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ANALYSIS OF TRAVEL PEAKING

William Ockert and Richard Easler, Regional Planning Council, Baltimore, Maryland; and
Franklin L. Spielberg, Alan M. Voorhees and Associates, Inc.

Transportation planning simulation models have generally been structured for total daily travel. A question that has seldom been raised is the extent to which peak travel patterns differ from 24-hour patterns. This paper describes a modeling technique that can help in evaluating future transportation plans and programs by directly simulating peak-period demand. The model basically converts 24-hour trips to peak-period trips then allocates them to modes, and assigns them to networks. Analysis of the model's output indicates that the orientation of peak-period travel is significantly different from that of 24-hour travel. Nine communities within the urbanized area of the Baltimore region were chosen to illustrate peaking characteristics for different types of movements, i.e., peaking from employment areas or peaking from residential areas. Comparison showed that projected peaking changes based on base year observation cannot provide reasonably accurate estimates of future peak-period conditions. Peaking characteristics were found to change through time as a result of the uneven growth in employment and population. Based on the analysis, it is clear that peaking factors change through time and are sensitive to the distribution of urban activities. Thus, the use of the peak-period simulation model will eliminate numerous errors in estimating future travel conditions.

●THE RUSH-HOUR PROBLEM—congestion, crowding, delays, and substandard speeds—not only creates frustration and tension for travelers but also leads to economic stagnation of the urban area and thus aggravates its social problems. In the Baltimore region, nearly 40 percent of all travel occurs in only 4 hours of the day, those hours during which people must travel to or from their jobs. In fact, 60 percent of all work trips in Baltimore occur in this period (according to data derived from a 1962 origin and destination study). Thus, people making the most repetitious trips and the ones least subject to personal adjustment face the worst travel conditions.

In recent years, transportation planners and urban area system designers have focused on the development of highway and transit facilities that will satisfy long-term demand within the constraints imposed by other elements of the urban system—resources and environment, for example. The projection of demand has generally been developed by using a series of generation, distribution, modal-choice, and assignment models, the techniques of which are well known.

These models, however, have generally been structured for total daily travel, although it is recognized that the requirements for most facilities are set by the peak-period demands. Many methods have been devised to bridge the gap between 24-hour and peak-period travel. Some of these have dealt with traffic on a particular route; others have considered the entire region; some have merely extrapolated present trends. A question that has seldom been raised is, to what extent do peak-travel patterns differ from 24-hour patterns. Shifts in patterns could lead to underdesign of some facilities and excess, unused capacity for others.

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For transit system design, in particular, peak-period patterns are critical because this period constitutes the major transit travel market. In the peak, when the majority of work trips are made and when highways are most congested, transit is most competitive. Failure to recognize peak-demand patterns can lead to incorrect investment decisions.

Different land use and transportation alternatives result because of variations in the amount and location of peak-period travel. In evaluating alternatives, peak-period travel conditions encountered by various segments of the population should be taken into account. For example, concentrations of activities that generate highly peaked travel are much more likely to cause severe traffic problems than activities of the same density that produce travel spread more evenly throughout the day.

PRIOR ESTIMATING METHODS

Transportation planners are familiar with the basic methods of estimating peak demand on specific facilities. Thirtieth highest hour distributions have been in use for years as a design standard. More refined estimates using peak-hour factors, K, and directional distribution factors, D, by facility also represent a popular method that has been the focus of many studies.

These methods, although applicable to short-term design, are difficult to relate to overall travel patterns and may fail to consider the changing nature of the region. A more refined method, based on the relationship between peak-hour factors, K and D, and the percentage of work trips on each facility, has been developed (1). This method approaches an analysis of trip patterns but is still focused on individual links. Others have applied area-wide factors, or factors for subareas, to either total trips or highway and transit trips separately. These methods tend to be unresponsive to changing conditions.

The best approach, perhaps, is one that involves a separate peak-travel model set. This approach deserves more research. In practice, it has been difficult to develop stable trip generation and distribution relationships, perhaps because the proper data, such as the relationship between peak-period travel times and trip-distribution patterns, have not been available. Furthermore, this approach requires a second complete model for total daily travel, a costly luxury for many studies.

The peak-period model described in this paper does not eliminate all difficulties either in logic or in data needs. It presents an approach to the problem that appears to give reasonable results both in base-year application and in future-year projection. It is presented to acquaint others with a different technique and to indicate the factors that, in this study, were found to be significant.

ANALYSIS AND MODEL FORMULATION

In the development of a set of transportation planning and evaluation models for the Baltimore Region, it was necessary to devise a method for estimating peak-period travel that is both responsive to changing conditions over time and also reflects the different peaking levels on individual facilities in the region. The methodology selected was to directly simulate peak-period demand. The developed model deals with overall person trip patterns and examines peaking of travel by trip purpose regardless of travel mode. The model basically converts 24-hour person trip tables to peak-period person trip tables, which are then allocated to modes and assigned.

The requirement that the temporal as well as the spatial distribution be considered raises many difficult questions. It is obvious that peak travel occurs at different times in various sections of the region; that, over the peak time span, the "demand" is limited by the capacity; that factors, such as working hours that are beyond the scope of transportation planners, will influence peaking conditions; and that, for certain modes (transit in particular), the peak travel time is set in part by scheduling practices.

It was felt, however, that, for long-range planning purposes, it was neither necessary nor within the scope of data reliability to attempt to pinpoint the peak over a short duration. Rather, the peak travel over a 2-hour period was deemed sufficient for demand analysis and evaluation. Although peaks on individual facilities within this period will exceed the average 2-hour demand, they are likely to be of short duration and subject to variation with normal demand fluctuation. They are best treated by recognizing and allowing for the inherent errors in projection methodology and data.

The basic travel data for the model development were obtained in the 1962 origin and destination study conducted for the Baltimore Metropolitan Area Transportation Study (BMATS). These travel data were supplemented by social and economic data developed by the Regional Planning Council.

Analysis of the travel data revealed that, for total person trips, the peak 2-hour period of the day occurred between 3:30 and 5:30 p.m. (Fig. 1). This period includes not only the majority of trips from work to home but also many school trips, shopping trips, and trips for other purposes not found in the morning peak.

WORK TRAVEL ANALYSIS

Variables Examined

The strategy for model development involved a stratification of trips into 4 purpose categories—work, school, and other home-based, and other non-home-based. After this, an analysis was made of the degree of peaking of each purpose as related to individual variables. Among the variables examined in this stage of the investigation were trip-end variables such as production zone income, production zone residential density, attraction zone employment density, attraction zone employment composition; interchange variables such as trip time and distance; and trip-maker variables such as occupation and industry.

A comparison of the percentage of work travel in both the morning and afternoon peak periods versus the residential density in the production zone clearly indicated that there is only a slight change in peaking within density ranges.

Similar relationships were observed for other individual trip-end and trip-interchange variables. The individual variable that appeared to have the most influence on peak period travel was the industry in which the trip-maker is employed (Fig. 2).

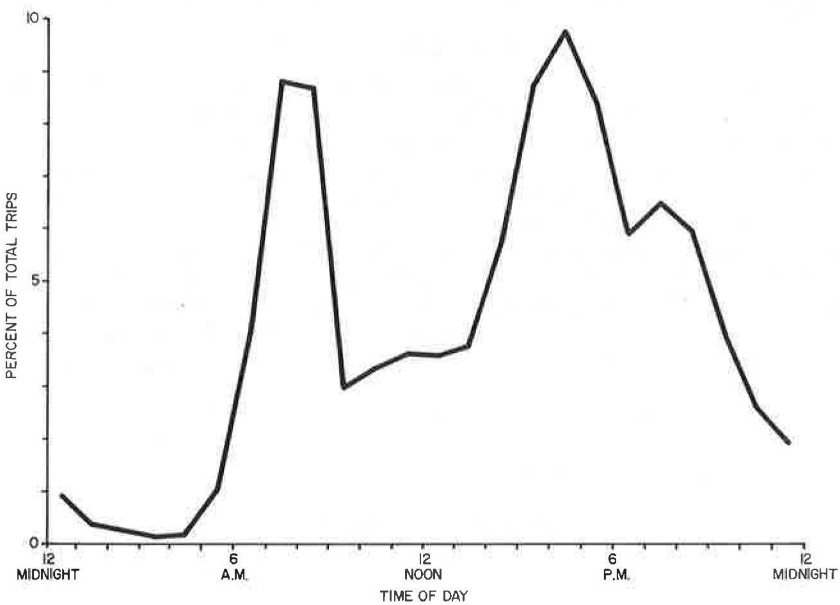

Figure 1. Person trips by reported hour beginning.

