Rank Classification: A Procedure for Determining Future Trip Ends

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This paper describes a procedure for forecasting future trip productions and attractions by traffic analysis zones. Traffic analysis zones having characteristics related to trip production and trip attraction were grouped together. A trip generation rate was determined from base year data for each grouping of zones. The generation rate for a group having like characteristics was assumed to hold true for the forecast year. However, changes in the forecast of variables related to trip production and trip attraction can shift a particular zone from its original grouping or cell to another higher or lower trip generation rate group.

•THIS paper outlines a procedure for forecasting person trip productions and attractions by Traffic Analysis Zone (TAZ). The procedure (1) was originally developed at the Puget Sound Regional Transportation Study (PSRTS). It was applied in a rather gross manner by Clark, Coleman, and Rupecks in Missoula, Montana, but the results were not documented. It has been used to compare results with a regression procedure forecast of person trips originally developed for the Albuquerque Transportation Study (2), completed in 1964.

Since September 1966 a continuing comprehensive and cooperative transportation planning program has been under way, directed by the Albuquerque Metropolitan Transportation Planning Department (MTP). The research described in this paper is part of the MTP program.

Although the procedure referred to as "rank classification" was originally developed to forecast total person trips, it has been used to derive vehicle trip productions and attractions in the same manner as for total person trips. PSRTS in 1966 developed an intermediate vehicle forecast for the year 1975 by developing vehicle trip generation rates, rather than total person trip generation rates. The same general procedure was also used at PSRTS to develop transit trip attraction generation rates. The author has no knowledge that it has ever been used to determine transit trip productions.

Several alternative procedures are available for forecasting trips. Regression procedures, as well as land use rates have been used to develop forecast of trips by TAZ. The "Direct Assignment Program," developed at Tri-State, may eliminate the need to segmentalize forecasting as a separate step in planning process. However, regardless of the procedure one selects, they all require some special "hand adjustment" and can reveal serious limitations for any given study area.

For example, one comparison carried out by the MTP revealed less than a 2 percent difference in study area total person trip productions forecasted between the regression and rank classification procedures. However, statistically significant differences of two and three standard deviations were reported at the TAZ level.

FORECASTING PERSON TRIP PRODUCTIONS

For the purpose of the gravity-type trip distribution model, trip ends are treated as trip "productions" or "attractions." Trips are considered to be "produced" at the home

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(whether the home is the origin or destination) and the home is the production end of the trip (such trips are termed "home-based"). The non-home end of a trip is the "attraction" end.

Seven factors which have been found to be related to person trip productions in a nationwide survey by the Bureau of Public Roads (3) are ranked below in order of their relative importance:

Rank	Variable	Beta Coefficients
1	Family size (linear)	.29
2	Car ownership (linear)	.23
3	Income	.14
4	Stage in the family cycle	.13
5	Occupation	.11
6	Density of the neighborhood	.10
7	Distance from the CBD	(insignificant)

Other studies (4, 5, 6) have shown similar relationships, but not necessarily of the same magnitude, which in large part can be explained by the unique area variances, sample bias, and the use of different statistical measures of relationships. However, the fact remains that household size, automobiles owned, and income are most often included as relevant variables to forecast trip generation from the home.

At PSRTS, the following household and environmental characteristics (independent variables) were used to determine the proper grouping of zones for trip production purposes: household characteristics—average automobiles per household, average household size, and median income of household head; environmental characteristics—population per net residential acre, and population per gross acre.

The trip generation rates for home-based person trip productions are expressed in terms of average trips per household by trip purpose. These rates may differ materially from zone to zone, depending on the characteristics of the analysis zone. Analysis zones having similar household and environmental characteristics were grouped, and an average household trip generation rate was calculated for the particular grouping of zones. Each internal analysis zone that had data for more than 25 samples at PSRTS was assigned a ranking (from low to high) on average trips per household. (Detail examination of the variation in the household variables, as well as the average trips per household for zones of small samples could be explained only by sampling variation. These zones were assigned to cell groups by a separate procedure.)

