
Percent	6.2	7.8	7.0	6.4	6.2	6.8	6.6	5.2	6.5
Heavy Commercial									
VMT	8.0	18.3	23.1	38.3	33.4	59.0	64.9	27.0	272.0
Percent	3.8	4.0	3.3	3.3	2.9	3.3	3.6	3.4	3.4
Passenger Car									
VMT	176.8	372.7	588.9	955.8	952.7	1,472.8	1,504.0	666.4	6,690.1
Percent	84.7	82.0	83.3	83.6	84.1	82.9	82.8	84.4	93.3

scheduled, PATS had not yet designated its analysis ring boundaries, so that a systematic sample by ring could not be drawn as it was in Chicago. The sample was drawn instead by judgment. To compensate for lack of some more systematic method, a comparatively large sample of 189 count locations was drawn. It was decided that 1 in 5 of these would be 8-hr manual classification counts, the rest, 24-hr machine counts.

The counts were made during November and the first week of December 1958, or concurrent with the home-interview and truck-taxi trip surveys. As the counts were made, they were checked for apparent accuracy, and if accepted, recorded on a worksheet. At this time, counts at 6 locations were discarded as non-typical of local streets. Analysis was delayed until about May 1959, when analysis rings were established. The count information was then totaled by ring to obtain the summary given in Table 7.

Table 7 shows some interesting results. Like arterial streets, local streets carry progressively lower volumes as distance from the CBD increases. The proportion of travel occurring during the peak hours rises gradually toward the outer rings, but not as markedly as it does on arterial streets. The higher range in peak hour travel, of 12.5 to 13.7 percent, excluding ring 0, indicates that the level of service during off-peak hours is much better, and more nearly uniform, for local streets generally, as would be expected. The percents of commercial vehicle travel show no definite trends, and this may be a function of the relatively few classification counts taken in each ring. The percents for rings 6 and 7 in Table 7 are weighted averages of the percents in rings 2 through 5, since, inadvertently, no classification counts were made in rings 6 and 7.

While a progressive decrease in the average local street count, as the distance from the CBD increases, is probably not consistent with the usual concept of the local street, it is the natural result of the method of street classification used. Thus, the designated "arterial" system in the inner rings of the study area generally omits a considerable mileage of streets that might otherwise be considered "arterial", as, for example, by the criteria established by the National Committee on Urban Transportation. This would tend to result in relatively high counts for "local" streets therein. The average "local" street counts both in Chicago and Pittsburgh were higher, in fact, than the averages found in Cincinnati, as reported by Howie and Young in their report, "The Traffic Counting Program in Cincinnati" (HRB Proceedings, 1957). It must again be emphasized that the criteria of street classification used in Chicago and Pittsburgh does not correspond to more usual criteria, and that the terms "arterial" and "local" as used in this paper have a special connotation for analysis purposes only.

A comparison shows that the 1,089.5- mile arterial street system (including express-

TABLE 7

DAILY VEHICLE-MILES OF TRAVEL (IN THOUSANDS) IN THE LOCAL STREET SYSTEM IN THE STUDY AREA ON A TYPICAL WEEKDAY DURING NOVEMBER 1958, WITH OTHER PERTINENT DATA, BY ANALYSIS RING

