ANALYSIS OF URBAN AREA TRAVEL BY TIME OF DAY

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This research project is a thorough analysis of the temporal distribution of vehicular travel in eight U.S. urban areas having populations of 100,000 to 3,500,000. Graphical models were developed during the analysis, and travel data from St. Louis are presented in detail along with tabular and graphical outputs of data for each of the other cities. Programs were developed that summed the total number of persons in motion and the total vehicle-miles of travel occurring every tenth of an hour for a 24-hour period. Five submodels were used to aggregate hourly travel into similar time groups: wee hours, morning, midday, afternoon, and evening. Areawide traffic count data were used to determine total vehicle-miles of travel occurring on various classes of highway, and at varying distances and orientations from the central core city, on directional and nondirectional bases.

•HIGHWAY congestion is a generally recognized problem of the U.S. transportation system in urban areas. Every major metropolitan area suffers some form of roadway congestion during peak use periods. The levels of congestion are directly related to the fact that total vehicular travel is not uniform throughout the 24 hours of the day; yet, for the most part, the supply of transportation service is uniform.

Traffic congestion and the associated problems of limited highway capacity and travel delays occur during the peak periods of the day, most noticeably in the afternoon hours of 4 to 7 p.m. when 40 to 42 percent of the daily vehicular traffic occurs. The second, and often very pronounced, short-term peak occurs in the morning hours between 7 and 9 a.m. In these two periods of relatively short duration, the capacity of the highway system is often approached. However, for most of the day, the capacity of the transportation system far exceeds the level of highway traffic.

The cost of highway investment is directly related to this peaking phenomenon. Indeed, if it were not for this peaking in traffic demand, the required highway investment could be considerably less than it is now or than it is anticipated to be in future years. Consequently, urban planners acknowledge the need to develop a complete understanding of urban travel behavior and associated temporal characteristics so as to analyze and evaluate alternative levels of transportation investments.

RESEARCH APPROACH

City Selection

An extensive effort was undertaken to contact state highway departments and local planning agencies of more than 50 urban areas in 26 states. Care was exercised in this selection of areas to ensure that the cities that were selected were representative of U.S. urban areas. Extensive data collection was undertaken in 20 of these cities, and a final choice was narrowed to the following cities: Boston, Massachusetts; Louisville, Kentucky; St. Louis, Missouri; Seattle, Washington; Oklahoma City, Oklahoma; Stockton, California; Fall River, Massachusetts; and Colorado Springs, Colorado. Data were also obtained for Manchester, New Hampshire, for checking the analysis. The geographical distribution of these eight cities is shown in Figure 1, and their descriptive characteristics are given in Table 1. The selection process resulted in a good cross section of large, medium, and small urban areas with a reasonable representation of high and low population density, high and low 24-hour modal split, geographic distribution, and age of central city.

Phase A: Area-Wide Analysis of Travel by Time of Day

Phase A involved the analysis of the hourly distribution of person-trips and travel by trip purpose and mode as reported in the base-year origin-destination (O-D) survey of each of the urban areas. Standard survey record files numbers 2, 3, 4, and 5 of the home-interview survey, external cordon line interview survey, truck survey, taxicab survey, and interzonal skim distances over minimum time paths for the base-year highway network all were utilized.

Phase A data processing included the tabulation for the survey files of trips in motion by time of day and of vehicle-miles of travel by time of day. Only the distributions of total vehicle-miles of travel were fully analyzed and graphical relations or models researched and calibrated. Five periods of the day were selected: wee hours (midnight to 5 a.m.), morning (5 to 9 a.m.), midday (9 a.m. to 2 p.m.), afternoon (2 to 8 p.m.), and evening (8 p.m. to midnight). After some experimentation, these groups were established, and models for each hour, or combination of hours in each period, were developed that related percentage of vehicle-miles of travel to the following socioeconomic characteristics: population, degree of compactness, and volume-capacity (V-C) ratio.

Phase B: Analysis of Travel by Time of Day for Specific Facility Types and Locations

The selection of the study areas for the phase B analysis was conducted in parallel with the phase A selection process. Traffic count data were collected for nine areas, of which three were later dropped, leaving the six locations of Boston, St. Louis, Louisville, Seattle, Stockton, and Fall River. Data for Manchester were collected also for use in checking the analysis with the six cities. Data assembled consisted of hourly traffic counts from throughout each urban area for the same year as the study area's O-D survey and the preceding for following years, if available. The data obtained were nondirectional vehicle counts, directional vehicle counts, and classified counts depending on availability. Overall, nondirectional counts for approximately 2,000 locations were obtained for the six study areas and subsequently processed into a common format for analysis purposes. Stratification of highway facility by type, location, and orientation to city center is given in Table 2.

The data obtained and processed are representative of April, May, September, or October traffic and are generally typical of an average weekday. The traffic data assembled consisted of approximately 35 to 50 percent of the total traffic in the selected urban area.

PHASE A: AREA-WIDE ANALYSIS OF TRAVEL BY TIME OF DAY

The hourly distribution of vehicle-miles of travel in a typical urban area, St. Louis, is shown in Figure 2 for internal automobile driver travel by purpose (home-based work, nonwork, and non-home-based). Internal automobile driver, taxicab, trucks, and total internal and external vehicle distribution are shown in Figure 3.

The peak hour for total vehicle-miles of travel is from 4 to 5 p.m. Both total automobile driver and total truck travel also peak in this hour. Internal home-based work automobile driver trips peak between 7 and 8 a.m. and between 4 and 5 p.m., but home-based nonwork automobile driver trips peak between 7 and 8 p.m. Internal taxicab trips peak between 7 and 8 a.m. In conclusion, although 4 to 5 p.m. is the peak travel period, considerable variation in the travel distribution occurs depending on the purpose of travel (work, nonwork, non-home-based) and mode (automobile, taxicab, and truck) of vehicular travel.