The first step in trip generation rate analysis, regardless of the procedure used, is to select the independent variables to be used in forecasting the dependent variable, in this case, trip productions from the home. The analyst-researcher is usually restricted in the selection of independent variables to those gathered in the initial survey and coded to traffic analysis zones. Variables collected in the home interview survey and found to be related to trip-making must themselves be forecasted before a forecast of trips can be obtained. (In this case, the prudent researcher selects a minimum number of strongly-related variables, rather than a maximum number.)

Next, guided by previous research findings, examination is made of the data at the study area level to see if those variables found to be important determinants of trip generation are relevant to the particular area under study. In the case of trip production from the home, the researcher focuses on the characteristics of the household. The rationale for such an approach is simply that households with different household and environmental characteristics have different travel patterns, different need for travel, and different need for the consumption and utilization of land. For example, the childless married couple living in an apartment on the fringe of downtown, with both persons employed generates quite different amounts and patterns of travel compared to the suburban couple with three school-age children, with only the father employed but the mother active in the local PTA.

It is not only the locational or environmental aspects of the household and the number of members in the household that generate different transportation and land-use needs, but also other factors, such as how the members of the household live. We can never precisely incorporate "style of life" into an explanatory model of trip generation behavior. Nor do we need to, for we can make use of such outward manifestations of this as household size, automobiles owned per household, income levels of the household, and density of the area in which the household is located. In fact, research has revealed these variables to be important determinants of trip generation from the home.

Selecting Household Characteristics

MTP decided to explore the validity of using the "rank classification" procedure, as developed at PSRTS, for forecasting trip productions from the home for the MTP area, since the resultant data could lend itself to more manageable traffic analytical capability. As a first step, a detail analysis of total study area data was made to see if the independent variables identified as significantly related to trip production from the home were also relevant for the MTP area.

Since the original procedure was developed using data from PSRTS, a comparison was made between the equivalent MTP data and the PSRTS data. Figure 1 shows the relationship between average trips per household, by number of persons in the household and number of automobiles owned by the household. The similarity between the two areas was encouraging, so it was decided to pursue further the rank classification analysis for determining trip productions from the home for the MTP area.

Figures 2, 3, and 4 show the relationships of number of persons in the household, number of automobiles per household, and family income of household to the average person trip per household.

For the MTP total study area, at least, each of the household characteristics (the independent variables) shows strong relationships to total trip production from the home (the dependent variable). However, this analysis tells us very little about the possible variance which might occur at the analysis zone level.

Variance of Household Characteristics and Trip Production

In order to examine the variance of household characteristics and trip production at the TAZ level, a nonparametric statistic, Spearman's rank correlation coefficient rho, was selected and is expressed as:

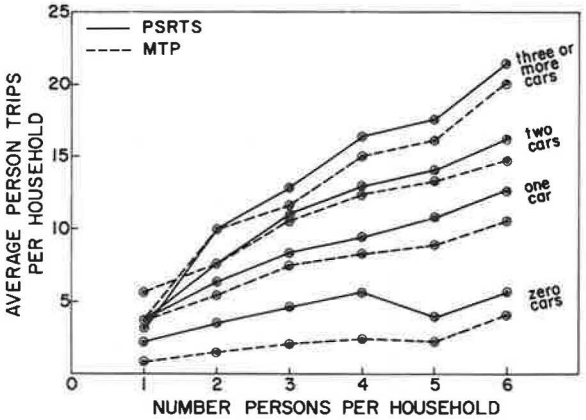
$$\text{Rho} = 1 - \frac{6\,d^2}{N(N^2-1)}$$

The rank correlation coefficient makes no assumptions about the universe from which the sample is taken and is, therefore, referred to as "nonparametric" or "distribution-free." This frees the researcher from the stringent restricting assumptions which the linear regression statistic demands.

The traffic analysis zones were ranked from lowest to highest on the control variable, average trips per household. Thus, a zone ranked 10 on average trips per household might have a rank of 20 on average household size, and a rank of 15 on average automobiles per household. In this manner, each of the independent variable rankings by TAZ is compared to the dependent variable separately, and the rank differences squared are computed and summed over all observations.

