Trip Generation and the Home

PAUL W. SHULDINER, Department of Civil Engineering, Northwestern University, Evanston, Ill.

The relationship between a number of household and neighborhood characteristics and the frequency of person-trips associated with individual dwelling units is analyzed. Family size and vehicle ownership are found to have the greatest effect on trip production. Other dwelling unit variables affect trip generation only slightly when the impact of associated variations in family size and vehicle ownership are accounted for.

A fuller understanding of observed variations in trip generation is derived from consideration of certain social characteristics of the generating area. Two indexes obtained from Census data—social rank and degree of urbanization—are found to be particularly useful in this regard.

The paper closes with a brief discussion of the apparent gain in precision which results from grouping data before regression analysis. Examples of the bias that such aggregation produces are considered.

•THIS REPORT is a study of the effect of variations in several household and neighborhood characteristics on urban trip generation. Neighborhood characteristics are described in terms of a social area typology developed by E. Shevky and W. Bell from data published in the U.S. Decenial Census of Population. The typology is composed of three indexes representing the social rank, degree of urbanization, and extent of segregation of a census tract or other limited geographic area. This phase of the analysis is limited to a sample of census tracts in the City of Chicago.

The variables relating directly to individual households (such as family size and vehicle ownership) were derived from standard O-D data. The source of individual household data was a home interview origin-and-destination study of 5,039 homes conducted in 1956 by the California Division of Highways in the Modesto, Calif., area. The survey area encompassed about 60 square miles and included the City of Modesto, the county seat and marketing center of Stanislaus County, and the neighboring town of Ceres. The population of the entire study area was 77,355 persons, of which 29,155 lived in Modesto and 3,870 in Ceres. A more complete description of the Modesto study is found elsewhere (1).

For most of this study, the basic unit of analysis is the individual household. The use of single households differs significantly from the customary practice of working only with geographic aggregations of dwelling units such as traffic or analysis zones. Single-unit analysis permits investigation of the effects of non-numeric and, therefore, non-averageable characteristics (such as occupation or dwelling unit type) on trip generation. Even where family size, vehicles ownership, or other numeric variables are employed, the use of individual dwelling units provides a much more sensitive and unbiased measure of existing relationships. A comparison of the results obtained using grouped and ungrouped data is presented, showing the extent of the aggregation bias and the apparent gain in precision obtained through grouping.

The analysis is concerned first with data from the Modesto survey. Considered here are the effects of five household characteristics: family size, vehicle ownership, occupation of the head of the household, distance to the CBD, and type of dwelling unit,

on frequency and kinds of trips made from the home. (Unless otherwise specified, for the Modesto data, "trips" include all person-trips made from the home by members of the household either as auto drivers or as auto or transit passengers. Walking trips, including walking trips to work, are not considered.)

FAMILY SIZE

If travel is a function of human activity, a relationship should exist between the frequency of trips made from the home and the size of the family making such trips. To test this hypothesis, the dwelling units in the Modesto study were grouped according to the number of persons in each household. Separate mean trip generation rates were then computed for each family size category. These data, summarized as marginal subtotals in Table 1, are shown in Figure 1. Average trip frequency increases with increasing persons per household—rapidly at first, then more slowly in the upper range of family size. The sharp dip at the 7 person-per-household level is probably due more to random variations caused by the small cell size in this category than to any inherent relationship between the variables.