Development of Relationship

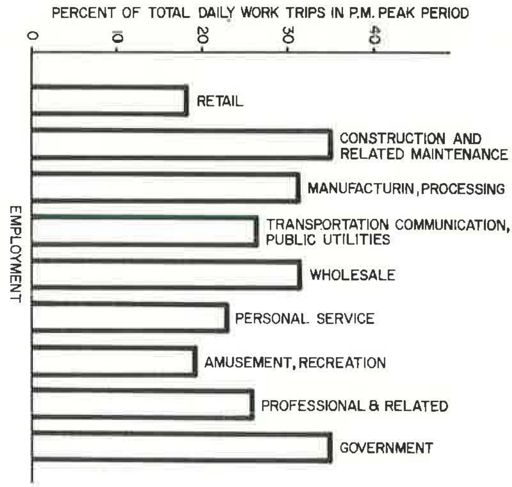

Figure 2. Daily work trips in afternoon peak period by employment of trip-makers.

Logically, those persons employed in industries (government, wholesale, manufacturing, and construction), which tend to maintain standard working hours beginning between 7 and 9 a.m. and ending between 4 and 6 p.m., have the greatest tendency to make their work trips in the peak period. On the average, more than 30 percent of their work trips are made in the afternoon peak. On the other hand, those persons employed in service industries (such as transportation, personal service, amusement, retail, and professional), which must tailor working hours to their clientele, make a smaller percentage of their work trips in the peak, approximately 20 to 25 percent.

Although the relationship between work-trip peaking and industry of each zone adequately reproduced attraction-zone peaking, the estimates by production zone were biased, apparently due to the spatial differences in the income of residents. An additional variable was then introduced—the income in the trip-production zone. With this formulation, the model is a trip-interchange relationship treating each i-j trip pair separately.

With this model, there appeared to be 2 distinct types of industries—those in which peaking decreases as income increases and those that illustrate the opposite trend. Office, retail, government, and intensive industries show the former relationships, whereas service, professional, and extensive industries show the latter. This is due to the type of work related to compensation in the respective industries. Higher paid office workers are less likely to have fixed hours (or more freedom to set their own schedules), whereas the reverse is true for those in service industries.

BASE-YEAR CALIBRATION

In some instances, specific model adjustments were required: for the CBD where the trend to uniform working hours leads to somewhat different relationships; for the 2 major employment sites in the region, the Sparrow's Point steel plant with a large third shift and the headquarters of the Social Security Administration that is a specialized office operation; and for other locations, such as hospitals and Friendship Airport, that also have around-the-clock operations.

The final developed relationships for the peaking of work travel are shown in Figure 3. Tests of the model were conducted by using independently derived employment composition data from the Regional Planning Council. On the whole, the model replicated base-year peak-period travel within 1 percent, and less than 3 percent of predicted trip interchanges varied from the origin and destination survey data by more than a single sampled trip.

Figure 4 shows a further independent check—the trip-length distribution of observed and estimated peak-period work trips. This comparison is significant because highway travel time is not a variable in the model.

FORM OF THE MODEL

The model, as developed from the origin and destination data, was of the form

$$P_{it} = f(MF_i, K_t)$$

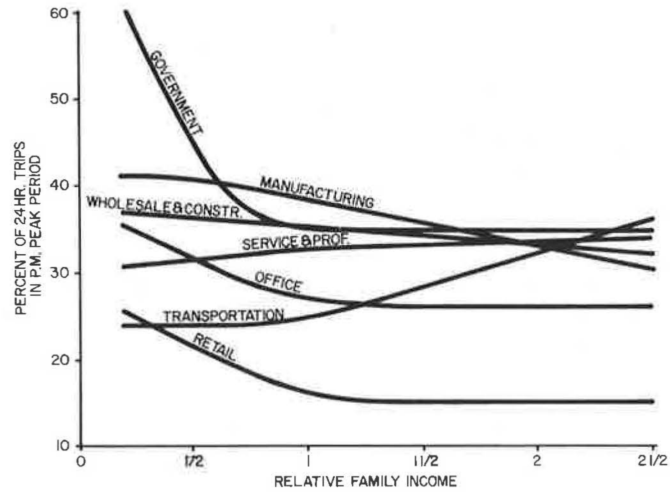

Figure 3. Travel peaking characteristics of non-CBD work trips.

where

P_{it} = percentage of total daily work trips that are produced in zone i by trip-makers employed in industry t, and that occur in the peak period;

MF_i = median family income in zone i; and

K_i = industry in which the trip-maker is employed.

Even though this type of relationship dealing with individual trip-makers can be used in model development, the application of the model to future conditions requires the use of zonal aggregate parameters. Adequate model operation is ensured also by using zonal aggregates in the testing with base-year data. These criteria were met by restructuring the model formulation to

$$P_{ij} = g(MF_i, K_j)$$

where

MF_i = median family income in zone i;

P_{ij} = percentage of total daily trips that are produced in zone i and attracted to zone j and that occur in the peak period; and

K_j = factor expressing the industrial composition of employment in zone j.

The exact formulation is given by

$$P_{ij} = \frac{E_{kj}}{{}_kE_{kj}} \times Q_{Iik}$$

where

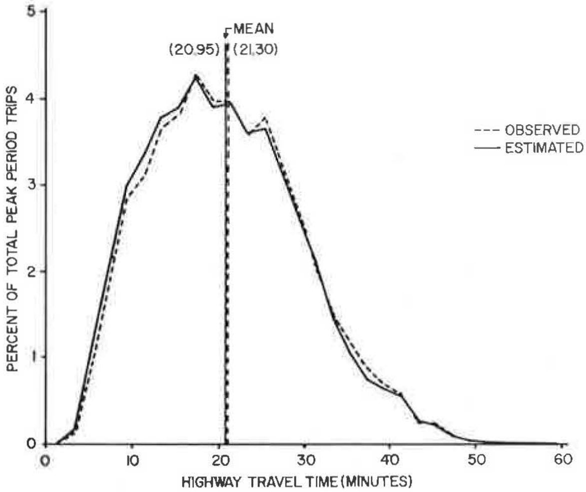

Figure 4. Observed and estimated peak period work trips

P_{ij} = percentage of total daily trips that are produced in zone i and attracted to zone j and that occur in the peak period; and
E_{kj} = number of persons employed in industry k in zone j;
${}_kE_{kj}$ = total employment in zone j;
Q_{Iik} = percentage of trips made in the peak period from zones with median family income I by trip-makers employed in industry k; and
I_i = median family income in zone i.

This equation says, in effect, that the percentage of work trips between zone i and zone j occurring in the peak period can be determined by developing the peaking factor for the median family income in zone i to each industry and then computing an average in which each factor is weighted by the proportion each industry is of the total employment in zone j.

The previously given formulation can best be explained with an example. Assume that there are 2 zones—zone i, which is the production zone (home), and zone j, which is the attraction zone (work)—and that there are 1,000 total daily work trips produced in zone i and attracted in zone j. Further assume the following zonal characteristics:

I_i = median family income in zone i = \$8,000;
E_{1j} = retail employment in zone j = 250;
E_{2j} = government employment in zone j = 200;
E_{3j} through E_{6j} = all other employment in zone j = 0;
${}_kE_{kj}$ = 250 + 200 = 450;
Q_{Ii1} = $Q_{8000,1}$ = percentage of total work trips to retail employment made in the peak period by persons living in zones with median income of \$3,000 = 0.17; and
Q_{Ii2} = $Q_{8000,2}$ = percentage of total work trips to government employment made in the peak period by persons living in zones with median in of \$8,000 = 0.37.

Therefore,

$$P_{ij} = \frac{E_{kj}}{{}_kE_{kj}} \times Q_{Iik}$$

$$= \frac{250}{450} \times 0.17 + \frac{200}{450} \times 0.37$$

$$= 0.095 + 0.164$$

$$= 0.259$$

The percentage of total daytime work trips occurring in the peak period is 25.9 percent and the number of trips is 1,000 x 0.259, or 259 trips. Thus, calibration of the model consists of determining the value of Q_{Iik} for each combination of income and employment type.