The distribution of travel varies among cities. The explanation for this variation is described in the results of the models developed for total vehicular travel. In

Figure 1. Geographical distribution of cities analyzed in time-of-day study.

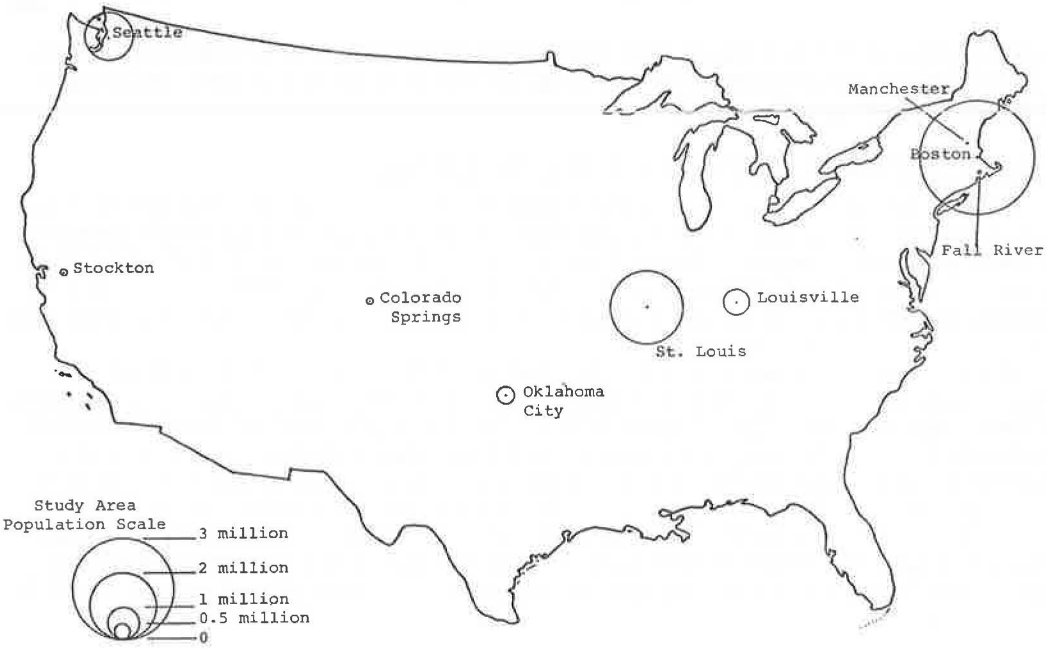


Table 1. Study area descriptive statistics.

Urban Study Area and Year	Total Population	Total Employment	Automobiles Owned	Gross Land Area (square miles)	24-Hour V-C Ratio[a]	24-Hour Modal Split (percent)	Employment Compactness Ratio[b]	Population Compactness Ratio[c]	Density Ratio[d]
Boston (1963)	3,541,000	1,297,000	1,066,000	2,500	0.04	11.9	0.45	0.30	10.0
St. Louis (1965)	2,175,000	878,000	758,000	1,640	0.48	5.1	0.48	0.30	7.9
Seattle (1961)	1,373,000	465,000	520,000	1,000	0.49	5.6	0.43	0.40	5.0
Louisville (1964)	752,000	310,000	249,000	910	0.44	6.0	0.69	0.70	10.0
Oklahoma City (1965)	564,000	229,000	231,000	1,250	0.30	0.8	0.81	0.75	1.5
Colorado Springs (1964)	174,000	48,000	68,000	290	0.23	1.4	0.60	0.55	3.5
Fall River (1963)	138,000	46,000	49,000	110	0.59	2.0	0.90	0.75	2.1
Stockton (1967)	170,000	56,000	66,000	190	0.26	1.1	0.66	0.56	4.2
Manchester (1964)	113,000	38,000	35,000	220	0.30	3.2	0.93	0.80	5.3

[a]V-C ratio = 24-hour vehicle-miles of travel (excluding school trips) divided by 10 times the hourly capacity.
[b]Employment compactness ratio = central city employment divided by study area employment.
[c]Population compactness ratio = central city population divided by study area population.
[d]Density ratio = central city population density divided by study area population density.

Table 2. Stratification of highway facilities.

Cell Number	Description of Facility: Type of Facility	Facility Location	Orientation to Center of Study Area[a]
1	Freeway	Central core	All orientations
2	Expressway	Central city	Radial
3	Expressway	Central city	Circumferential-crosstown
4	Expressway	Suburb	Radial
5	Expressway	Suburb	Circumferential-crosstown
6	Expressway	Rural	Radial
7	Expressway	Rural	Circumferential-crosstown
26	Expressway	Other subcenter	Radial
27	Expressway	Other subcenter	Circumferential-crosstown
8	Arterial	Central core	All orientations
9	Arterial	Central city	Radial
10	Arterial	Central city	Circumferential-crosstown
11	Arterial	Central city	Feeder to expressway
12	Arterial	Suburb	Radial
13	Arterial	Suburb	Circumferential-crosstown
14	Arterial	Suburb	Feeder to expressway
15	Arterial	Rural	Radial
16	Arterial	Rural	Circumferential-crosstown
17	Arterial	Rural	Feeder to expressway
18	Arterial	Other subcenter	Radial
19	Arterial	Other subcenter	Circumferential-crosstown
20	Arterial	Other subcenter	Feeder to expressway
21	Collector	Central core	All orientations
22	Collector	Central city	All orientations
23	Collector	Suburb	All orientations
24	Collector	Rural	All orientations
25	Collector	Other subcenter	All orientations

[a]Or to center of subcenter, as applicable.

modeling, the distribution of total vehicle travel was considered. Thorough analysis and modeling of the five component distributions (i.e., internal automobile, taxicab, and truck and external automobile and truck) would probably improve understanding of the total vehicle distribution and should be undertaken when the opportunity presents itself. In the present analysis, for example, knowledge of the distribution of home-based work internal automobile driver trips was very useful in the interpretation of the peak-period portions of the total vehicle distribution.