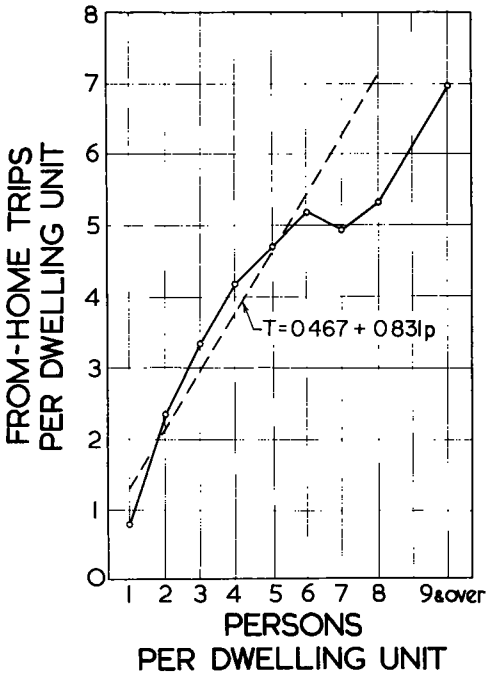

Figure 1. Frequency of from-home trips per dwelling unit at various levels of family size.

The general concavity of the curve reflects the changing age composition of the family as the household grows. Table 2 shows that the percentage of persons 14 years of age and older in the family falls from 99 percent in two-person families, to 45 percent where there are 7 persons in the household. Because children do not make as many vehicle trips as adults, a smaller and smaller portion of each increment of family size is available to affect trip generation. Reduction in the rate of increase is also a result of the restriction in trip making imposed by lower car/person ratios in larger families (see Table 2).

Although the shape of Figure 1 is clearly curvilinear, most of the observations are concentrated in the middle range. For this reason, the relationship among the data

TABLE 1

EFFECT OF FAMILY SIZE AND VEHICLE OWNERSHIP ON FROM-HOME TRIP FREQUENCY

No of Persons per DU	0 Veh per DU		1 Veh per DU		2 Veh per DU		3 Veh per DU		4 Veh per DU		5 Veh per DU	
	Trips per DU	No of DU	Trips per DU	No of DU	Trips per DU	No of DU	Trips per DU	No of DU	Trips per DU	No of DU	Trips per DU	No of DU
1	0 37	403	1 21	330	1 73	15	--	--	--	--	0 77	748
2	0 79	193	2 49	947	2 64	352	3 17	23	--	--	2 31	1,515
3	1 66	56	3 16	452	3 80	333	3 96	57	--	--	3 35	898
4	2 16	25	3 88	462	4 48	337	5 46	60	6 27	11	4 19	895
5	2 11	18	4 03	274	5 39	229	6 31	39	--	--	4 68	560
6	3 50	12	4 29	100	5 98	90	6 81	16	--	--	5 12	218
7	--	--	4 03	34	4 83	41	7 64	14	--	--	4 96	89
8	--	--	5 14	14	--	--	--	--	--	--	5 14	14
Total	0 75	707	2 95	2,613	4 08	1,397	5 20	209	6 27	11	3 05	4,937

TABLE 2

FAMILY COMPOSITION AND AVERAGE VEHICLE OWNERSHIP FOR DIFFERENT HOUSEHOLD SIZES

Persons per DU	Percent Family 14 Years and Older	Avg. No. of Wage Earners per Family	Percent of Family Wage Earners	Avg. No. of Veh. per Dwelling Unit	Avg. No. of Veh. per Person
1	100	0.82	82.0	0.48	0.48
2	99	1.33	66.5	1.13	0.57
3	80	1.66	55.4	1.44	0.48
4	62	1.47	36.8	1.52	0.38
5	64	1.55	31.0	1.51	0.30
6	47	1.39	23.2	1.50	0.25
7	45	2.01	27.7	1.78	0.25

may be described by a linear regression equation as a first approximation. The least squares regression equation relating family size and from-home trip frequency was computed to be

$$T = 0.467 + 0.831p \quad (1)$$

in which

T = average number of person trips made from the home per day;