Item	Analysis Ring 0	1	2	3	4	5	6	7	Total All Rings
Number of counts									
Machine	-	6	24	23	16	28	31	24	152
Manual	8	4	4	8	4	1	-	-	29
Weighted average count	1,997	1,749	1,188	1,140	996	718	515	466	939
Local street mileage	3.3	88.6	181.7	263.3	350.5	607.3	699.4	372.9	2,567.0
Total VMT	6.6	155.0	215.9	300.2	349.1	436.0	360.2	173.8	1,996.8
Peak hour									
VMT	0.5	20.8	27.0	38.4	46.4	58.9	49.3	22.9	264.2
Percent	7.2	13.4	12.5	12.8	13.3	13.5	13.7	13.2	13.2
Light commercial									
VMT	0.7	14.1	18.1	28.8	20.6	37.9	29.9	14.4	164.5
Percent	10.4	9.1	8.4	9.6	5.9	8.7	8.3	8.3	8.2
Medium commercial									
VMT	0.6	14.4	10.4	13.5	12.6	29.2	16.2	7.8	104.7
Percent	8.8	9.3	4.8	4.5	3.6	6.7	4.5	4.5	5.2
Heavy commercial									
VMT	-	2.6	3.5	3.3	3.3	0.4	1.8	0.9	12.8
Percent	0.1	1.7	1.6	1.1	0.1	0.1	0.5	0.5	0.1
Passenger cars									
VMT	5.3	123.9	183.9	254.6	315.6	368.5	312.3	150.7	1,714.8
Percent	80.7	79.9	85.2	84.8	90.4	84.5	86.7	86.7	86.5

ways) accommodates 8.0 million DVMT, and that the 2,567.0-mile local street system accommodates 2.0 million DVMT. Thus 29.8 percent of the total street mileage in the study area carries 80.1 percent of the total travel, while the remaining 70.2 percent of the mileage carries only 19.9 percent, as summarized in Table 8.

TABLE 8

SUMMARY OF DAILY VEHICLE-MILES OF TRAVEL IN THE STUDY AREA BY STREET SYSTEM

Item	Local Street System	Arterial Street System, Excluding the Parkway	Parkway System	Total Systems
Total mileage	2,567.0	1,054.6	34.9	3,656.5
Percent	70.2	28.8	1.0	100.0
Total VMT	1,996.8	7,226.3	803.3	10,026.4
Percent	19.9	72.1	8.0	100.0

These proportions are very much the same as were found in Chicago. A further breakdown shows that the Penn-Lincoln Parkway system of 34.9 miles, including all ramp connections, representing only 1.0 percent of the street mileage, carries 8.0 percent of the total travel.

Comparison with Trip Survey Data

Trip Survey Data by Airline Distance.—Every trip card resulting from the PATS trip surveys shows the calculated airline distance between the trip origin quarter-square-mile grid and the trip destination quarter-square-mile grid. Summary tabulations were made by type of vehicle for the different trip surveys (Table 9) to develop the total airline distance DVMT represented.

TABLE 9

AIRLINE DAILY VEHICLE-MILES OF TRAVEL WITHIN THE STUDY AREA, AS DEVELOPED FROM PATS TRIP SURVEYS, ON A TYPICAL WEEKDAY DURING SEPTEMBER-NOVEMBER 1958

Vehicle Type	Home Interview Survey (trips entirely within the study area only)	Truck-Taxi Survey (trips entirely within the study area only)	Roadside Interview Survey (all trips, but distance with the study area only)	All Surveys
Passenger cars	3,295,142	-	1,417,195	4,712,337
Taxis	-	59,101	-	59,101
Light commercial	-	230,706	113,163	343,869
Medium commercial	-	132,462	88,421	220,883
Heavy commercial	-	8,768	91,151	99,919
Total	3,295,142	431,037	1,709,930	5,436,109

Conversion of Airline Distance to Over-the-Road Distance.—The difficult problem was to convert airline distance to over-the-road distance. To find a correction factor, the airline versus over-the-road distance by shortest arterial street route was measured for a randomized sample of 70 pairs of quarter-square-mile analysis "grids." When these were plotted (Fig. 3) a linear relationship was found. The correlation of airline (x) and over-the-road distance (y) was $r^2 = 0.939$, and the equation $y = 1.175 + 1.349\ x$.

The conclusion, however, was that this factor was too low. It was reasoned that not all trips would follow the shortest route. Social-recreation trips, for example, would frequently take the long way around. Trips for other purposes might do the same—to avoid congestion, to relieve monotony, or simply to look at something in passing. Lost or unfamiliar drivers probably could not follow the shortest route, nor could truckers restricted from segments of the route. For these reasons, a correction factor of 1.6 was used to convert airline to over-the-road distance.