After some preliminary comparison of the study areas' travel on a strictly chronological basis (i.e., the same time period for all study areas), it became obvious that comparisons were better made between time periods of comparable functional significance. Analysis of the distributions, expressed in the standardized hour periods led to the conclusion that the best comparisons would be obtained by assembling groups of hours of similar character (Table 3).

The cumulative percentage of travel in each of these groups of hours for all eight study areas is shown in Figure 4. After rank-ordering the hours by percentage of daily travel within these groups, models were developed for all 24 1-hour periods. Individual attention was paid to the 3 highest hours of the afternoon and 4 of the morning. The remaining hours were treated primarily as groups or were derived in proportion to other hours. This approach allowed some interesting detailed analysis of the most significant hours, although aggregating the lesser hours of diverse character at a tractable level.

The characteristics of the study areas that proved most definitive in this analysis were the study area size, as measured by population, and the level of congestion on highway facilities, as measured by the 24-hour ratio of volume to capacity for the urbanized portion of the study area. Congestion levels were obtained from the overall 24-hour modal split, which proved useful in some instances. In the morning peak period, a measure of population centralization proved most significant. This measure was taken as the ratio of central city population to study area population. A similar ratio of employment was actually preferred, but the two ratios were very highly correlated with each other, and population was held to be the more readily obtainable of the two statistics.

With only eight study areas, it was virtually impossible to include more than three variables in the development of any model, and generally only two were useful. It is entirely possible that inclusion of more study areas in this investigation could result in a revised shape of the models and perhaps allow use of other secondary variables to account for some of the situations that did not model well with present variables. Particular attention was given therefore to the reasonableness and internal consistency of the models developed, for the greatest confidence in the shape of the curves as currently modeled. A description of the individual models developed is as follows.

Wee Hours Period

Travel during this period is of very little consequence, amounting to approximately 2.4 percent of the total daily travel. An attempt was made to correlate the variations with several descriptive variables, but it was not successful. Therefore, 2.4 ± 0.6 percent of the average value for these eight study areas is recommended for the total amount of travel during the wee hours. The average breakdown by hours is as follows:

Hour	Average Percentage of Total Daily Travel
12 p.m. to 1 a.m.	0.75
1 a.m. to 2 a.m.	0.50
2 a.m. to 3 a.m.	0.35
3 a.m. to 4 a.m.	0.30
4 a.m. to 5 a.m.	0.50

Morning Period

The 3 highest hours were modeled by lumping together the 2 highest hours, splitting

Figure 2. Hourly distribution of vehicle-miles of internal auto driver travel by purpose.

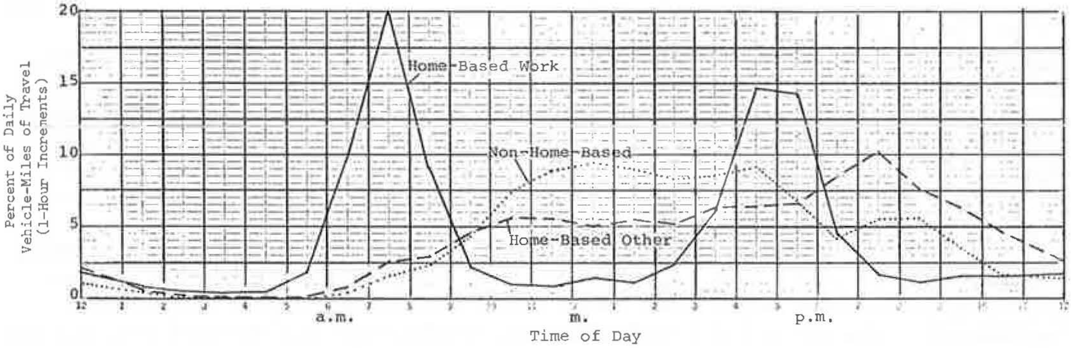


Figure 3. Hourly distribution of vehicle-miles of internal automobile driver, taxicabs, trucks, and total internal and external vehicles.

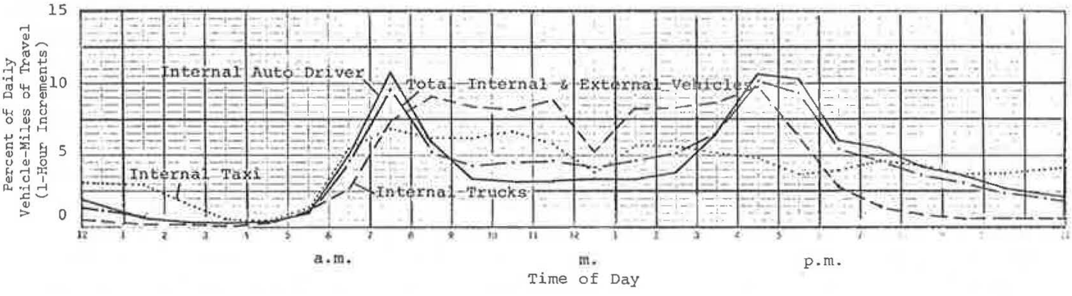


Table 3. Total vehicular travel from O-D surveys summarized in standardized hour periods.