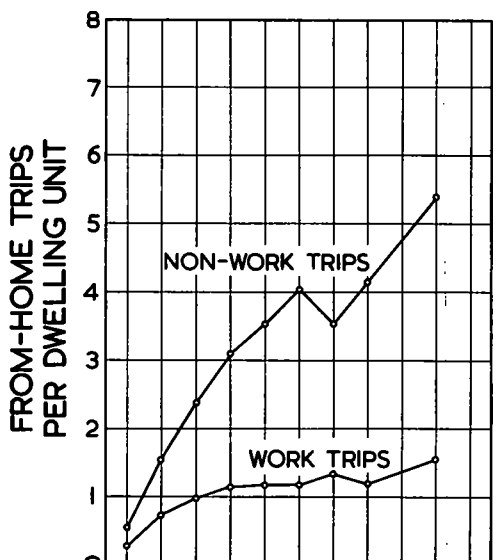

Figure 2. Frequency of from-home work and non-work trips per dwelling unit at various levels of family size.

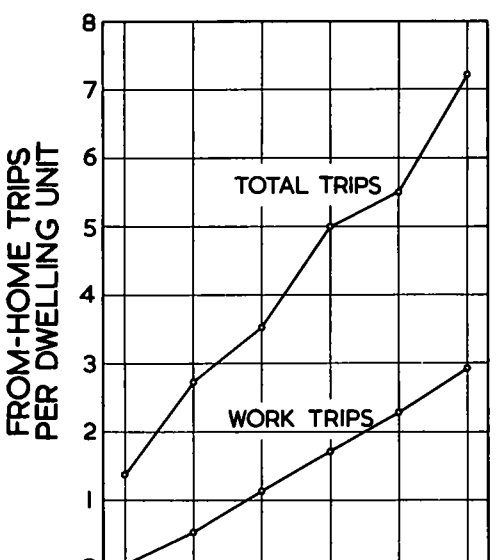

Figure 3. Frequency of from-home work and non-work trips per dwelling unit for various numbers of wage earners per dwelling unit.

p = number of persons living in the dwelling unit.

The coefficient, 0.831, indicates that the addition of each family member increases from-home trip production by about 0.8 trips per day. Comparison of the slope of the regression line with the curve in Figure 1 shows that the coefficient, 0.8, approximates the true increase only in the middle range of household size. It underestimates the effect of family size at the lower end and exaggerates it for the larger families. Over the entire range, the standard error of estimate, σ_e, is ±0.76 trips per day and the coefficient of variation is 24.5 percent. (The inclusion of non-linear terms in this and subsequent equations increases the precision of the estimate only a negligible amount due to lumping of the data in the middle and lower range of the independent variable. The gain is much too slight to justify the additional computations involved.)

The increase in trip production accompanying increased family size is mainly in the non-work category. Figure 2 shows work trips level off at the 4-person-per-dwelling-unit level, whereas non-work trips continue to rise beyond this point. Because work trips vary almost linearly with number of workers (see Fig. 3), limitation of the number of wage earners in even the largest families results in the leveling off in the frequency of work trips which is observed.

VEHICLE OWNERSHIP

Although it is the activities of persons which produce the demand for trips, it is chiefly the presence of the automobile and an adequate system of streets and highways which makes the satisfaction of these demands possible. Assuming that in any one community the relative adequacy of the road system is more or less uniform throughout that community, the opportunity to travel will be principally a function of the number of motor vehicles available for use by the members of the household. By separating the households in the Modesto area according to the number of vehicles owned, this hypothesis could be tested. These data, summarized along the lower margin in Table 1, are shown in Figure 4. As noted in the case of family size, the curve is concave downward, indicating that the intensity of vehicular use in terms of trips per vehicle is lower for multi- than for single-car households. The relationship beyond three vehicles per dwelling unit is based on only 54 observations and therefore, should not be given as much weight as the other points.

Most of the observations fall in the one- and two-car-per-dwelling-unit range, and, as before, the data may be summarized by a linear regression equation. The least squares equation is

$$T = 1.229 + 1.379v \qquad (2)$$

in which

T = average number of person trips made from the home per day;
v = number of vehicles per dwelling unit.