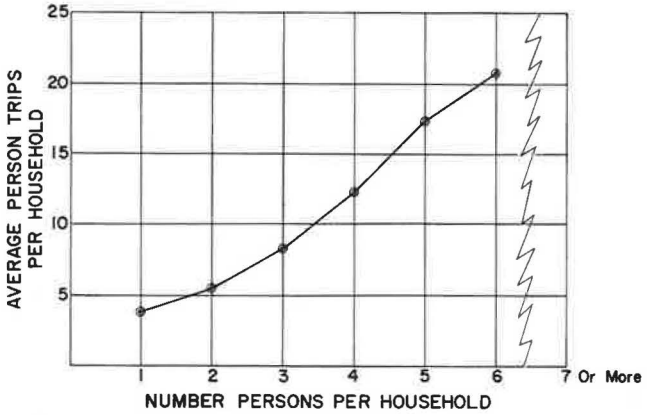
The following table shows the rank correlation coefficient (rho) derived from this analysis. Only zones having more than 10 samples were used in this analysis.

Household Characteristics	No. of Zones	Sum of d^2	Rho
Aver. autos per household	98	41,908.25	.73
Aver. household size	98	69,365.50	.56
Income class	98	91,271.75	.42



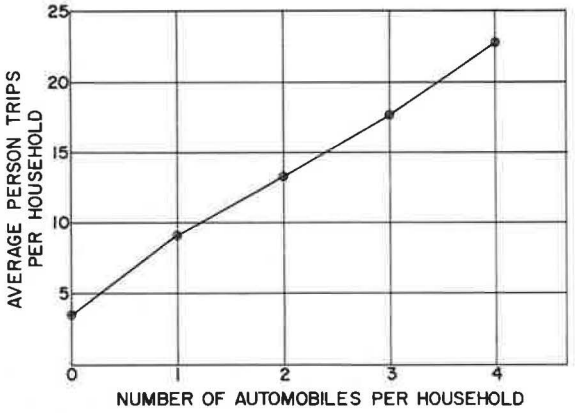
Source: Puget Sound Regional Transportation Study (PSRTS)
Metropolitan Transportation Planning Department (MTP)

Figure 1. Average person trips per household by persons in household and number of automobiles per household.



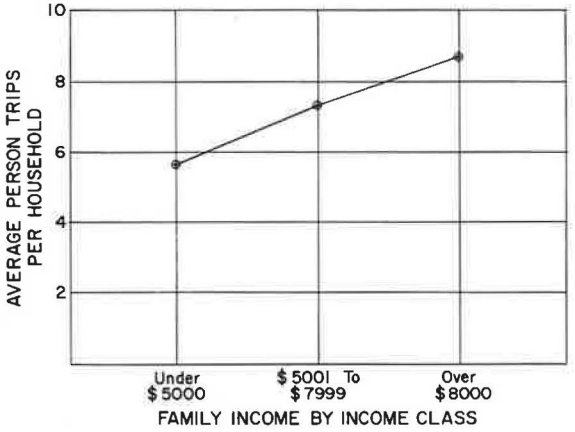
Source: Metropolitan Transportation Planning Department (MTP)

Figure 2. Average person trips per household by number of persons per household.



Source: Metropolitan Transportation Planning Department (MTP)

Figure 3. Average person trips per household by number of automobiles per household.



Source: Metropolitan Transportation Planning Department (MTP)

Figure 4. Average person trips per household by income class.

The two plots of average household size and average automobiles per household against average trips per household for the study area data showed a rather straight line relationship. Also, in the nationwide survey by the Bureau of Public Roads (3), a linear relationship was noted to exist for these two variables. Thus, the following least-squares regression analysis was performed to determine how strong this relationship was when using zonal data:

Variables	Coefficient of Correlation (r)	Coefficient of Determination (r^2)
X_1 = Aver. autos per household	.93	.86
X_2 = Aver. household size	.78	.61

In general, the results of the examination of the relationship of household characteristics to trip production from the home for the MTP data look promising and agree with previous findings.

Selecting Environmental Characteristics

Density of development has often been shown by research to be inversely related to trip generation from the home. As density increases, person trips per household decline because of smaller household sizes, fewer automobiles, lower incomes, and opportunity to make more walking trips. As in the household characteristics analysis, the relationship of zonal density of occupied household units (HU's) to total trip production was examined using the rank correlation coefficient (rho). The following table was derived from this analysis:

Environment Characteristics	No. of Zones	Sum of d^2	Rho
Occupied HU's per residential acre	98	101,245.50	.42
Occupied HU's per gross acre	98	134,559.50	.14

The density relationship for the MTP area appears not to be strongly related to trip production from the home. This is not surprising, since in 1962, when the basic data were gathered, this area was basically a single-family residential area. The high-rise and multiple-unit residential structures existing in 1967 were built since 1963. Even so, less than 7 percent of all housing units in 1967 are in structures containing 10 or more housing units. Considering the unique density of this area, the rank classification procedure, as developed for the PSRTS area, was modified for the MTP study area.