NONWORK TRAVEL

The use of industrial composition as an explanatory variable is obviously not valid for nonwork trip purposes. The relationship with income, however, appears to hold for the remainder of the home-based travel. Adult school trips are treated as work trips to a common industry showing a rising percentage of peak travel with rising incomes. For other home-based travel, income seems to be a measure of relative freedom in choosing travel time and of mobility. Those with low and high incomes make other trips in peak hours, perhaps because they are not as likely to be job-holders, whereas the middle-income populations make their shopping and recreational trips outside the peak periods. The relationships for school and other trips are shown in Figures 5 and 6.

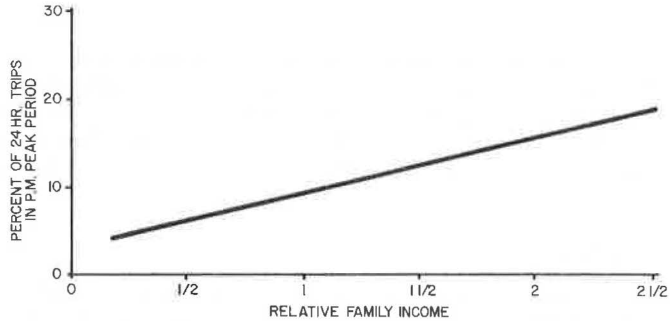

Figure 5. Travel peaking characteristics of school trips.

For non-home-based travel, the peaking percentage showed little variation about a mean value of 16 percent, and further analysis was not deemed necessary.

PEAKING ANALYSIS

A comparison of travel patterns occurring in the peak periods with total daily travel patterns indicates that the orientation of travel in these 2 time periods is significantly different. This difference is due to the wide variation in the type of interaction between various activities in the region. In many cases, the travel from one area to another is made primarily in the peak period; whereas, in other cases, the travel is spread more uniformly over the entire day resulting in less travel, proportionally, in the peak period. This phenomenon depends on the purpose of the trip and social and economic composition of the trip-makers. The highly peaked movements in the afternoon period are from areas that have high employment uses to areas that are more residential in character. This is, of course, quite logical because work-to-home trips are much higher peaked than nonwork trips and, thus, make up the largest share of these movements. The reverse movements, i.e., from residential areas to employment areas, are highly peaked in the morning and therefore much below the average in the afternoon peak period. Movements between 2 areas, both having about the same mix of employment and population, are spread out over the entire day and conform more closely to total daily travel patterns.

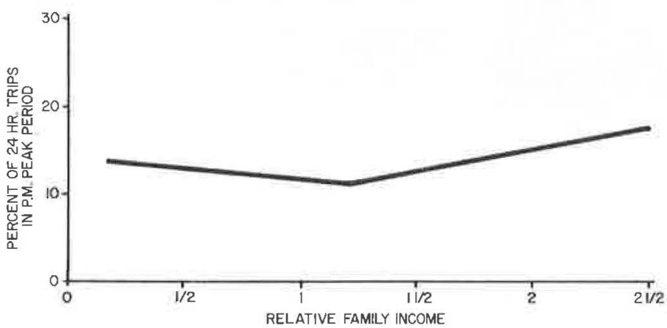

Figure 6. Travel peaking characteristics of other trips.

Method of Analysis

An extensive investigation of all future travel movements between subareas was undertaken to gain a better understanding of the peaking phenomenon. For this discussion, selected subareas, or communities, have been chosen to represent the full range of conditions. The analysis was made by comparing the peaking characteristics of individual communities, as shown in Figure 7, with the average peaking for the entire region.

Peaking From Employment Areas

Figures 8, 9, and 10 show peaking of travel made from the regional core (area 0), the Pulaski-Broening Highway industrial area (area 8), and the Friendship Airport area (area 25). Almost all movements made from these areas are far above the average peaking of 20 percent. A majority of the movements are over twice as peaked as the average. Across-the-board factoring of total daily travel movements would understate these movements by more than a factor of two. Only trips made from the Friendship Airport area to other more predominant employment areas could be described as average or below average. All other movements are at least 50 percent above average. Although not illustrated, similar peaking was found for travel generated from other employment areas in the city and counties, e.g., those with an employment-to-population ratio of 0.5 and more. Table 1 gives the average peaking of all travel made from

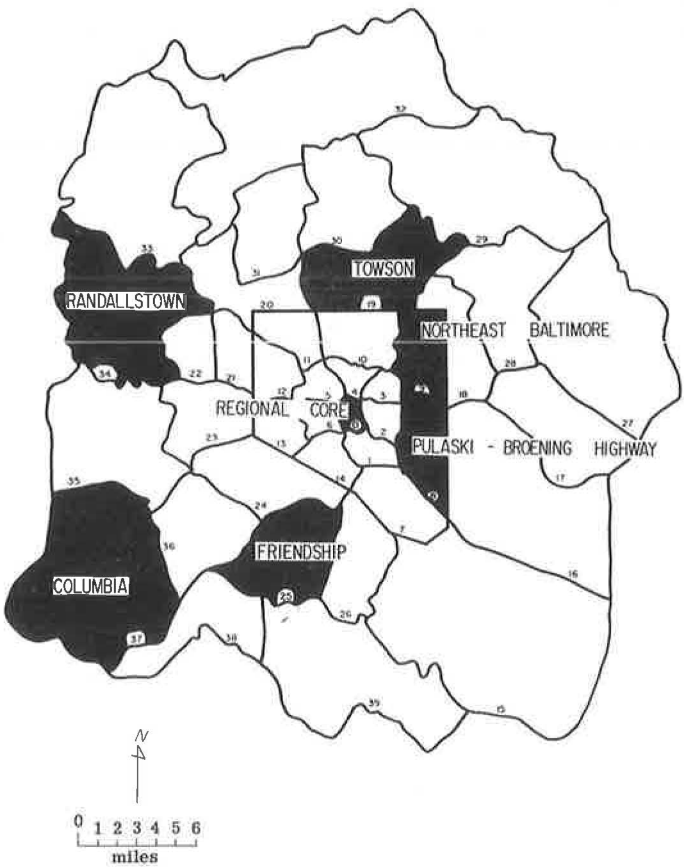

Figure 7. Communities selected to illustrate peaking characteristics.

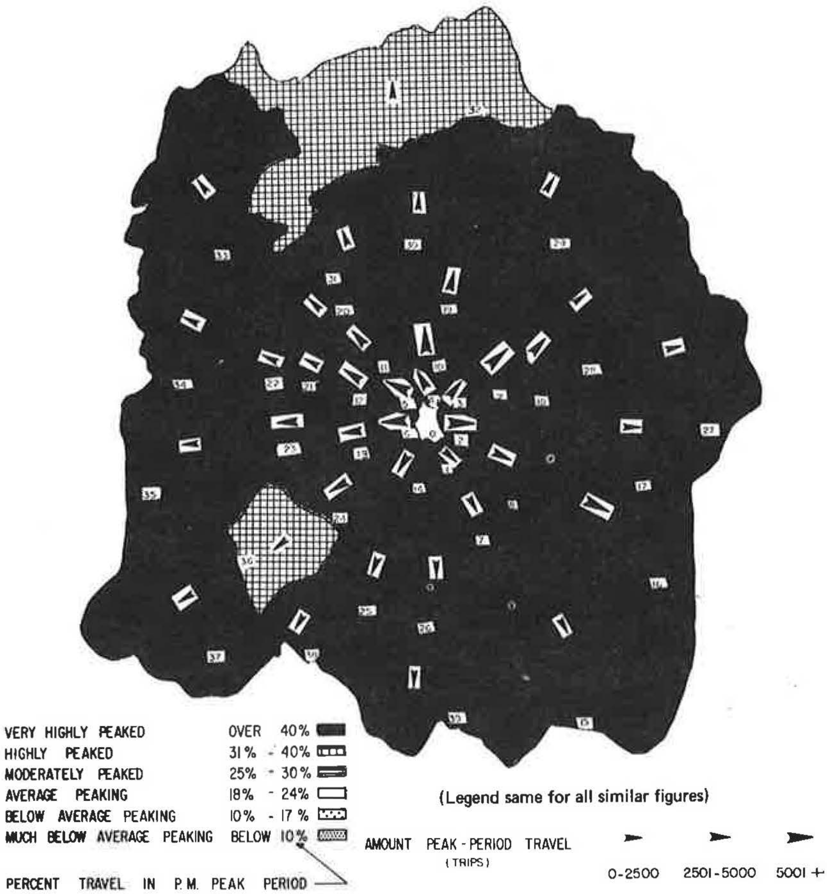

Figure 8. Peaking of 1990 travel leaving the regional core, a dominant employment community.

communities that are primarily employment areas. As can be seen, a great amount of travel would be understated by applying a uniform factor to total daily travel.