The graph of this expression is superimposed on the curve of the tabulated data in Figure 4, which shows that the coefficient, 1.379, understates the effect of vehicle ownership in the lower range of the independent variable and overstates it in the upper portion of the curve. This will always be the case where a straight line is fitted to data that are concave downward. The standard error of estimate, σ_e, is ±0.78 trips per day and the coefficient of variation is 25.2 percent.

In addition to summarizing the relationship between vehicle ownership and from-home trip frequency for Modesto, Figure 4 includes similar data prepared for 36 cities by Schmidt and Campbell (2). The agreement between these data and the curve derived from tabulated Modesto information is quite good in the lower range of vehicle ownership. However, linear extrapolation beyond the one-vehicle-per-dwelling-unit limit would grossly overestimate the frequency of generated trips.

The effect of auto ownership on travel mode is shown in Figure 5. As car ownership increases from zero- to four-vehicles-per-person, auto-driver trips rise, both numerically and as a proportion of total trips. Auto-passenger trips decline proportionately, although their absolute numbers generally increase. The frequency of transit trips, though consistently low at all levels of vehicle ownership, represents a significant mode of travel for families owning no vehicles. This would indicate a definite and continuing need for transit service even in areas of high auto ownership such as those characterized by Modesto and cities of similar size.

JOINT EFFECTS OF FAMILY SIZE AND VEHICLE OWNERSHIP

Because high vehicle ownership is usually associated with large family size, the effect of either of these variables on trip frequency tends to be exaggerated by the contributory effects of the other. Interference of this type can be eliminated by cross-tabulating the two independent variables. Table 1 shows such a cross-tabulation permits analysis of the relation between family size, for example, and trip frequency at any level of vehicle ownership. Conversely, it allows the study of effects of variations in vehicle ownership at any level of family size.

The data of Table 1 are shown graphically in Figures 6 and 7. Figure 6 illustrates the effect of family size on trip production at four different levels of vehicle ownership. This set of curves shows that not only do trips per dwelling unit increase with increasing family size, but also that the rate of increase is least at the zero-vehicle level and greatest for families owning two or three cars. It would appear that the greater trip potential inherent in larger families is fully realized only where a sufficient number of automobiles is available for use by the family members. (It is also likely that multi-car families contain a greater number of adults than single-car families of the same size and, therefore, would produce more trips, all other things being equal.) A similar effect is noted in Figure 7, where the rate of increase in trip frequency with increasing vehicle ownership is greatest for large families and least for small ones.

Figures 6 and 7 have been combined into Figure 8, an isometric block diagram, to illustrate the joint relationship between family size, vehicle ownership, and frequency of from-home trips. In this diagram, as in the previous two, only data for those classes containing ten or more dwelling units have been shown in order to exclude erratic values resulting from very small class sizes.

The surface of relationship in Figure 8 may be estimated by

$$T = -0.137 + 0.632p + 0.950v \qquad (3)$$

in which T, p and v are defined as before. The standard error of estimate is ± 0.72 trips per day and the coefficient of variation is 23.2 percent.

Comparison of Eq. 3 with the two equations discussed previously indicates the extent to which consideration of either one of the variables, person or vehicles, by itself, overestimates the effect of that variable on trip generation. In Eq. 1, the addition of one person to the household resulted in an increase of 0.8 trips per dwelling unit per day. Because family size and vehicle ownership are, themselves, related in a positive manner, inclusion of the effect of vehicle ownership in the regression equation reduces the impact of family size from 0.8 to 0.6 trips per day, a reduction of 25 percent. A comparable reduction in the effect of vehicle ownership on trips is noted when family size is also considered. In this instance, the coefficient drops from 1.4 to 0.95 trips per dwelling unit per day.

DISTANCE TO CENTRAL BUSINESS DISTRICT

An increase in the average frequency of motor vehicle trips with increasing distance of the dwelling unit from the CBD is a well-observed phenomenon in most urban traffic studies. CBD distance, however, is also associated with household size and level of vehicle ownership—variables which, themselves, are closely related to trip production.