Furthermore, in trying to apply the same procedure to MTP 1962 data as was applied to the PSRTS data, it became apparent that for certain zones the total person trip production rate seemed too high when one examined the various household and density variables. Checking census data, reviewing land-use data, and making field trips to inspect these zones revealed them to be of high family size, medium-to-low car ownership, and low family income—they might be termed "economically depressed."

Also, in other zones where the family income was high, automobile ownership was medium-to-high, and average household size was medium-to-low, average trips per household appeared to be too low. Thus, it was reasoned that for the MTP area, income might be substituted in the rank classification matrix analysis in place of the density variable. This analysis is now being explored further by the MTP research staff.

HOUSE-HOLD CHARAC-TERISTICS	ENVIRONMENTAL CHARACTERISTICS		
	Low	*Medium*	*High*
Low-Low	(1)*	(2)	(3)
High-Low	(4)	(5)	(6)
Low-Medium	(7)	(8)	(9)
High-Medium	(10)	(11)	(12)
Low-High	(13)	(14)	(15)
High-High	(16)	(17)	(18)

(CELL NUMBER)*

Source: Puget Sound Regional Transportation Study (PSRTS)

Figure 5. Rank classification matrix.

HOUSE-HOLD CHARAC-TERISTICS	ENVIRONMENTAL CHARACTERISTICS		
	Low	*Medium*	*High*
Low-Low	—	2.88	3.19
High-Low	5.51	6.03	5.29
Low-Medium	7.57	6.94	6.26
High-Medium	7.96	7.53	6.84
Low-High	8.47	8.38	7.79
High-High	9.08	9.54	—

Source: Puget Sound Regional Transportation Study (PSRTS)

Figure 6. Rank classification matrix, average person trips per household.

The Rank Classification Matrix

The rank classification matrix developed at PSRTS (Fig. 5) will be discussed only as an example of the rank classification matrix approach. An 18-cell matrix is shown combining household characteristics with environmental or density characteristics. The cells are numbered from 1 to 18, beginning in the upper left-hand corner. There are three cells on each horizontal line; for example, cells 4, 5, and 6 contain zones which have like household characteristics and differ only in density. Proceeding from left to right, the density of the zones goes from low to high. In addition, going downward from cell 1 to 16 within the same density classification, averages of the household characteristics associated with trip generation from the home increase.

Figure 6 shows the PSRTS average person trips per household by each cell number. No zones were classified in cells 1 or 18. In general, as density increases, trips decline; while trips increase as household size, automobiles per household, and income increases.

Determining Changes in Cell Group for Forecast Year

The rates for the cell number (Fig. 6) were developed from the 1961 PSRTS survey data. They were used to determine forecast of trip productions from the home for the forecast year. Whether or not a zone changes to a different cell number between the base year and the forecast year depends upon the amount of change in the household and density variables.

Change in Density Classification—The frequency distribution of the 1961 ranks for density were collapsed into three frequency intervals representing density groups as low (0-249 rank intervals), medium (250-449), and high (450-600). The forecasts of population per gross acre and population per net residential acre were assigned ranks using the 1961 rankings. For example, if a zone in the forecast year registered an increase in gross or net population density over 1961, it would be assigned a new rank, the rank assigned such a density in the 1961 table. The 1961 rank was determined by averaging the ranking of population per gross acre and population per net residential acre. However, it was reasoned in determining the forecast year density rank that a change in population per gross acre was of more significance for trip production than a change in the population per net residential acre. Therefore, it was given a weight twice that of the latter rank.

After the forecasted weighted density rank was determined, the zone was classified as being in one of the three density columns of the matrix on the basis of rank intervals (Fig. 5). In cases where zones were on the borderline between density intervals, they were placed according to the geographical density continuity of neighboring zones. Fewer

than 15 zones (out of a total of 662) were involved in decisions of this kind (7). A density shift of a zone in the matrix for the forecast year is a horizontal shift and it occurs before a vertical shift, which is based on changes in the forecasted household characteristic variables.