Standardized Time Period	Percentage of Daily Travel Occurring in Each Time Period Boston (+0.5)*	St. Louis (+0.2)	Seattle (+0.4)	Louisville (+0.5)	Oklahoma City (+0.6)	Colorado Springs (+0.1)	Stockton (+0.9)	Fall River (+0.3)
Morning								
5 to 6 a.m.	1.81	1.80	1.76	2.83	1.65	1.49	3.18	1.83
6 to 7 a.m.	6.52	6.04	6.23	7.03	6.61	4.77	6.57	5.62
7 to 8 a.m.	8.80	9.52	8.58	8.01	8.75	6.71	6.52	8.67
8 to 9 a.m.	5.47	5.38	4.98	4.97	5.26	4.64	5.03	5.22
Midday								
9 to 10 a.m.	4.72	4.37	4.53	4.82	5.05	4.84	5.28	4.69
10 to 11 a.m.	4.75	4.53	4.95	4.67	5.14	5.34	5.65	4.89
11 a.m. to noon	4.85	4.51	5.08	4.93	5.41	5.85	5.89	5.21
12 to 1 p.m.	4.81	4.33	4.95	4.89	5.58	6.27	5.82	5.51
1 to 2 p.m.	5.13	4.72	5.17	5.13	5.64	5.80	6.09	5.38
Afternoon								
2 to 3 p.m.	6.08	5.35	6.39	6.14	6.47	6.15	7.29	5.45
3 to 4 p.m.	7.64	7.29	8.09	8.52	7.98	7.27	8.47	7.03
4 to 5 p.m.	10.52	10.79	10.62	9.67	10.73	10.26	9.67	9.09
5 to 6 p.m.	7.44	8.10	7.17	6.94	7.38	7.92	6.39	6.78
6 to 7 p.m.	5.30	5.19	4.96	4.81	5.35	5.36	4.95	6.02
7 to 8 p.m.	4.40	4.48	4.19	4.22	3.60	4.93	2.99	5.45
Evening								
8 to 9 p.m.	3.36	3.49	3.28	3.53	3.07	3.70	2.48	4.36
9 to 10 p.m.	2.69	2.91	2.66	2.69	2.32	2.60	2.03	3.40
10 to 11 p.m.	2.29	2.33	2.13	1.80	1.40	2.09	1.67	2.41
11 p.m. to midnight	1.43	1.87	1.62	1.50	0.81	1.59	0.99	1.40
Wee hours								
12 to 1 a.m.	0.72	1.16	1.10	0.87	0.52	0.89	0.69	0.54
1 to 2 a.m.	0.39	0.62	0.51	0.49	0.36	0.47	0.48	0.27
2 to 3 a.m.	0.24	0.41	0.29	0.43	0.26	0.28	0.39	0.20
3 to 4 a.m.	0.22	0.33	0.20	0.41	0.21	0.24	0.52	0.18
4 to 5 a.m.	0.46	0.51	0.42	0.75	0.41	0.50	0.94	0.46
Total	100.04	100.04	99.86	100.00	99.96	99.96	99.98	100.06
Period subtotals								
Wee hours	2.03	3.03	2.52	2.95	1.76	2.38	3.02	1.65
Morning	22.60	22.74	21.55	22.85	22.27	17.61	21.30	21.23
Midday	24.25	22.47	24.68	24.39	26.82	28.10	28.73	25.68
Afternoon	41.38	41.20	41.42	40.30	41.51	41.89	39.76	39.82
Evening	9.77	10.60	9.69	9.52	7.60	9.98	7.17	11.57
Offset morning period								
Peak minus 2 hours	2.24	2.01	1.93	2.84	2.27	1.74	3.63	2.00
Peak minus 1 hour	5.01	5.43	5.29	6.13	4.78	4.39	4.59	4.65
a.m. peak hour	9.11	9.60	8.93	8.31	9.47	6.75	7.46	9.09
Peak plus 1 hour	6.24	5.70	5.40	5.57	5.75	4.73	5.62	5.59

*Offsets from actual p.m. clock hours shown in parentheses below each location.

that sum into two parts, and separately modeling the third hour. The model for the top 2 hours is shown in Figure 5 with the portion allocable to the higher hour shown in Figure 6. Increasing population size is seen to cause an increase in the percentage of daily travel in this 2-hour period, a consequence of more extensive home-to-work tripmaking and longer trip lengths in the larger metropolitan areas. The impact of greater diffusion of the population base (and also the employment base) was also noted and used to account for the relatively low level of travel in Stockton and Colorado Springs as compared to Fall River, all of which are of comparable size.

The fraction attributable to the higher hour of these two is seen to be higher for the smaller study areas, decreasing as population increases (Fig. 6). This corresponds to the concept of the occurrence of rather broad peak periods in large metropolitan areas and narrower, sharper peaks in small study areas. This suggests a number of effects: One is congestion, which is usually worse in large areas; another is the greater diversification of activities in a large study area, promoting diffusion of trip-making away from a specific peak hour; and a third is that travel develops earlier in large areas because of the longer time required by many commuters to travel to work in large metropolitan areas as compared to travel time in small areas. It is very interesting to note that, in the home-based work travel distributions for Stockton and Louisville, there are two distinct start times for work shifts in these two areas, separated by 1 hour. This split of starting times had a marked effect in reducing the peak-hour percentage of travel, making the 2 top hours more closely equal.

The percentage of daily travel in the third highest a.m. hour is very nearly a constant 4.5 to 5 percent for all study areas, increasing slightly for larger study areas.

The fourth hour, split before and after the 3 high hours, is quite low in volume and proved to be difficult to relate to any meaningful region-wide descriptive variable. A constant value of 2.2 percent was determined as the appropriate average value to assign for this hour. It was applied with reasonable accuracy in most cases.