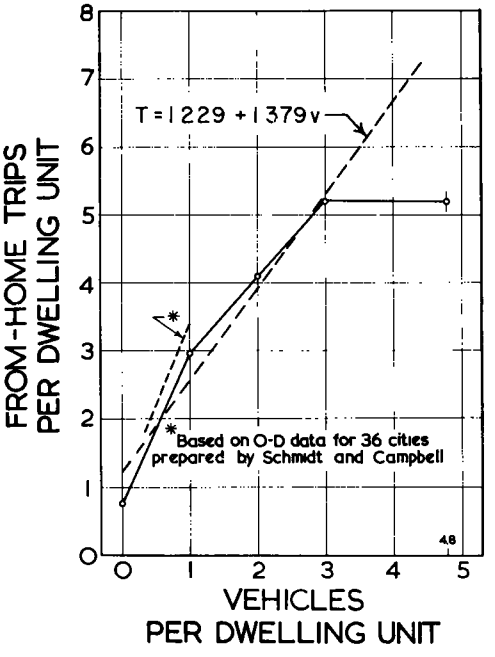

Figure 4. Frequency of from-home trips per dwelling unit at various levels of vehicle ownership.

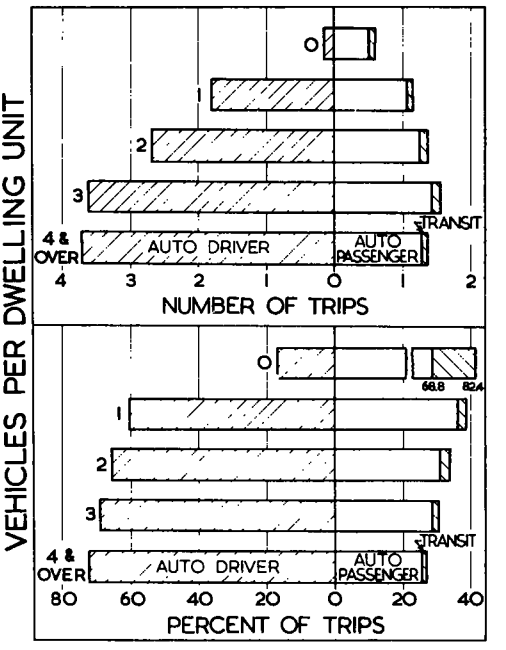

Figure 5. Number and percent of from-home trips per dwelling unit by mode of travel at various levels of vehicle ownership.

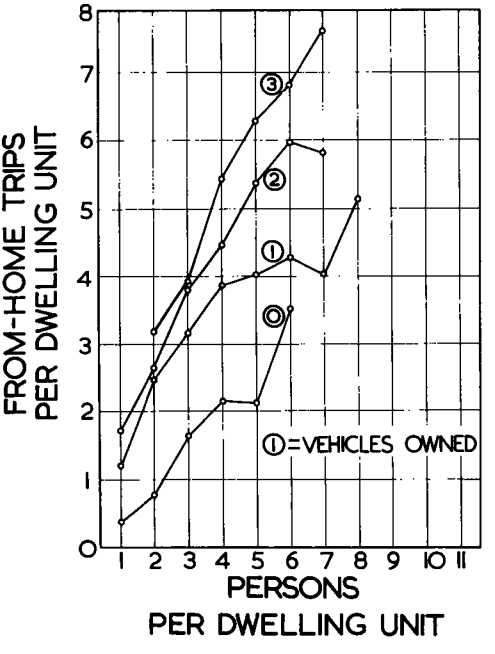

Figure 6. Frequency of from-home trips per dwelling unit at various levels of family size and vehicle ownership.