Change in the Household Characteristics Classification—For each cell in the matrix the base year average household size, average automobiles per household, and median income of head of household was known. Also known was the range, the average, and the mode for each of the household characteristic variables within the cell. After the zonal forecast of the household characteristic variables had been completed, each zone was individually examined to see if it should remain in the same cell or be transferred to another cell because of forecasted change in the household characteristics of the zone.

Before a zone was permitted a vertical change in cell-group number because of changes in forecasted household charactertistics, the average household characteristics of two of the three household variables must be equal to the average for the cell to which it was to move. A change of more than one vertical row in the matrix, for example from 4 to 10, was not permitted unless all three variables were at least equal to the cell group averages for cell 10.

Rationale

The analytical rationale behind the development of the rank classification matrix was referred to earlier when discussing "style of life." However, conceptually, one is postulating that a "true" theoretical matrix exists for any given area with a particular style of life. Regardless of the variables used to develop this matrix, if the variables are representative of a given area or that part of the resident's style of life which determines the frequency of trip productions from the home, then it can be reasoned that the variances in the empirically determined trip production rates from the "true" rates are the result of errors in sample selection, data collection, or data-processing and analysis. The simplifying assumptions for this procedure are basically that within any particular cell in the matrix, the zones comprising the cell are more like each other than they are like any of the other zones occupying a different cell. The "likeness" refers to the style-of-life concept, or those variables for a particular area that are the determinants of trip productions from the home. This implies that the best estimate of the "true" rate is the determined rate from the zones occupying a particular cell in the matrix. Thus, if the magnitude of the variables related to trip production from the home change enough in the forecast period, the zone will shift to a new cell in the matrix. The zone is thus placed with zones having similar future household characteristics. All of this, of course, assumes that variables important for determining trip generation from the home today will also be significant determinants in the future.

Conclusion

Admittedly, the procedure may lack statistical sophistication and may be unattractive to computer-oriented people. However, it permits the analyst to understand why he is getting a particular forecast for a particular TAZ and it enables the researcher to question the "reasonableness" of the forecasts derived for small areas. Furthermore, it has been demonstrated to be particularly useful in a continuing transportation planning program for evaluating the effect of small area changes on the original forecast of trips for small areas.

FORECASTING PERSON TRIP ATTRACTIONS

It is possible to clearly demonstrate the utility of selecting household and environmental characteristics for analyzing and forecasting total person trip productions. It is, however, not as clearly demonstrable which of the variables used in forecasting person trip attractions are the best (or the only ones) to use. At the present stage of development, forecasting trip attractions is still the most difficult problem for the researcher.

Nonetheless, the number of trip ends attracted to a particular analysis zone is rationalized to be related to the amounts and type of activities located in the zone. Before a

forecast of trip attractions can be made, it is necessary to determine the factors which define and quantify the activity or drawing power of a zone.

Selecting Attraction Variables

The generalized concept of "drawing power" is to trip attractions as the concept of "style of life" is to trip productions. Both are assumed to be capable of operationalizing, but most researchers will agree that operationalizing the drawing power of a zone so it will yield some understanding of the "why" of the drawing power is a much more formidable task. It is one thing to select variables that in the base year reflect a strong relationship to trip attractions, and something else again to forecast these variables with any degree of reliability.

Many studies have found population, employment, and school enrollment related to the forecasting of trip attractions by trip purpose. After much experimentation and analysis at PSRTS these variables were also finally selected. Examination of the attraction rates for these variables at the analysis zone and the analysis district level, based on different combinations of employment and population, showed considerable variation in the person trip attraction rates. Some zones had relatively little or no employment or population in the base year, thus making calculation of rates based on sample data for small areas very unstable, even though the relative amount and type of activity occurring in the zones were similar. This is particularly true for the trip purposes other than work and shop, for which total employment and retail and service employment in the zone were used, respectively.

For the social-recreational and miscellaneous trip purposes, either employment or population was used to determine the person trip generation rates for groups of zones. This was necessary because many zones are primarily residential or nonresidential in character with statistically unreliable numbers of population or employment, yet attracting significant numbers of social-recreational and miscellaneous trips.