Midday Period

Travel in this time period is basically for non-work-related trip purposes and was found to be a function of population and V-C ratio. The population impact was the reverse of the situation in the peak periods, as might be expected. Small cities may be characterized as having less diverse travel patterns, more to-and-from-home-for-lunch trips, and travel is more restricted to daytime hours, whereas large metropolitan areas continue to show activity and, hence, travel in the evening hours. Thus, the midday percentage of daily travel decreases as population becomes larger. Although the fraction of daily travel may be less in larger areas, the amount of vehicular travel remains significant because the daily total is quite large. Thus, the impact of increasing daily congestion levels continues to force a reduction in the percentage of travel during the midday period. The instantaneous V-C ratio may not be as high during the midday as during the peak periods, but it is still larger than during the evening period.

The model for the aggregate percentage in this 5-hour period is shown in Figure 7. There is so little meaningful variation among the hours in this group that it is unimportant to model them explicitly. Dividing the aggregate percentage by five yields an average hourly percentage that may be taken as within ±10 percent of all hourly values for the period.

Afternoon Period

The 3 highest hours of this period constitute the p.m. peak period. Each of these 3 hours had been successfully modeled independently. Total study area population and the ratio of area-wide daily volume to capacity are the major variables. Modal split is slightly noticeable in the 2 highest hours but not in the third. This is an acceptable finding because it is only in the most highly congested times (peak hour) that significant diversion of trips to public transportation takes place. It is important to note here that a large modal split may occur as a consequence of high congestion, as represented by V-C ratio.

Figure 4. Cumulative percentage of total travel occurring in each group of hours for each city.

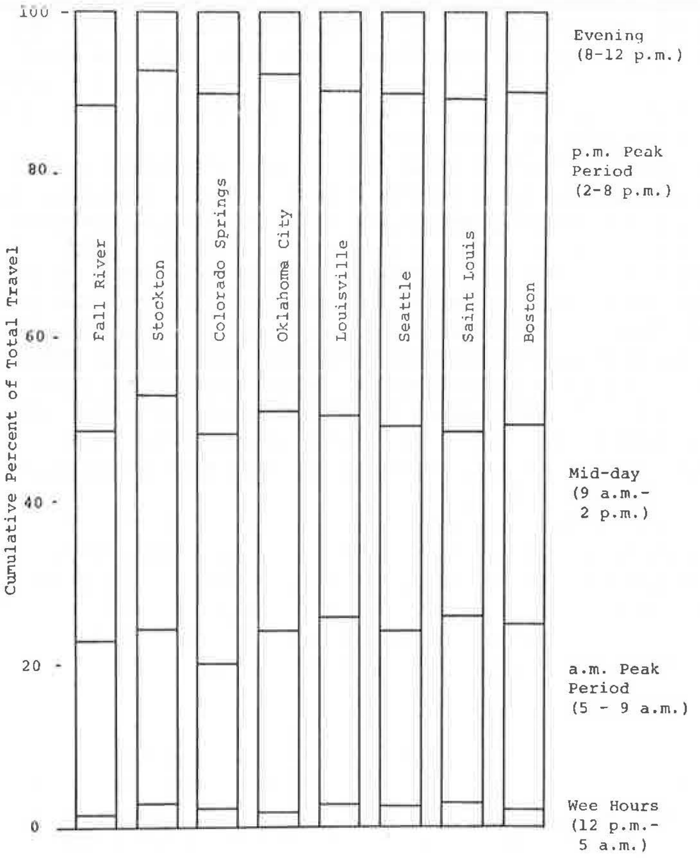
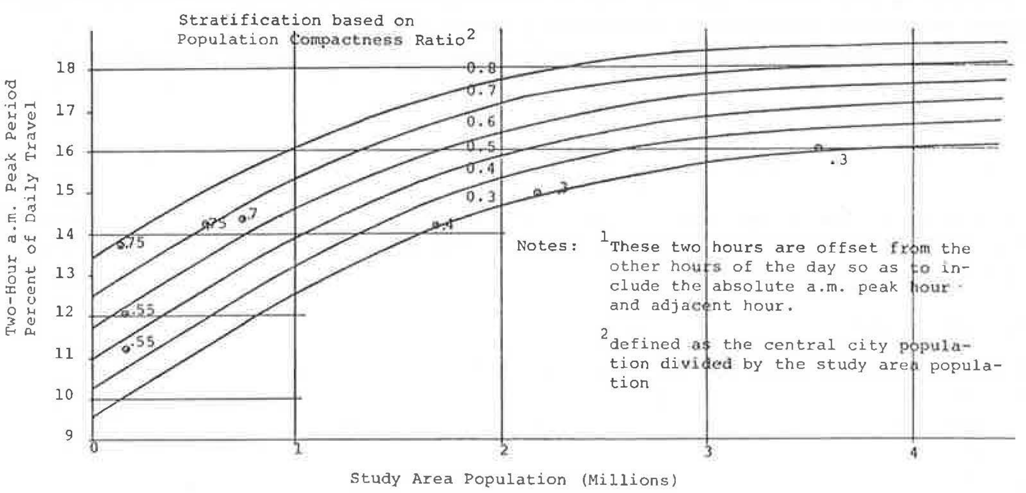


Figure 5. Percentage of travel in morning 2-hour period.



The relations between hourly travel percentages and the regional descriptive variables are shown in Figures 8, 9, and 10 for the 3 highest hours. The form is similar to the morning peak period curves, except that the V-C ratio replaces population compactness ratio. The percentage generally increases with increasing population, again reflecting diversity of travel purposes and patterns in larger areas, whereas increasing congestion lowers the percentage ostensibly forcing some travel to occur in hours that the drivers might not have freely chosen.