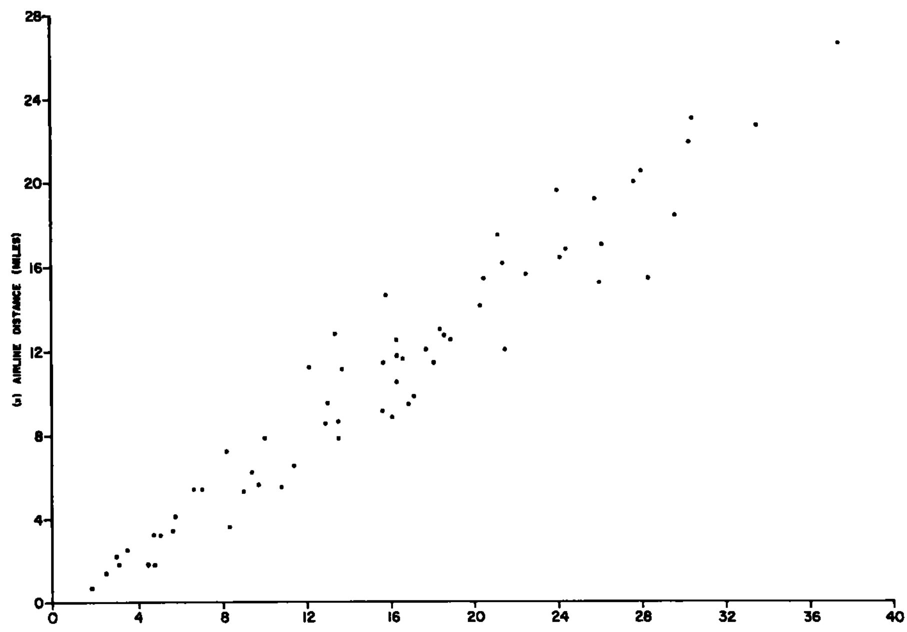

Figure 3. Scattergram comparison of airline and over-the-high road distances between 70 selected grids.

Accuracy Check.—The accuracy check obtained is given in Table 10. Because the independent estimate includes bus travel and the trip surveys did not (except in terms of person trips only), 80,000 VMT for buses were added to the trip surveys total for commercial vehicle VMT.

The 90.8 percent check for passenger cars is very good. The combined 70.5 percent check for commercial vehicles is fair. It seems probable that the latter may be accounted for, in part, by a large number of trips inside the study area by commercial vehicles garaged outside the study area. The first trip entering and the last trip leaving the study area, of course, are intercepted at the cordon line and recorded in the roadside interview, but subsequent and preceding trips inside the study area, on the same day, are not accounted for by any of the trip surveys. There is no way to measure the extent of this kind of tripmaking, but it is felt that in the Pittsburgh area it might be significant. The 87.5 percent total check for passenger cars and commercial vehicles combined must, nevertheless, be rated as very good.

In the months that have passed since this check was made there have been various suggestions regarding the use of the 1.6 factor—the principal one being that the factor was too high and hence exaggerated the percent of check, and that, despite the findings shown in Figure 3, a curvi-linear relationship actually exists and should have been used for the conversion of airline to over-the-road trip distances, particularly for the truck trips. This suggestion may very well be valid. It certainly points up the need for better information regarding the actual routes of travel chosen by drivers. An ideal method of obtaining this in an origin-destination study might be to have a sub-sample of home-interview respondents trace actual trip travel routes on a small-scale street map of the study area, the map to be appended to the home-interview schedule for later measurement and coding of the true over-all trip length. Besides derivation of airline versus over-the-road distance ratios, the results could well be useful for obtaining expressway usage diversion curves appropriate to the area, whenever that method of traffic assignment is anticipated. While getting such information would involve some problems, it is felt to be not impractical.