The procedure for the grouping of attraction zones for the calculation of person trip attraction rates by trip purpose, expressed as person trip attractions per unit of population, employment, or school enrollment, had to be computed separately for each purpose. Unlike the trip production cell groupings of zones, the individual trip attraction groupings by trip purpose, in which a zone was assigned, need not be the same group for each trip purpose. A zone may be in a high trip attraction rate grouping for the shopping trip purpose, but in a relatively low trip attraction rate grouping for the social-recreational trip purpose.

Grouping Zones for Calculating Trip Attraction Rates

Work Trip Attractions—In examining the employment trip generation rates at PSRTS by zone, considerable variation was noted, particularly for those zones which had a small employment base. In order to assure that the information had statistical stability, zones for which the trip information indicated less than a selected level were omitted from the analysis for determining the grouping of zones. The selected levels of employment were as follows: Seattle—625, remainder of King County—300, Kitsap County—150, Pierce County—300, and Snohomish County—200. This is the equivalent of saying that a zone must have at least 25 or more samples of work trips before it can be considered to influence the establishment of zone groupings for the calculation of the person trip attraction generation rates based on employment.

The grouping of work trip attraction zones together presented less of a problem than the grouping for some of the other trip purposes. This was primarily because the number of home-based work trips that an individual makes in a day is usually limited to two: from home to work, and from work to home. Therefore, the variation in zonal work trip attraction rates (as a function of total employment) was not as great as for some of the other trip purposes. However, some variation was noted by county between zones located within the city vs zones located outside the urban area. In general, the former zones manifested lower home-based work person trip generation rates than the latter. This was because in built-up urban areas the number of opportunities for making a trip from work to shop, or to some other trip purpose, is greater than in the less developed areas, where the employee is more likely to live close to work, and thus, go directly

home from work rather than stop along the way for one purpose or another. This was particularly noticeable in Pierce and King Counties.

The person trip attraction rates for the work trip purpose were much more stable at the district level than at the zone level. Districts were then grouped by placing those with similar person trip attraction rates together. The final grouping of districts within county yielded six groups: two each for Pierce and King Counties and one each for Snohomish and Kitsap Counties. The person trip attraction rates for the work trip purpose were then computed for each of these groupings of districts using the data from the zones within the particular districts in the group. The resulting rate was then applied to all zones within the particular district in the group, including those zones which had been excluded from the computation of rates because of an inadequate number of samples in the zone.

Shopping Trip Attractions—Retail and service employment yielded more meaningful shopping trip attraction generation rates than any other combination of employment categories, although there was still considerable variation among zones and among districts. Because of this variation it was necessary to establish more shopping-type trip attraction groupings than were used for work trips. It also required using a combination of grouping districts and, in the case of zones which were predominately major shopping centers, a grouping of zones to form the attraction generation groups.

First, district rates were established. Next, zonal rates were calculated for these zones having at least the following number of retail and service employment: Seattle—250, remainder of King County—120, Kitsap County—60, Pierce County—120, and Snohomish County—80. This minimum employment in a zone represents 10 sampled home-based retail and service employment work trips to the zone. This lower number of samples was used for the shopping trip purpose rather than for the work trip purpose in establishing the calculation of a zonal rate, because of the larger number of trips generated for the shopping purpose by an employee, compared to the work trip purpose.

If the shopping trip attraction rate for a zone exceeded the overall district rate it was separated for a special grouping and the overall district rate was adjusted accordingly. However, only those zones which had either the minimum employment or a generation rate larger than eight trips per retail and service employee were finally included in three generation groupings based on zonal rather than district rates. The zones not meeting these requirements were grouped with the rest of the zones in the district. There were six groupings composed of districts (or partial districts, if any of the zones had been pulled out for a special zonal grouping). This, plus the three special zone groups, yielded nine trip attraction rate groupings for the shopping trip purpose.

Social-Recreational and Miscellaneous Trip Attractions—For social-recreational and miscellaneous home-based trip attraction purposes either total employment or population was used to establish the person trip generation rates. The groupings of zones were always based on one or the other variable, but never both.