Peaking to Employment Areas

Peaking patterns of trips going to the same 3 selected employment areas are shown in Figures 11, 12, and 13. As would be expected, the reverse movements to these high employment areas are far below average in the afternoon peak period. Total daily movements factored by a uniform factor would overstate these movements by a significant amount. However, some trips made from certain city industrial areas to the Friendship Airport area are highly peaked in the afternoon because the number of workers heading to their homes in the Friendship Airport area exceeds the number of workers heading to homes in these city areas. Therefore, there is a preponderance of flow toward Friendship Airport in the afternoon.

Peaking to Residential Areas

Two communities, northeast Baltimore (area 9) and Randallstown (area 34), were selected to illustrate peaking of travel destined to residential areas. Many other communities in both the city and counties are also primarily residential and have similar

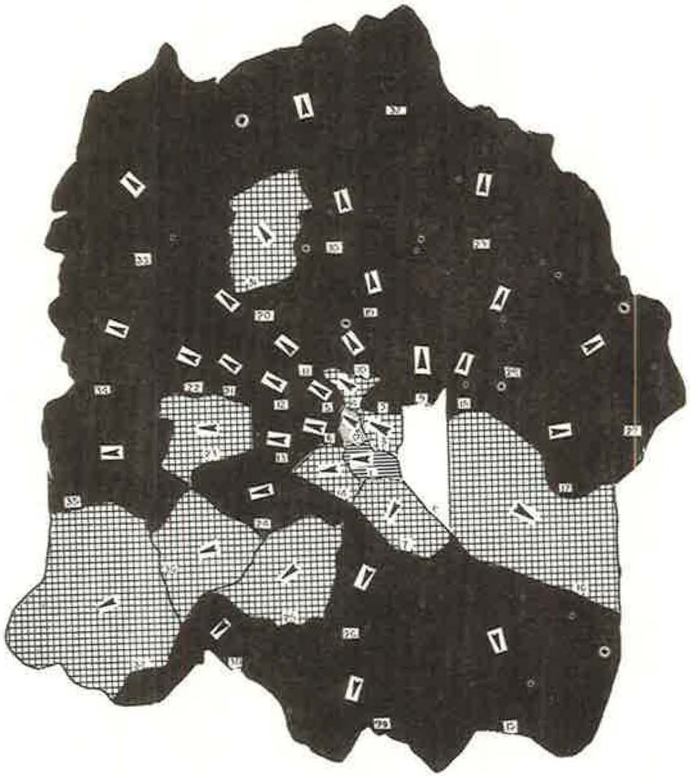

Figure 9. Peaking of 1990 travel leaving the Pulaski-Broening highway area, a dominant employment community.

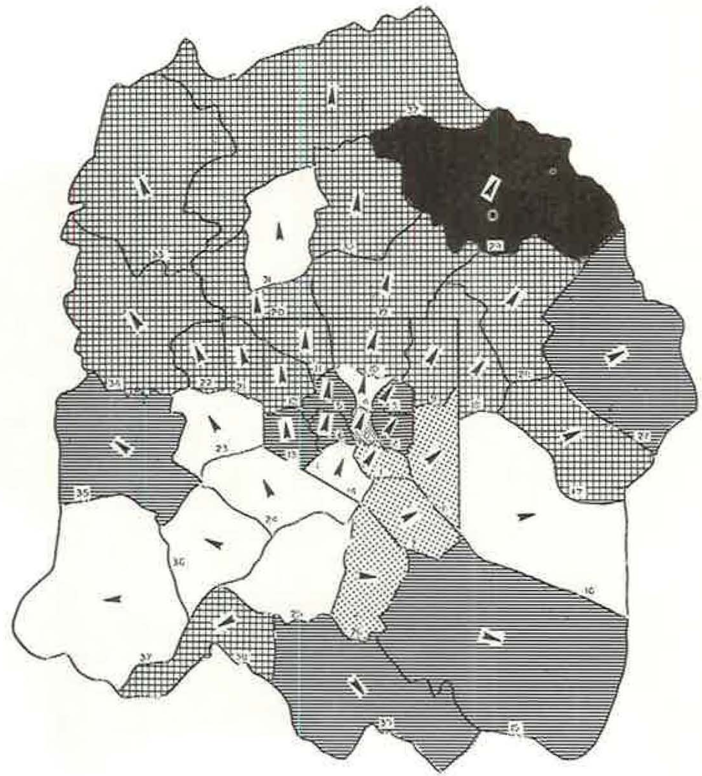

Figure 10. Peaking of 1990 travel leaving the Friendship Airport area, an area of high employment.

TABLE 1

AVERAGE PEAKING OF ALL TRAVEL MADE FROM COMMUNITIES THAT ARE PRIMARILY EMPLOYMENT AREAS

Area, Designation	Employment to Population Ratio	1990 Daily Origins	Peak-Period Origins Based on Uniform Factor[a]	Simulated Peak-Period Origins	Difference
Regional core, 0	4.5	258,500	51,700	112,900	61,200
Pulaski-Broening Highway, 8	1.6	107,000	21,400	39,600	18,200
South Baltimore, 1	1.0	28,600	5,700	10,200	4,500
Curtis Bay, 7	1.0	29,300	5,900	10,100	4,200
Hampden-Waverly, 4	0.9	81,200	16,200	21,600	5,400
Friendship Airport, 25	0.8	85,800	17,000	18,800	1,800
Social Security Administration, 23	0.7	142,500	28,600	41,600	13,000
Dundalk-Sparrows Point, 16	0.5	164,900	33,000	34,800	1,800
Eastern Howard, 36	0.5	53,600	10,700	13,200	2,500
East Baltimore, 2	0.5	102,700	20,500	26,800	6,300
Cherry Hill-Lakeland, 14	0.5	69,400	13,900	16,200	2,300
Total		1,123,500	224,600	345,800	121,200

[a]Uniform factor of 20 percent, i.e., average peaking factor for all travel in metropolitan area.

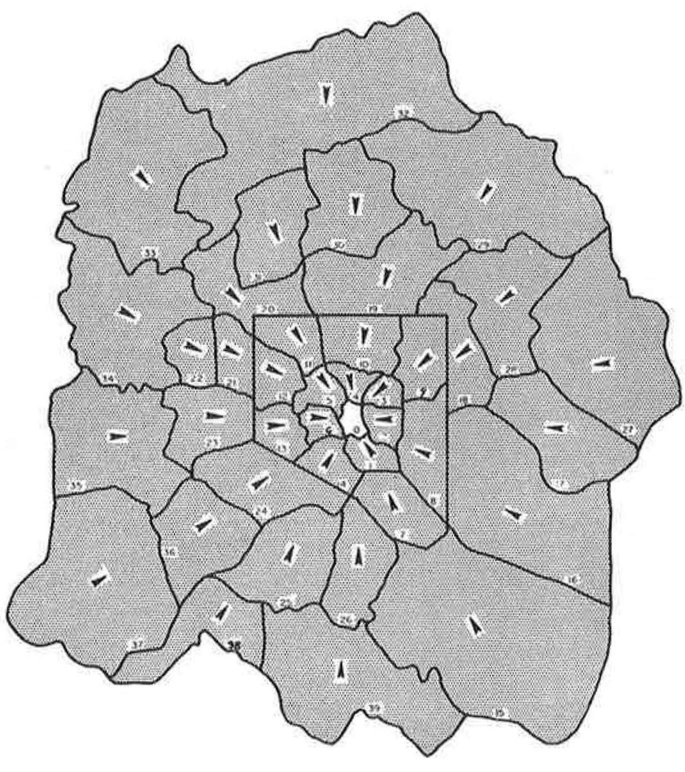

Figure 11. Peaking of 1990 travel going to the regional core, a dominant employment community.