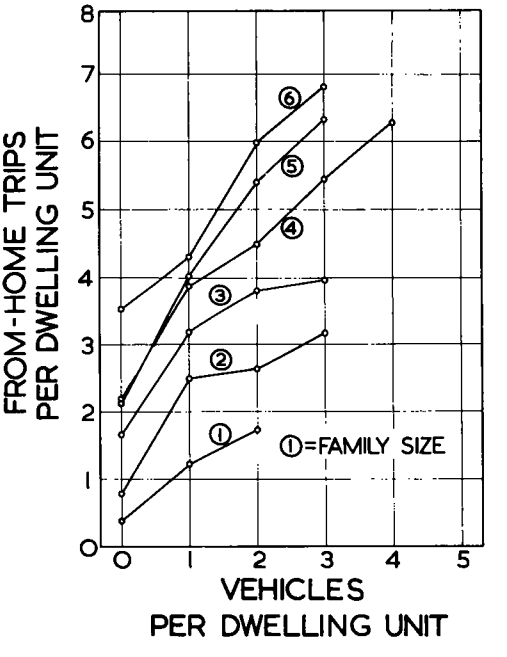

Figure 7. Frequency of from-home trips per dwelling unit at various levels of vehicle ownership and family size.

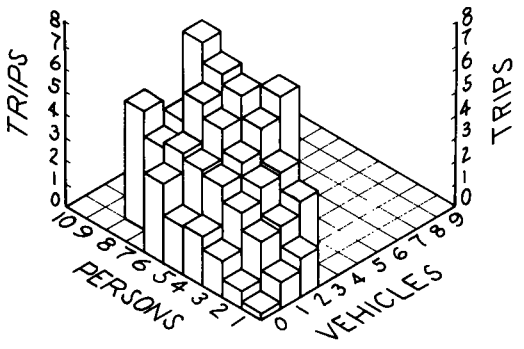

Figure 8. Frequency of from-home trips per dwelling unit at various levels of family size and vehicle ownership.

Average trip frequency, family size, and vehicle ownership have been summarized in Table 3 according to distance of the dwelling unit from the CBD. The resulting relationships are shown in Figure 9. Vehicle ownership and family size rise parallel with trip frequency as distance from the city center increases.

To test the effect of distance on trips, independent of variations in the other two variables, the Modesto households were cross-tabulated according to each of the three independent variables. In this manner, each of the nine distance categories was subdivided into 20 subclassifications depending on dwelling unit size and number of vehicles owned. Average trip frequencies for the resulting 180 cells are given in Table 4. Mean trip frequencies for two- and four-person households owning one vehicle are shown in Figure 10. A very slight upward trend is still discernible (almost obliterated by sampling variability due to small cell frequencies), but the strong relationship between distance and trips which is apparent in Figure 9 is no longer evident. The association between trip frequency and distance from the city center is seen mainly to reflect concurrent variations in family size and vehicle ownership.

DWELLING UNIT TYPE

A number of alternative hypotheses may be appropriate in explaining the association of different trip generation rates with different types of dwelling units. Perhaps the most interesting and fruitful of these considers dwelling unit type to be a reflection of the degree of integration of the family into the community. Families residing in single family dwelling units are assumed to be the most highly integrated, whereas those living in hotels are considered to be the least integrated. Associated with higher degrees of integration should be greater participation in social and community activities which, on the average, may result in a great number of trips from these types of dwelling units as compared to less settled households.