First, a person trip generation rate for each zone for the two trip purposes was calculated using employment and population. Zones having less than the minimum total employment as established for the work trip purpose were automatically allocated to the pool of zones which would have the trip generation rate computed on the basis of population. Once the zones had been assigned to either the category for which population was used as the basis of computing the rate or the category for which employment was used, the following procedure was used to further group them within these two general trip generation categories.

Those in the population category were grouped by establishing a frequency distribution of the district trip generation rates by county after the employment zones had been eliminated from the district total. This resulted in six groupings being established: two groups each for King and Pierce Counties and one each for Kitsap and Snohomish Counties. A trip generation rate was then calculated for each of the six groupings based on total population.

For those zones placed into the employment category for computing trip generation rates and having the minimum required employment, a trip generation rate in terms of trips per employee was calculated. This led to 12 separate groups for the social-recreational trip purpose and 13 for the miscellaneous trip purpose. Four of the employment groupings for the two trip purposes were made up of the Seattle and Tacoma central

business districts; the Everett and Bremerton central business districts; the Duwamish and Tacoma tideflats industrial areas; and special zones such as the Seattle-Tacoma Airport, Point Defiance Park, and the University of Washington.

School Trip Attractions—Examination of the district trip attraction rates for school trips, based on the number of trips per unit of enrollment, suggested that nine groupings of districts would be required in order to account for the differences among districts. There were two groups set up for Kitsap, Pierce, and Snohomish Counties, individually, and three groups for King County. As one might expect, districts in the more densely populated areas exhibited lower trip generation rates, since in these areas the probability of the student living within walking distance of the school is greater.

Trip Generation Rates for Non-Home-Based and Commercial Vehicle Trips

A separate estimate of the non-home-based trip projections generated by households was made to serve as a control total in comparing with the independently derived number of non-home-based trips. Since by definition a non-home-based trip has neither end of the trip at home, its generation rate is related to a measure of the activity occurring in the zone where the trip begins or ends. The same reasoning applies to commercial vehicle trips.

Population and total employment were the two variables used to represent the amount of activity which produces and attracts non-home-based and commercial vehicle trips. The generation rate is expressed (as were the home-based trip attractions rates) in trips per unit of population or per employee.

The problem of balancing the trip productions and attractions of these two types of trips was resolved by averaging the production and attraction generation rates. This was decided upon after examining, by zone and by district, the differences between the trip production and attraction rates and finding these differences to be small. This is to be expected since for a non-home-based or commercial vehicle trip the production and attraction end of the trip was defined as the origin and destination end of the trip, respectively.

Grouping Zones for Non-Home-Based and Commercial Vehicle Trips

Just as for home-based trip attractions, non-home-based and commercial vehicle trips tend to peak in zones and districts with high levels of commercial and industrial activity. For these zones and districts total employment was used as the variable to represent the activity occurring there. However, in primarily residential areas, total population was used.

The procedure for determining which variable to use for a particular zone or district was the same as that used for home-based social-recreational and miscellaneous trip attractions. Zones having less than the minimum required employment were assigned to use population as the variable for determining trip generation, and the district rate was adjusted accordingly so as not to include these zones in the generation rate calculation based on employment.

Likewise, in grouping zones and districts for determining the trip generation rate, use of the frequency distribution to determine cutting points for the grouping of districts by county was applied in the same manner as when grouping for the social-recreational and miscellaneous trip attractions. No attempt was made to have the same number of groups or the same zones and districts within each group, although the number of groups is almost identical for four of the seven trip purposes.

There were 20 groupings for the non-home-based trip purpose compared to 19 for commercial vehicles. Eight of the groupings for non-home-based trips and seven of the groupings for commercial vehicles were based on population. The remaining 12 groups for both trip purposes used total employment for determining the trip generation rate.

Final Adjustments

The task of classifying zones for the calculation of total person-trip production and attraction generation rates can be thought of as twofold: first, determining future home-based trip productions and trip attractions; second, determining future non-home-based

trip productions and trip attractions. Empirically, total trip productions should be equal to total trip attractions. Consequently, a forecast of total trip productions must equal a forecast of total trip attractions. Any difference between the separate forecast of total person trip productions compared to that of total person trip attractions is largely the result of using different sets of variables for determining trip production and attraction generation rates and applying these rates independently.