The vehicle-miles of travel accuracy check has several advantages over the standard accuracy checks previously reported. Most importantly, it compares the results of the combined trip surveys against the true universe of tripmaking (except by streetcar and railroad) in the study area, not just trips to particular places (like the CBD accumulation and work place checks), or across particular lines (like the screenline check), or by particular modes (like the mass transit check), or for particular purposes (like the labor force check). Furthermore, in the course of making the independent estimate from traffic counts and street mileage measurements, considerable data are developed which have other important uses. The check might well become standard procedure in all major transportation planning projects.

TABLE 10

COMPARISON OF OVER-THE-ROAD DAILY VEHICLE-MILES OF TRAVEL AS DEVELOPED FROM PATS TRIP SURVEYS AND AS CALCULATED FROM TRAFFIC COUNTS AND STREET MILEAGE MEASUREMENTS

Vehicles	From Trip Surveys	From Traffic Counts	Percent Check
Passenger cars (includes taxis)	7,634,301	8,404,900	90.8
Light commercial	550,190	709,100	77.6
Medium commercial	353,413	627,600	56.3
Heavy commercial (includes buses)	239,870	284,800	84.2
Total	8,777,774	10,026,400	87.5

CONCLUSIONS AND RECOMMENDATIONS

Some conclusions can now be stated in a summary fashion, ranging from the particular to the general. Where these conclusions refer to arterial or local streets specifically, the method of street classification used in Chicago and Pittsburgh must be kept in mind. Unless otherwise noted, the conclusions refer to both the Chicago and Pittsburgh work, inasmuch as more or less comparable results were obtained in both places.

In addition, some recommendations can be made with reference to future work of the type reported, which in themselves are another kind of conclusion.

Conclusions

The average daily traffic count on both arterial and local streets generally decreased with increased distance from the CBD, although arterial counts in the CBDs themselves were lower than in the first several analysis rings. Over-all, the progressive decrease was smoother for local streets, the arterial counts tending toward a plateau in the first several analysis rings. To some extent, these patterns were a result of the method of street classification used.

The peak hour percents on both arterial and local streets generally increased with increased distance from the CBD and with decreased traffic counts.

While existing traffic counts were not a specific criteria for street classification, it was found in Chicago that, had an average daily traffic count of 3, 000 vehicles been used as the dividing line between an arterial and local classification, much the same street systems would have been designated except in the outer analysis rings.

The estimation of the daily vehicle-miles of travel in a metropolitan area is a relatively easy procedure requiring only traffic counts and street mileage measurements. Where no breakdown by vehicle type is required, a rather small manpower investment is required.

The results of such estimation are not only valuable in themselves but have other important uses, notably as an accuracy check of origin-destination study trip data. Another use, not discussed in this paper, is to verify and to compare with the output from certain traffic assignment programs.

Recommendations

In future work of this kind, particular attention should be paid to improving the techniques of count location selection. This is especially true where a sample is taken for updating existing, arterial flow maps (as in Chicago), or for obtaining counts on local streets (as in both Chicago and Pittsburgh); but it is also true with regard to the exact count locations on specific route sections wherever these run to rather long lengths.

At the same time, consideration should be given to long-range programming and to the use of either repetitive or accumulative count locations. In Chicago, since the original work described in this paper, two more "samples" have been drawn making four in all, and it is expected that an annual census-taking of the daily vehicle-miles of travel will become a feature of the continuing transportation agency.

The scheduling of counts over the period of count taking should be explicitly related to the problem of factoring counts to the average for a particular time period; for example, to the average annual daily traffic.

To conserve cost, great care should be taken in the scheduling of manual classification counts. This should be kept to the minimum possible, and a technique of short counts employed wherever feasible.

Where the results of this kind of work are used as an accuracy check of origin-destination study trip data, there is a great need for more reliable information concerning over-the-road trip lengths. This may be obtained from a sub-sample of home-interview trip respondents in several ways and should prove useful as well for deriving so-called diversion curves appropriate to particular areas.

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