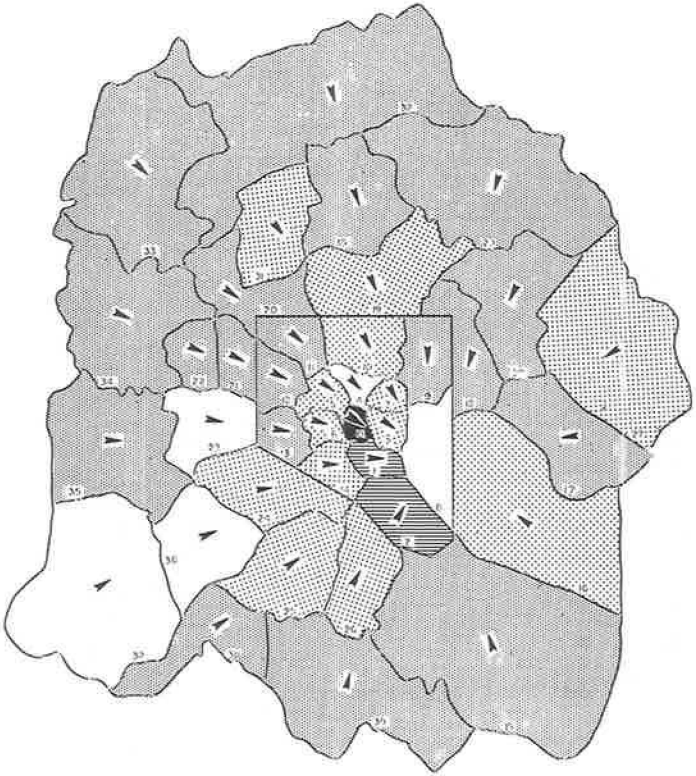

Figure 12. Peaking of 1990 travel going to the Pulaski-Broening Highway area, a dominant employment community.

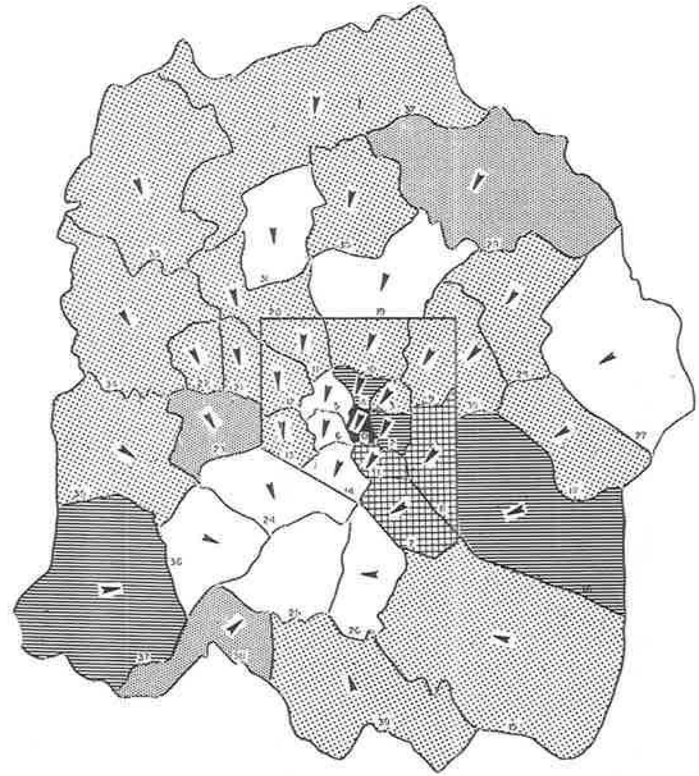

Figure 13. Peaking of 1990 travel going to the Friendship Airport area, a high employment community.

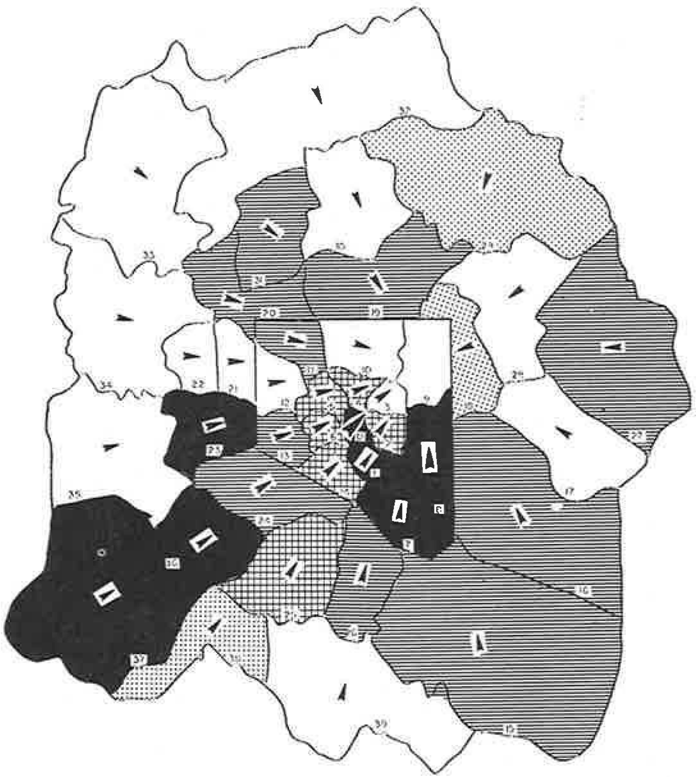

Figure 14. Peaking of 1990 travel going to northeast Baltimore area, a dominant residential community.

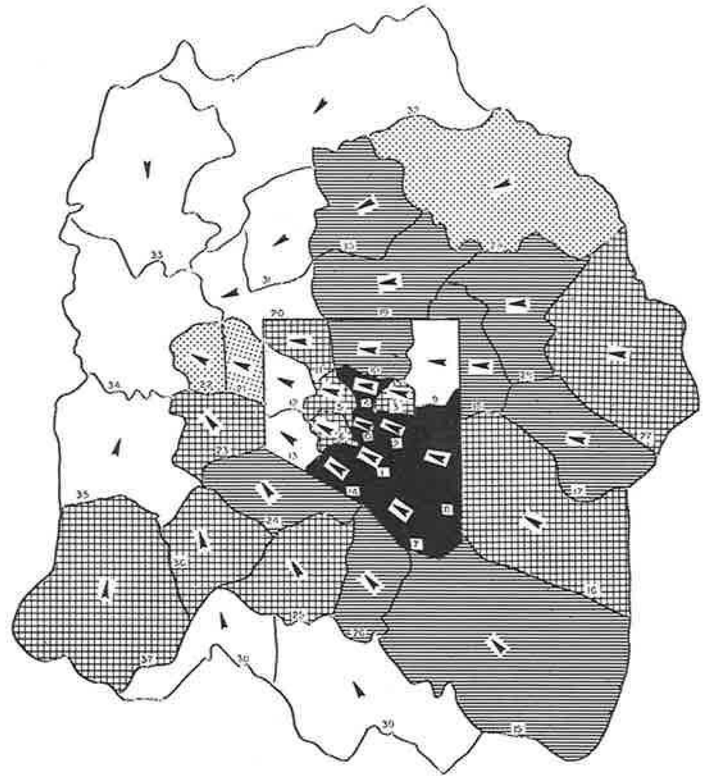

Figure 15. Peaking of 1990 travel going to the Randallstown area, a dominant residential community.

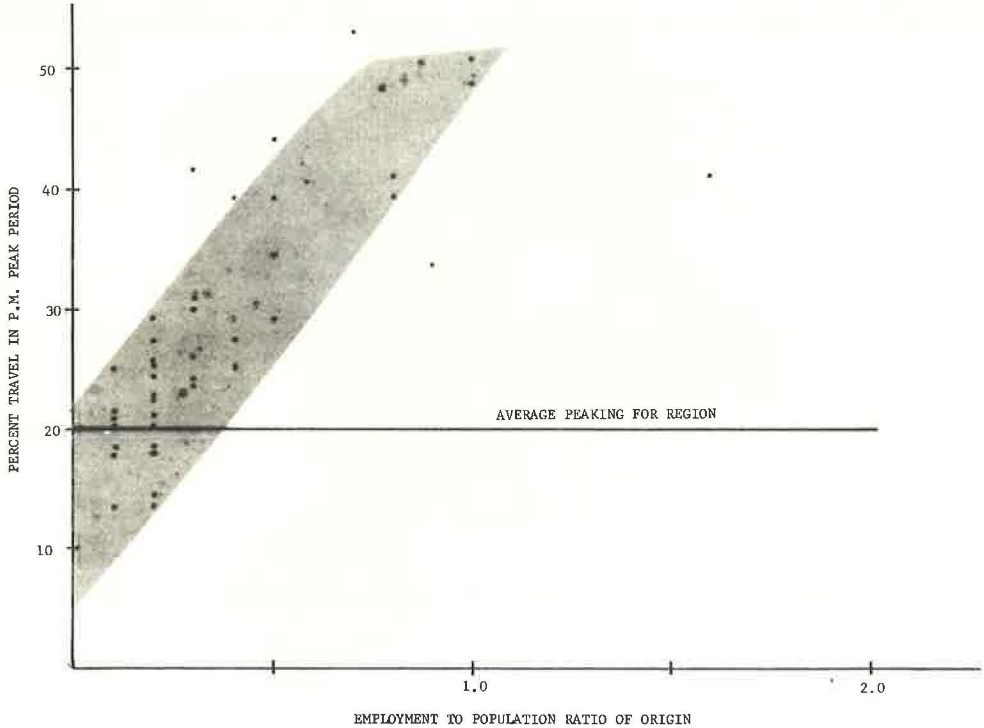

Figure 16. Peaking of travel going to northeast Baltimore as related to the employment and population mix of the origin.

peaking patterns. An examination of Figures 14 and 15 clearly shows that the degree of peaking to these areas depends, to a large degree, on where the travel originates. As shown earlier, travel from predominant employment areas is highly peaked, whereas travel from other residential areas more nearly conforms to the average. Figure 16 shows the relationship between peaking of travel destined to northeast Baltimore and the employment and population mix of the origins of the travel. Logically, peaking of travel is highest from high employment areas and is consistently less from areas more residential in use.