Where differences occur in total or by trip purpose, adjustments to bring the productions (P's) and attractions (A's) into balance are done by adjusting the number of person trip attractions. This is logically defensible for all trip purposes, except work, because the procedure for forecasting trip productions for these other purposes is more reliable. For work trips, however, the forecast of employment by site location and, therefore, the forecast for the attraction end of the work trip, which is based on a detailed economic forecast analysis, is believed to be the more reliable. As a result, the productions for the work trip purpose are adjusted to the forecast of work trip attractions, which are derived from applying work trip generation rates based on employment.

Special Trip Attractors

The application of the procedure described for forecasting trip attractions by trip purpose by analysis zones should not be applied at the zone level without consideration of any special trip generator, which may make up only part or all of the zone but requires that a separate forecast of these trip attractions be made. For example, trips to airports are increasing faster than either employment or population, and therefore, any rate developed for them using the procedure outlined in this paper would tend to underestimate future attractions. Thus, special generators of this nature have to be forecasted separately. Likewise, future special trip generators, where known, should also be considered as possibly requiring separate consideration in developing zonal forecasts of attractions.

Theory of Trip Attraction

Most researchers agree that in order to develop any theory of trip attraction, one must start by examining how the land is being used and for what purpose. People use land from a transportation planning point of view, because they wish to satisfy certain basic physical and emotional needs, to wit: the need to work, so they may shop for goods and services; the need to play and rest, so they may be rejuvenated in order to continue to work. However, the degree to which people are willing to use land or to be attracted to land in order to satisfy these basic, and usually daily needs, is a function of several interrelated sets of conditions.

The activity occurring on a piece of land suggests to the people which of their needs can be satisfied by interacting with the particular piece of land. Also, the size of the land's activity sets physical limits upon the amount of interaction or attraction that can occur between people and the land's activity in any given length of time. However, the limits of interaction or attraction for several pieces of land of equal size and like activity will vary depending upon several basic locational and functional characteristics of the land: First is the location of the land. The attraction of like sizes and activities of land will be directly related to the land's accessibility to the total number of possible interactions perceived by the user. Second is the accommodation of the land. The attraction of like sizes, activities, and accessibilities of land will be directly related to the land's ability to accommodate the interactions or attractions to the land's activity. Accommodation includes both the ability to facilitate ease of ingress and egress, as well as ability to satisfy the personal needs of the user in a manner that makes the user want to continue to interact with the land's activity. Finally, the amount of interaction or attraction to land having like sizes, activities, location, accessibilities, and accommodations is directly related to the land's general status-image or reputation. This last point, as many businessmen know, is often the difference between a mediocre and a highly successful business.

Conclusion

The procedure for forecasting person trip attractions by trip purpose outlined in this paper leaves much to be desired from a theoretical point of view, nevertheless, it yielded what was felt to be a reasonable forecast of attractions for the PSRTS area. Considerably more systematic research is needed before the forecasting of attractions can compare in sophistication to the forecasting of trip productions.

REFERENCES

1. Cowan, G. and Walker, J. Forecasting Future Trip Ends by Trip Purpose. PSRTS Staff Report No. 16. Puget Sound Regional Transportation Study, Oct. 1964.
2. Walker, J. Comparison of Two Home-Based Trip Procedure Forecasting Techniques. MTP Internal Documentation Report No. 2. Albuquerque Metropolitan Transportation Planning Dept., New Mexico, May 1967.
3. Heit, Chris, et al. Household Trip Production: Results of a Nationwide Survey. In Highway Planning Technical Report No. 2, U. S. Bureau of Public Roads, Aug. 1965, p. 18.
4. Oi, Walter Y., and Shuldiner, Paul W. An Analysis of Urban Travel Demand. Northwestern University Press, 1962.
5. Cowan, G., and Walker, J. Rationale for Production-Generation Rate Analysis. Puget Sound Regional Transportation Study, March 1964.
6. Cowan, G., and Walker, J. Forecasting Household Characteristics for Determining Trip Production-Generation Rates. Puget Sound Regional Transportation Study, June 1964.
7. Cowan, G., and Walker, J. Comparison of Plan A and Plan B Characteristics As They Affect Person Trip Productions. PSRTS Staff Report No. 18. Puget Sound Regional Transportation Study, Dec. 1964.