The lower 3 hours of this period happen to occur in the early evening, for the most part, and include some of the travel presumed to be deferred from the peak period. Figure 11 shows how each of these 3 hours is derived as a percentage of the highest hour in the group (p.m. peak hour). Population enters mildly, but otherwise the factors are nearly constant from all study areas. Note that the first of these decreases with increasing population, representing the immediate reaction to the previous peak hours, and that the next 2 hours gradually shift back to the familiar positive trend.

As checks on overall accuracy of the modeling, the sum of these latter 3 hours should work out to be approximately 15 percent. The eight study areas all fall in the range of 14 to 16½ percent. Similarly, the range for the sum of all 6 hours was found to be from 39½ to 42 percent, which can also be used as a check.

Noteworthy phenomena in this 6-hour group include the split-peak aspect of the Lousiville and Stockton distributions and the fact that Stockton and Colorado Springs are frequently quite different in their distributions although they are practically identical with respect to most study area descriptive variables.

It has been assumed in developing the factors for the lower 3 hours that an erroneously high percentage would be modeled for the peak hour of Louisville and Stockton, and thus the lower hours are modeled to be factored from this value. The second highest hour, as predicted by this model, is as low in such cases as the first hour is high.

The difficulties in matching up the data from Colorado Springs and Stockton emphasize the fact that either the data contain errors or there are other as yet unknown variables that could differentiate between these cities, given more intensive research in this area.

Evening Period

All attempts to model this period accurately were fruitless. In every case, two or three of the eight study areas were misrepresented by 30 to 50 percent, whereas the others were well represented. In consequence, it is proposed that this 4-hour period be assigned a flat value of 9.5 percent. Some of the smaller study areas had values as much as 2 percent above or below this level, but no variable was found that could describe these variations. Attempts were made to correlate this period to the V-C ratio, midday period's percentages, morning period's percentages, and evening period's percentages. All proved particularly incapable of satisfactorily representing some of the small urban areas.

Given the 4-hour total as allocated by the preceding method, it is possible to distribute accurately this percentage among the 4 hours. A rather linear decline was noted from the highest to the lowest of these hours in all cases. Only the slope, or rate of decay, varied among the study areas. As would be expected, travel diminishes most rapidly for small areas and most slowly for the large areas where there is much more late-night activity. The decrease per hour, δ, is to be used as follows:

$$\text{Highest hour} = \frac{\text{total percentage}}{4} + \frac{3}{2}\delta$$

$$\text{Each lower hour} = \text{preceding hour} - \delta$$

These rank-ordered hours were in most cases also in chronological order from 8 p.m. to midnight.

Figure 6. Morning peak-hour fraction of 2 highest morning hours.

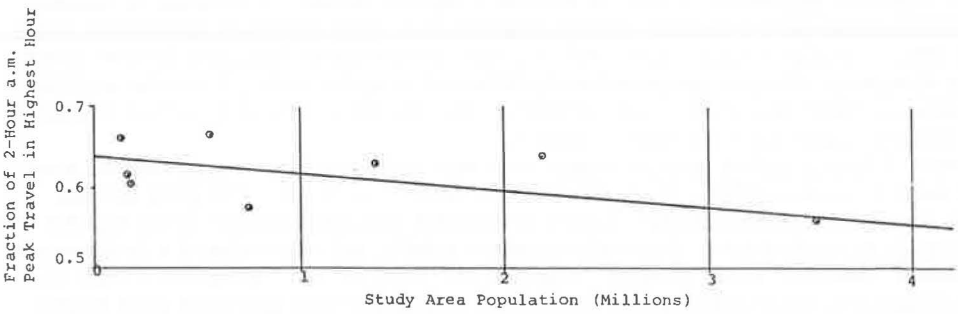


Figure 7. Percentage of total travel in 5-hour midday period.

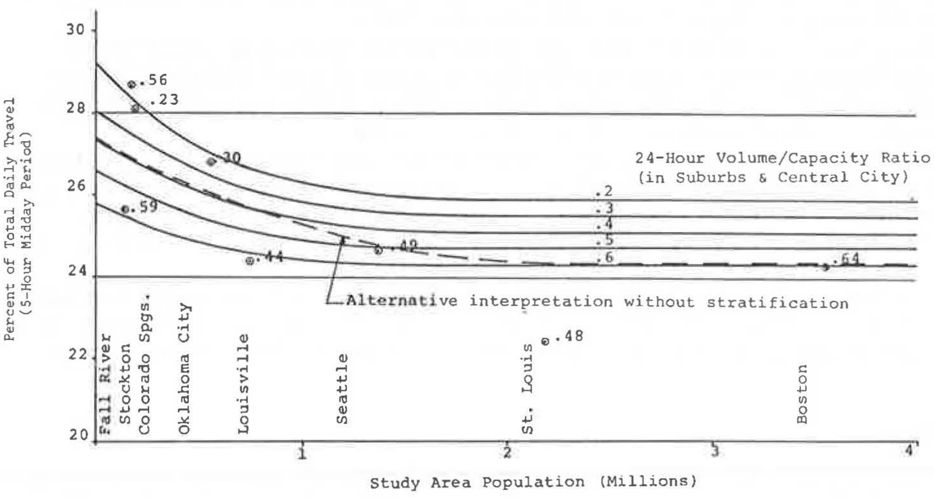


Figure 8. Percentage of total travel in p.m., highest hour.