Peaking From Residential Areas

Figures 17 and 18 show peaking of travel destined to the same 2 residential areas. These patterns form a "reverse mirror image" of peaking patterns of travel originated in these areas. Where peaking is high for trips from employment areas, the reverse movement is low.

Peaking to and From Mixed Areas

Both Towson (area 19) and Columbia (area 37) conform to the average mixture of employment and population of the region. Peaking of travel to and from these communities is shown in Figures 19, 20, 21, and 22. The degree of peaking varies depending on the specific movement. Figure 23 shows how peaking of movements going to Towson varies as a function of the employment-to-population ratio of the origin of the trip. This relationship appears to be quite logical.

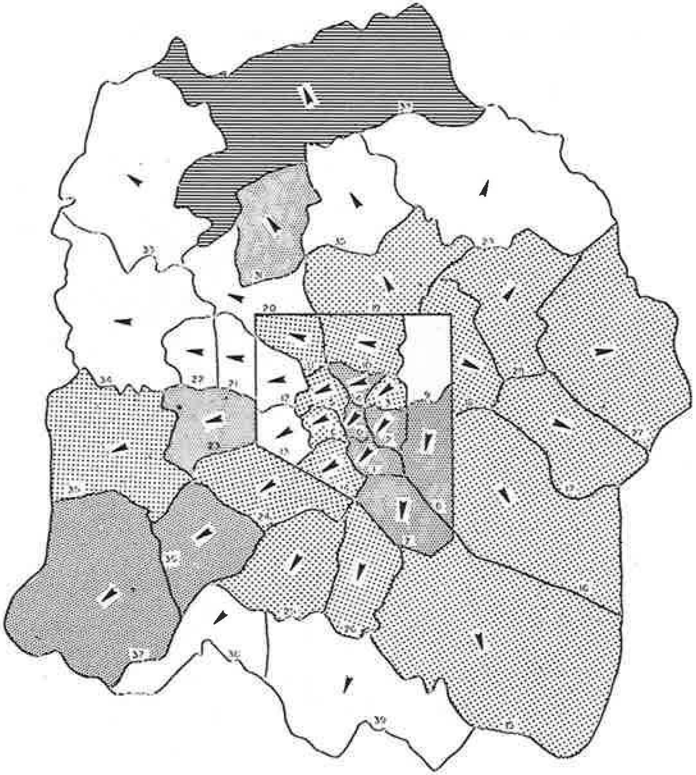

Figure 17. Peaking of 1990 travel leaving northeast Baltimore, a dominant residential community.

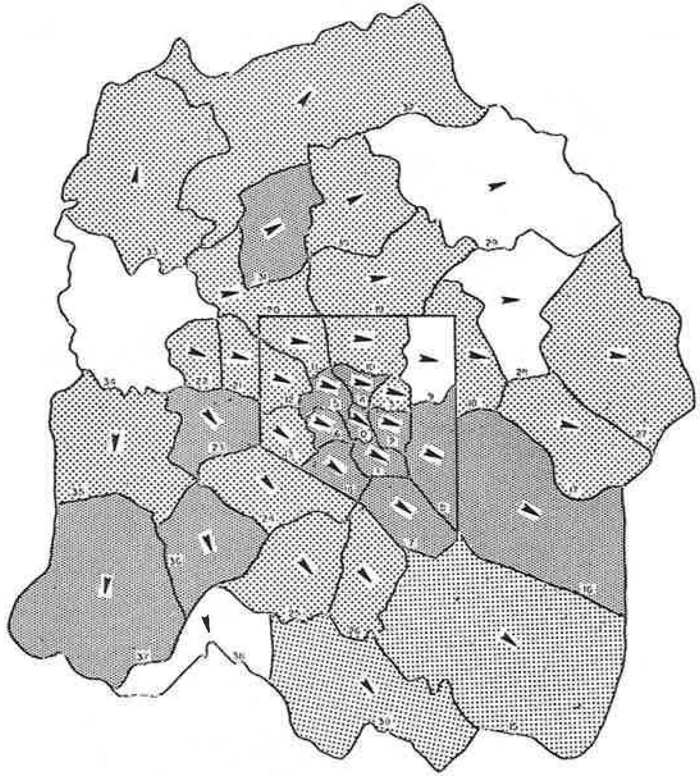

Figure 18. Peaking of 1990 travel leaving the Randallstown area, a dominant residential community.

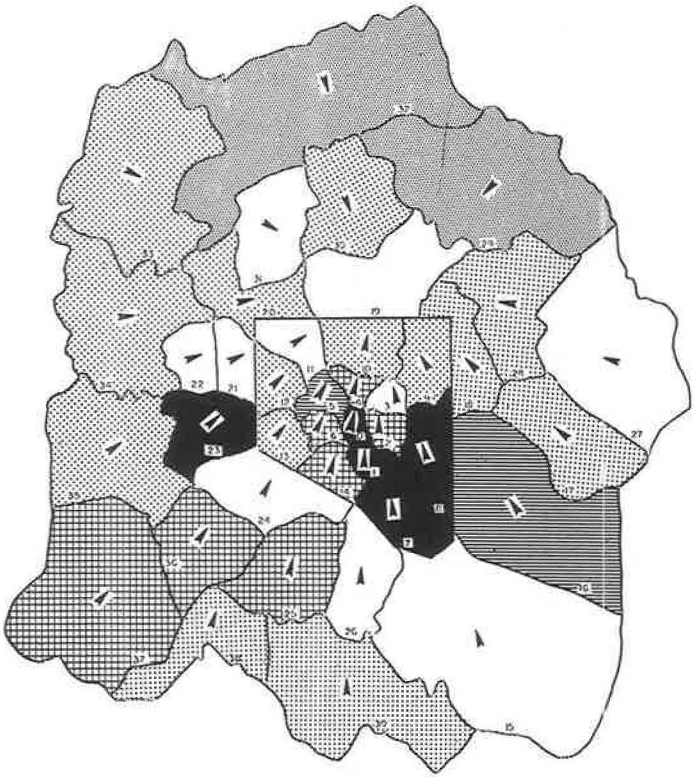

Figure 19. Peaking of 1990 travel going to the Towson area, a mixed community.

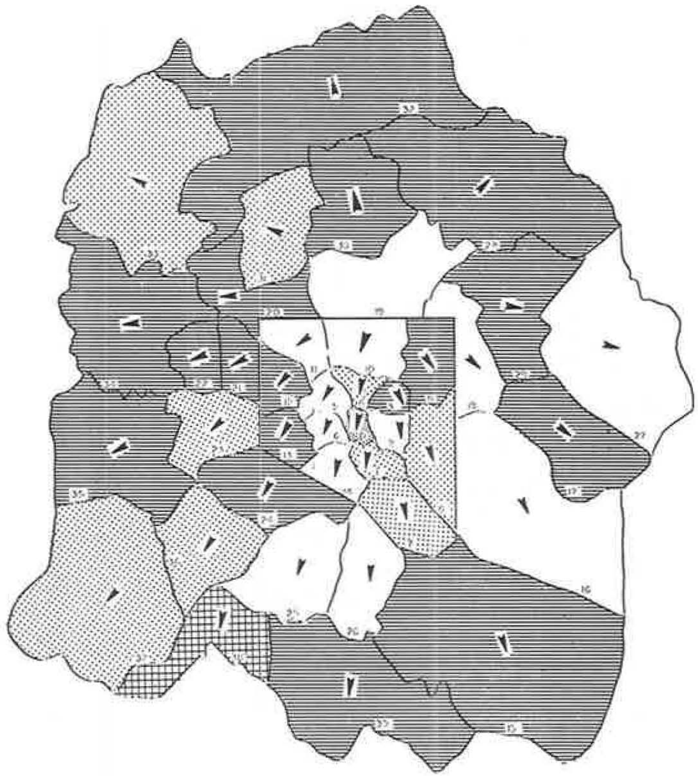

Figure 20. Peaking of 1990 travel leaving the Towson area, a mixed community.

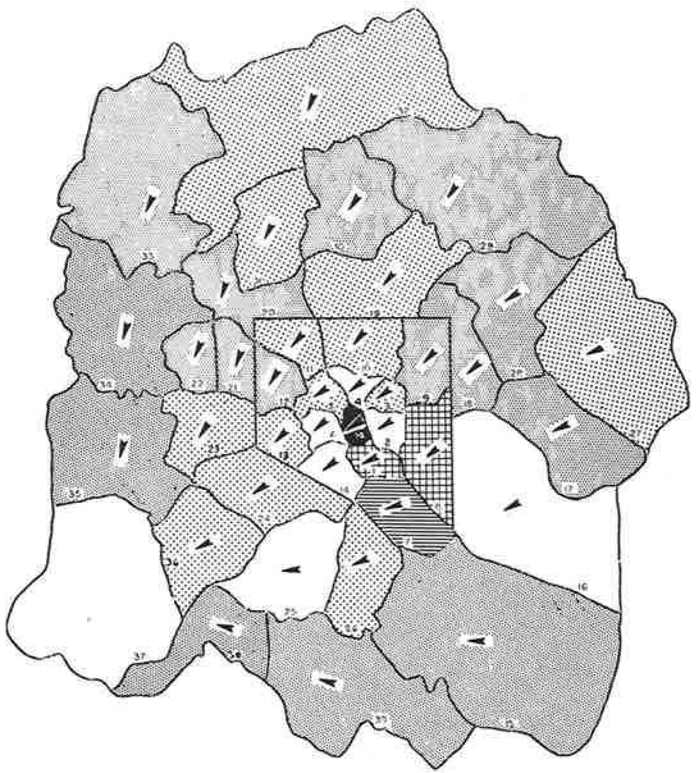

Figure 21. Peaking of 1990 travel going to the Columbia area, a mixed community.

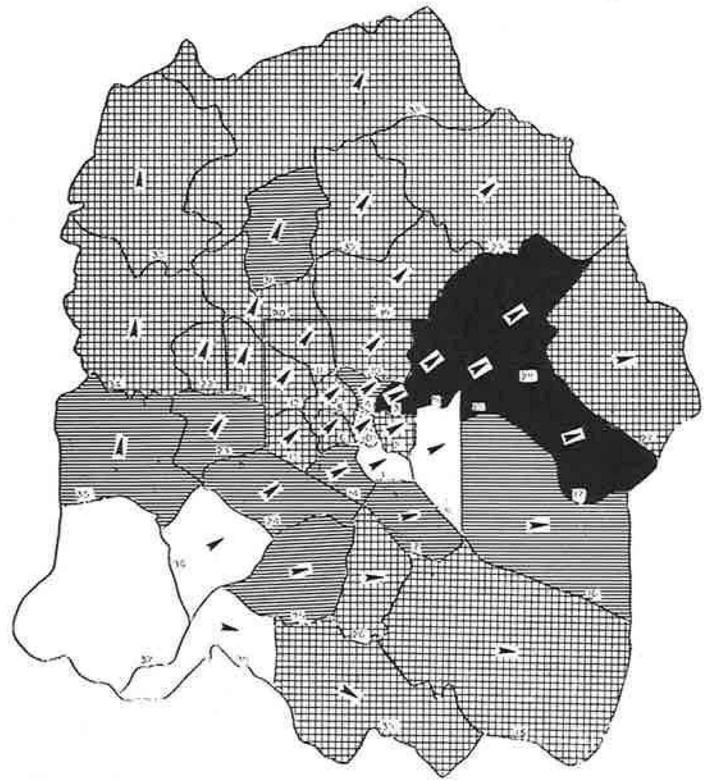

Figure 22. Peaking of 1990 travel leaving the Columbia area, a mixed community.

TABLE 2

AMOUNT OF INTERCOMMUNITY PEAK TRAVEL
THAT FALLS INTO EACH PEAKING CATEGORY

Peak Category	Percent of Travel	Peak-Period Trips	
		Number	Percent
Very highly peaked	Over 40	156,000	21
Highly peaked	31 to 40	91,000	12
Moderately peaked	25 to 30	92,000	12
Average peaking	18 to 24	242,000	33
Below average peaking	10 to 17	136,000	19
Much below average peaking	below 10	22,000	3
		739,000	100

Note: Data include all internal travel made in the metropolitan area in 1990.

Overall Peaking Variation

Clearly, peaking of specific travel movements varies greatly depending on the composition of the movement. Table 2 gives the amount of intercommunity peak travel that falls into each peaking category. Only about one-third of the travel conforms to the average regional peaking percentage. Nearly 50 percent of the travel can be described as being significantly peaked (more than 25 percent above the average). More

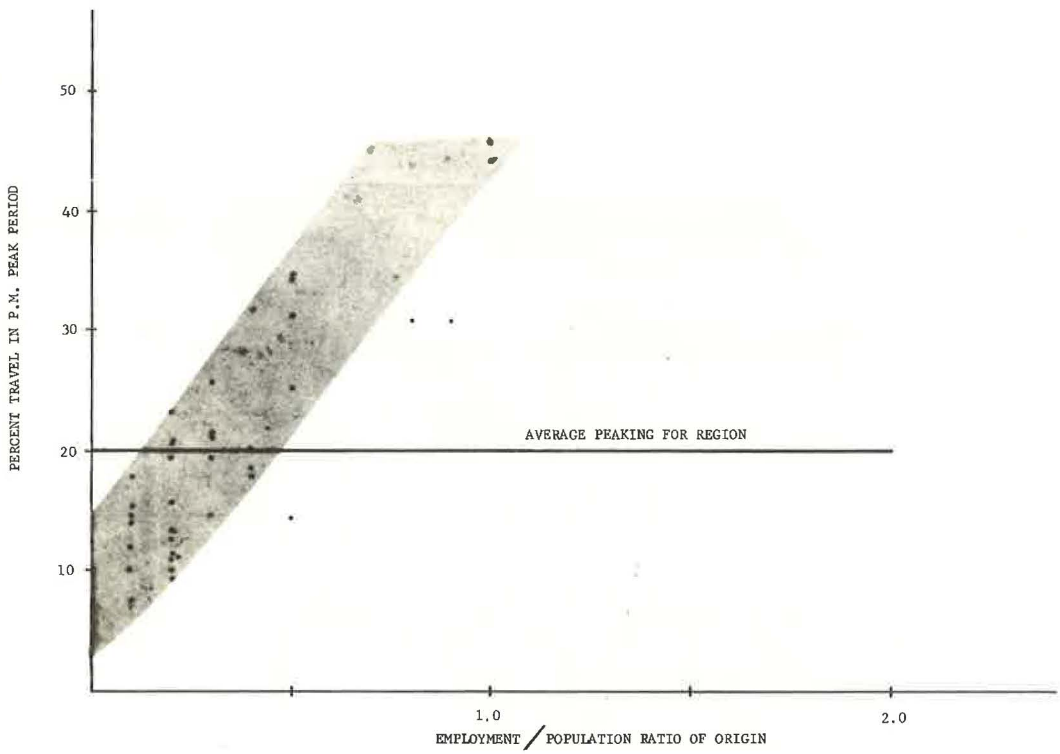

Figure 23. Peaking of travel going to Towson as related to the employment and population mix of the origin.