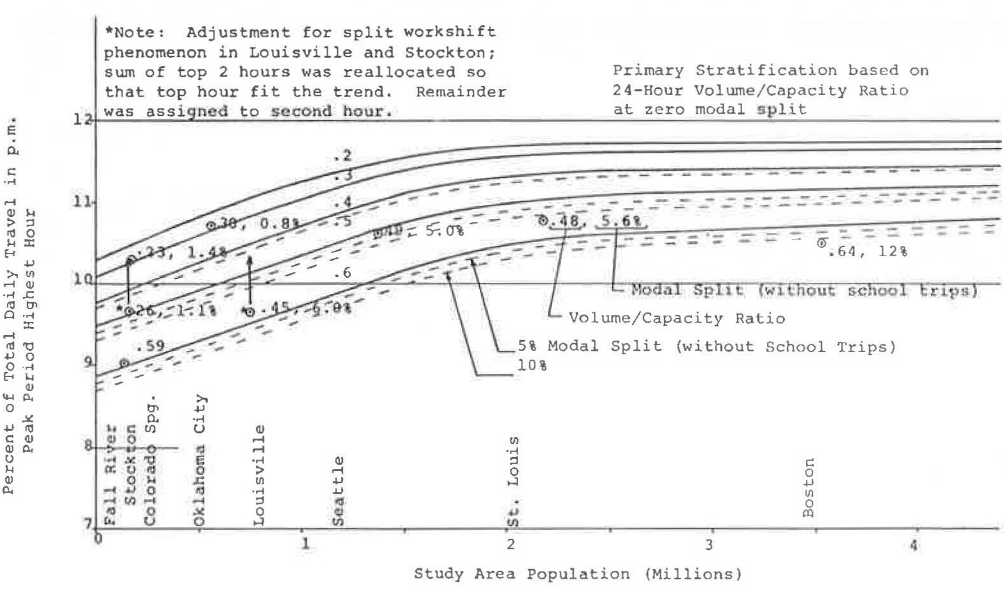


Figure 9. Percentage of travel in p.m., second highest hour.

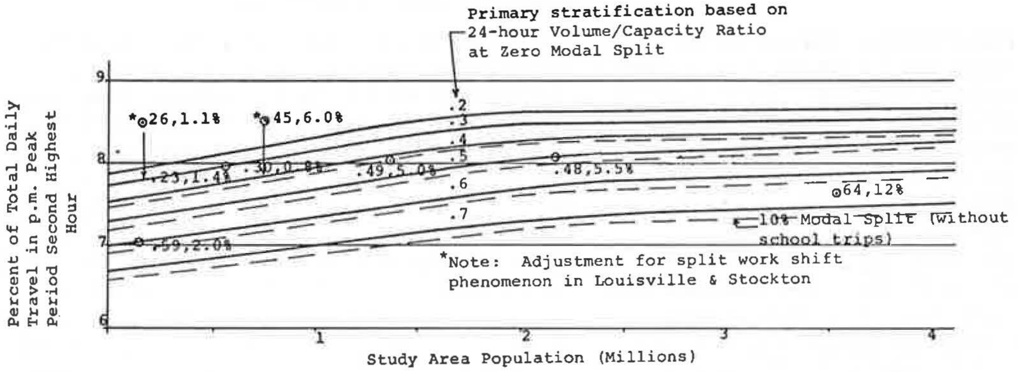


Figure 10. Percentage of total travel in p.m., third highest hour.

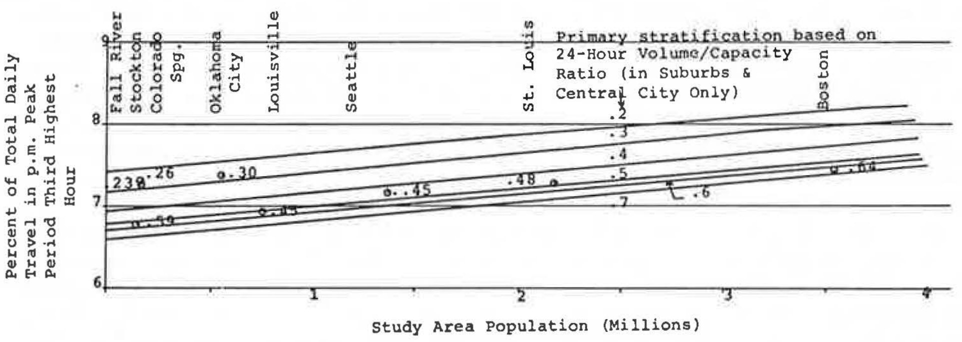
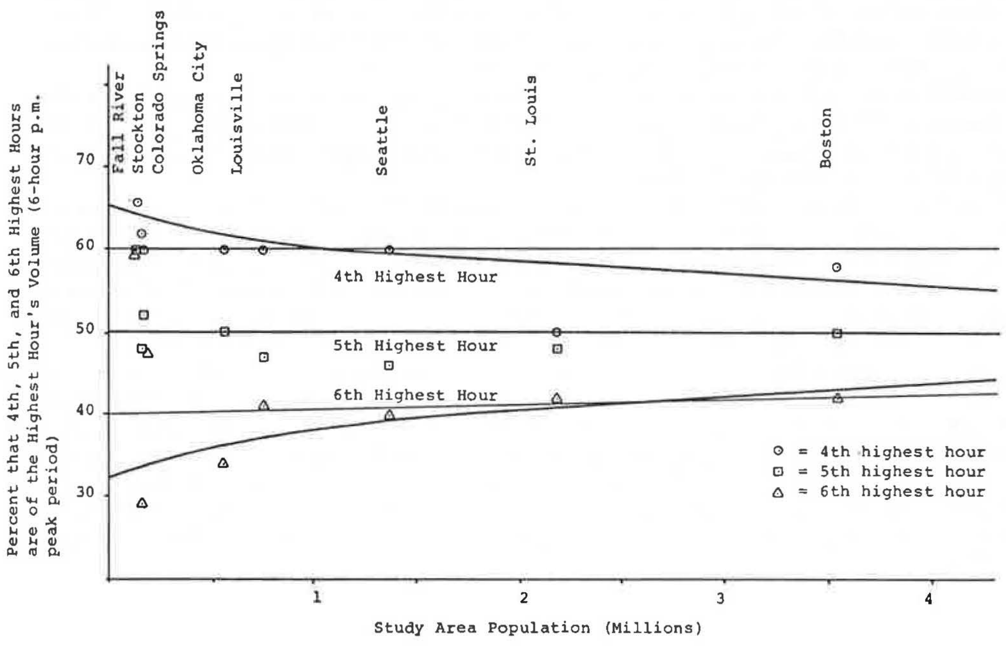


Figure 11. Percentage of travel in p.m., 3 lowest hours.