TABLE 3

AMOUNT OF ERROR RESULTING FROM USE OF 1962 PEAKING FACTOR TO ESTIMATE 1990 PEAKING

Community Number	1962 Afternoon Peak-Period Origins (percent)	1990 Daily Origins	Peak-Period Origins Based on 1962 Factor for Each Community	Simulated Peak-Period Origins	Difference[a]
0	47	258,500	121,200	112,900	+8,300
1	30	28,600	8,600	10,200	-1,600
2	23	102,700	23,600	26,800	-3,200
3	15	53,300	8,000	8,800	-800
4	32	81,200	26,000	21,600	+4,400
5	14	94,300	13,200	18,300	-5,100
6	17	78,600	13,300	18,700	-5,400
7	25	29,300	7,300	10,100	-2,800
8	30	107,000	32,000	39,600	-7,600
9	10	143,300	14,300	17,600	-3,300
10	15	138,500	20,800	21,700	-900
11	15	110,400	16,600	19,600	-3,000
12	11	67,800	7,500	7,700	-200
13	13	78,500	10,100	11,100	-1,000
14	31	69,400	21,500	16,200	+5,300
15	10	103,700	10,400	14,500	-4,100
16	14	164,900	23,100	34,800	-11,700
17	10	79,300	7,900	10,200	-2,300
18	11	103,300	11,400	14,000	-2,600
19	19	211,400	40,200	42,100	-1,900
20	19	69,300	13,200	11,000	+2,200
21	9	43,500	3,900	5,100	-1,200
22	11	44,900	4,900	5,200	-300
23	19	142,400	27,000	41,600	-14,600
24	15	122,500	18,400	19,400	-1,000
25	27	85,800	23,200	18,800	+4,400
26	13	125,300	16,300	22,100	-5,800
27	36	68,900	24,800	12,100	+12,700
28	11	106,400	11,700	14,800	-3,100
29	12	39,400	4,700	4,100	+600
30	16	74,400	11,900	10,600	+1,300
31	18	32,800	5,900	6,700	-800
32	12	23,900	2,900	2,700	+200
33	19	97,300	18,300	14,500	+3,800
34	10	102,200	10,200	11,600	-1,400
35	14	66,300	9,300	8,900	+400
36	19	53,600	10,200	13,200	-3,000
37	16	116,100	18,600	27,800	-9,200
38	16	29,100	4,600	2,700	+1,900
39	9	83,300	7,500	9,800	-2,300
Total	19	3,631,400	684,500	739,200	-54,700

[a] A plus sign indicates that trip-making would be overestimated with 1962 peaking factor, whereas a negative sign indicates that trip-making would be underestimated.

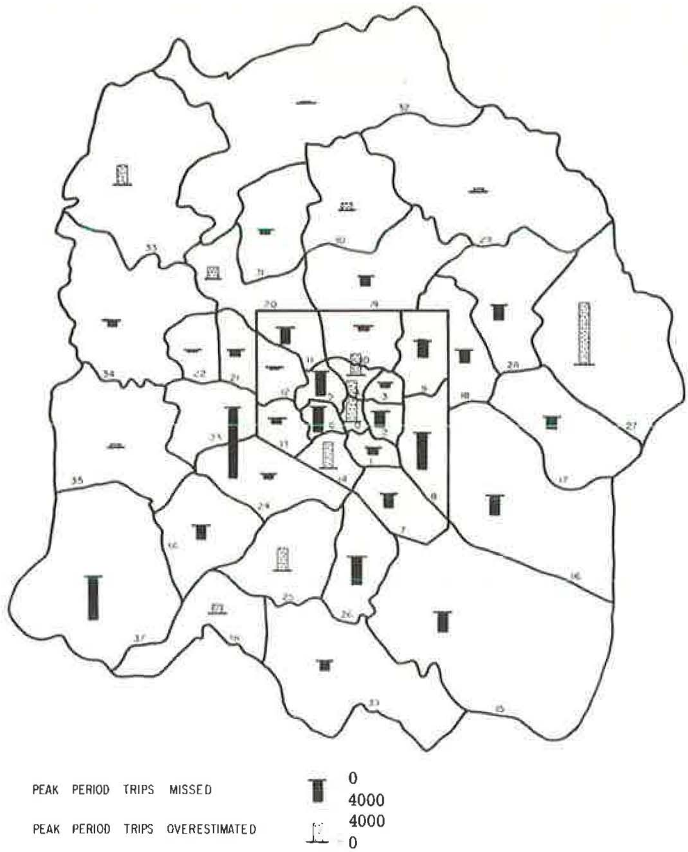

Figure 24. Amount of error resulting by using 1962 peaking factor on 1990 travel origins.

than 20 percent of the travel, mostly radiating out of employment areas, is very highly peaked.

Peaking Changes Through Time

Travel simulation techniques make it possible to account for changes in travel patterns through time. An analysis of projected peaking changes between 1962 and 1990 indicates that estimates of peak-period travel based on base-year observations cannot provide reasonably accurate estimates of future peak-period conditions. Peaking characteristics were found to change through time as a result of the uneven growth in employment and population. Major errors would result by applying peaking percentages existing in the base year to future total daily travel patterns.

Table 3 gives a comparison, by community, of the simulated 1990 peak-period travel origins with 1990 24-hour origins factored by the 1962 peaking factor for each community. Overall, nearly 55,000 trips in a 2-hour period would be missed. The resulting errors of travel made from most communities could be very serious. These errors, as shown in Figure 24, would vary depending on the type of growth expected. For instance, in 1962 about 36 percent of the travel made from the Middle River community (area 27) was made in the afternoon peak period. This high peaking was primarily due to the large employment in the area in proportion to the population residing in the area. By 1990 this is estimated to drastically change. Employment in 1990 is projected to be less than in 1962 because of the major employment drop at Martin-Marietta, whereas the population will grow significantly. Therefore, the peaking factor will decrease to 18 percent. Application of the base-year peaking factor to future total day travel would overestimate future peak-period travel by nearly 13,000 trips in the 2-hour period. Another example is the area of the Social Security Administration (area 23). In this case peaking will become more pronounced through time as a result of the rapid employment growth expected at the Social Security Administration. The peaking factor in 1962 was about average at 19 percent. In 1990, it is expected to be nearly 30 percent. Applying the 1962 factor to the 1990 forecast of total daily traffic would underestimate the 1990 peak-period demand by nearly 15,000 trips.

Based on these analyses, it is clear that peaking factors will change through time and that the use of peak-period simulation model will make it possible to avoid serious errors in estimating future level of service.

CONCLUSIONS

The greatest component of travel in the peak period is the trip from the place of employment to home. As discussed previously, the peaking characteristic of this type of trip is dependent on the income of the trip-maker and the industry in which he is employed. Further, there appear to be 2 distinct types of industries showing differing relationships with income, based on the relative position of white-collar workers in these industries.

As would be expected, those industries that are fairly well self-contained and have standard working hours, such as government, manufacturing, and construction, show a greater percentage of travel in the peak period than do industries that must adjust their working hours to customer demand, such as service, retail, and recreation.

The amount of travel in future peak periods, then, will be mainly a function of the industrial composition of the region. Increased employment in the governmental sector could cause more severe peaking problems than found today, particularly in areas with concentrations of government workers. On the other hand, if there is a shift of workers into service and retail categories away from manufacturing and construction, then there may well be a substantial drop in peak-period travel demand resulting in more efficient utilization of transportation facilities.

The school relationship as developed is a linear function increasing with increasing income. Because school bus travel is not included, the model relates mainly to higher educational institutions. The model suggests that the higher the income is, the greater the percentage of home-based school trips will be in the peak period. Although upper income groups probably do make more trips to educational facilities, low-income people also attend these schools but quite frequently hold a job while attending school. Their trips from jobs to school (or vice versa) are categorized as non-home-based trips and thus do not appear in the school peak-period model. However, as incomes and greater educational participation increase, more school travel seems likely to occur in the peak period in future years.

The relationships for other trips state that the degree of peaking for these trips declines slightly as income increases up to a specific income, $6,500 for the Baltimore Region, and then increases as income increases further. This is logical because the lower a person's income is the more restricted he is as to when he can make a trip. Moreover, he usually will not make a trip in the other category unless it is absolutely necessary. As income increases above the $6,500 level, people start making trips that are associated with more affluence. These trips include those by women coming home from club meetings or picking up children from some after-school function. This indicates that as incomes rise and more leisure time becomes available, more other trips will occur in the afternoon peak period.

Travel not originating from the home is difficult to quantify, and the peak period apparently is a common characteristic of this type of trip throughout the region. This lack of variation, illustrated by the use of a mean value to reproduce the peak-period travel pattern, indicates that little change can be expected in this group in future peak periods.

The comparison of model projections against extrapolation of present trends clearly indicates that a model that is sensitive to changes in the distribution and composition of urban activities is needed to properly project future peak-travel demand as part of evaluation and design of transportation systems.

REFERENCE

1. 1975 Transportation Plans. Penn-Jersey Transportation Study, Vol. 3, May 1965.