PHASE B: ANALYSIS OF TRAVEL BY TIME OF DAY FOR SPECIFIC FACILITY TYPES AND LOCATIONS

The temporal distribution of total vehicular travel, as measured from area-wide coverage traffic counts, was conducted in two separate steps. The first was to disaggregate the 24-hour area-wide total vehicular travel into the 27 classes of highway facilities used in this research investigation. The second step involved the development of hourly distributions for each of the 27 classes (where data existed) for 2,000 urban area locations and the further disaggregation of the distributions according to predominant direction of travel within each cell, again subject to the availability of data (Table 2).

The modeling procedure used to allocate the 24-hour total vehicular travel to the 27 classes of highway facilities was structured such that the total vehicular travel by classifications that were outside the current urban-in-fact area (e.g., the rural area and other subcenters within the urban transportation area) were removed at the beginning. The total vehicular travel on collector facilities within the urban-in-fact area was removed next.

Series of submodels were developed for the temporal distributions of travel developed for each of the 27 classes of highway facilities on a nondirectional basis. The initial analysis of the distributions developed for each of the study sites indicated that major differences in temporal distribution of travel occurred within a given facility class depending on whether it was located within a small or large study area. Therefore, the submodels were further stratified into small urban areas (less than 250,000 population) and large urban areas (more than 250,000 population). This resulted in the final 41 nondirectional submodels. Another observation was from the comparison of cities, which showed that St. Louis' distribution differs from Boston's because of a lower congestion factor.

The next series of submodels took the nondirectional temporal distribution of total vehicular travel and split it in the two directions of travel. Again, as with the nondirectional submodels, the classifications were further stratified, dependent on urban size, with the stratifications the same as before. This led to the creation of 39 directional submodels. Travel in the (morning) peak direction accounted for a high of 70 percent between 7 and 8 a.m. Boston was generally higher than St. Louis, again because of the higher congestion factor.

Examples of the temporal distributions of nondirectional travel were prepared in particular for the following types of facilities: freeway-expressway, central city—radial; freeway-expressway, suburb—radial; arterial, central city—circumferential-crosstown; and arterial, rural—circumferential-crosstown.

The distributions are consistent for all the cells, and the findings generally match distributions of the area-wide analysis. Travel is low in the wee hours, peaks in the morning peak hours, falls off in the midday hours, peaks again in the afternoon hours, and then falls off in the evening hours.

The most noteworthy difference occurs between Boston and St. Louis. St. Louis' travel has a higher peak in the morning and afternoon hours and peaks about 1 hour sooner, but a lower distribution occurs midday and in the evening hours. This finding parallels closely the results of area-wide analysis because of the lower V-C ratio in St. Louis. It is recognized that Boston has higher overall congestion, and, hence, the temporal distribution tends to be more evenly distributed throughout the day.

Plots of the percentage of travel in morning peak direction distributed to time of day were prepared for directional travel. As in the case of nondirectional travel, the most significant difference in the temporal distributions is between large-city and small-city groupings. The percentage of travel in the morning peak direction is lowest in the wee hours (42 percent), falls off and then peaks again at 55 percent between 6 and 7 p.m., and drops off to 42 percent from 11 p.m. to midnight. St. Louis shows a generally lower percentage (approximately 5 percent) than Boston because of the lower level of traffic congestion.

CONCLUSION AND RECOMMENDATIONS

In general, the results of the research achieved the objectives of the program. There are, however, several areas where further research could well lead to increased knowledge and improved modeling techniques.

The first of these recommendations is to use the total vehicular travel data from the same sites as was used in this modeling effort and to expand the number of independent (causal) variables that could be used in the modeling process. For example, urban area characteristics could be disaggregated by subarea and subclass. Also, V-C ratio and perhaps modal split to transit could be calculated for time periods consistent with the modeling periods rather than on just a 24-hour basis.

The second recommendation is to include more flexibility through the use of more urban area studies. The number of study areas (eight and six used in phase A and phase B respectively) are at best the very minimum number acceptable. As it is, there are still a number of urban area types and sizes that are not represented in the data used to create the models. Also, the limited amount of information available did not allow for the independent checking of the models. For these reasons, it seems that the addition of several more sites would be appropriate.

The next recommendation would be to carry out this investigation for two or more points in time using the same study site. This effort had been intended for the original research investigation, but it was found that the time and effort required to locate and collect data in a compatible format from the older (pre-1960) studies were markedly greater than permitted by the time constraints of the research project. It would be most interesting to carry out this time-series analysis for both phases A and B. However, based on the results obtained from this study, it might be almost as interesting to carry out the analysis using only phase B data, which are considerably more available and would, therefore, be much easier to obtain than data for phases A and B together.

The final recommendation deals with attempting to obtain phase B data for a shorter time period than the 1-hour basis used, particularly during the morning and afternoon time periods. These data (perhaps on a 15-min interval basis) would allow for the identification of absolute peak hours and periods of travel as was the case in phase A. Although the differences between clock hours and absolute peak hours were not too great for area-wide data, they were acceptable. It would be expected that these differences are perhaps somewhat greater when individual facilities in the highway network are considered.

The four recommendations for further research listed previously are only a few of the possible ones growing out of this research investigation.

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