To test this hypothesis, the dwelling units in the Modesto area were classified

TABLE 3

AVERAGE NUMBER OF FROM-HOME TRIPS, PERSONS, AND VEHICLES PER DWELLING UNIT AT VARIOUS DISTANCES FROM THE CITY CENTER

Distance to CBD (mi)	From-Home Trips per DU	Avg. No. of Persons per DU	Avg. No. of Veh. per DU	No. of Cases
0.0 - 0.3	1.19	1 72	0 52	155
0.4 - 0.6	2.00	2.26	0.94	508
0.7 - 0.9	2 66	2.65	1.19	432
1.0 - 1.4	3 26	2.99	1 32	861
1.5 - 1.9	3.21	3 26	1.27	1,086
2.0 - 2.4	3.44	3.46	1.35	806
2.5 - 2.9	3.50	3.32	1.39	476
3.0 - 3.9	3.56	3.42	1.50	350
4.0 and over	3.50	3.49	1.40	364

TABLE 4

FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT AT VARIOUS DISTANCES FROM CBD FOR DIFFERENT COMBINATIONS OF FAMILY SIZE AND VEHICLE OWNERSHIP

0 VEHICLES PER DWELLING UNIT

DISTANCE TO CBD, miles	FROM-HOME TRIPS PER DWELLING UNIT					
	PERSONS PER DWELLING UNIT					TOTAL
	1	2	3	4	5 & MORE	
0.0-0.3	0.21 *70*	0.43 *14*	1.00 *4*	—	1.00 *1*	0.29 *89*
0.4-0.6	0.29 *99*	0.58 *40*	1.00 *8*	1.00 *3*	2.00 *2*	0.44 *152*
0.7-0.9	0.53 *43*	0.50 *20*	0.33 *3*	1.00 *1*	3.00 *1*	0.56 *68*
1.0-1.4	0.44 *50*	0.95 *22*	1.00 *10*	3.67 *3*	6.75 *4*	1.02 *89*
1.5-1.9	0.52 *60*	0.92 *39*	2.13 *15*	2.30 *10*	2.09 *11*	1.07 *135*
2.0-2.4	0.34 *32*	0.96 *28*	2.54 *13*	1.40 *5*	2.78 *14*	1.27 *92*
2.5-2.9	0.35 *17*	1.50 *12*	0.00 *1*	0.00 *1*	1.00 *2*	0.79 *23*
3.0-3.9	0.27 *15*	0.50 *4*	2.00 *1*	6.00 *1*	1.00 *2*	0.70 *23*
4.0 & OVER	0.41 *17*	0.71 *14*	3.00 *1*	3.00 *1*	2.00 *2*	0.77 *35*
TOTAL	0.37 *403*	0.79 *183*	1.66 *56*	2.16 *25*	2.69 *39*	0.77 *716*

1 VEHICLE PER DWELLING UNIT

DISTANCE TO CBD, miles	FROM-HOME TRIPS PER DWELLING UNIT					
	PERSONS PER DWELLING UNIT					TOTAL
	1	2	3	4	5 & MORE	
0.0-0.3	0.81 *21*	2.25 *16*	1.86 *7*	7.67 *6*	1.00 *1*	2.28 *51*
0.4-0.6	1.12 *60*	2.26 *113*	3.00 *43*	2.88 *26*	5.06 *19*	2.39 *261*
0.7-0.9	1.02 *41*	2.42 *112*	2.97 *39*	2.91 *24*	4.00 *23*	2.45 *239*
1.0-1.4	1.41 *66*	2.57 *200*	3.97 *63*	4.19 *79*	3.95 *61*	3.05 *469*
1.5-1.9	1.36 *56*	2.66 *179*	3.20 *112*	3.68 *118*	3.73 *117*	3.06 *582*
2.0-2.4	1.50 *24*	2.34 *123*	3.46 *91*	3.71 *96*	3.71 *85*	3.12 *419*
2.5-2.9	1.15 *27*	2.76 *98*	2.57 *35*	4.15 *46*	4.69 *54*	3.21 *260*
3.0-3.9	1.21 *19*	2.10 *40*	2.54 *33*	3.56 *36*	5.12 *34*	3.04 *162*
4.0 & OVER	0.88 *16*	2.44 *66*	2.58 *29*	5.22 *31*	5.96 *41*	3.58 *183*
TOTAL	1.21 *350*	2.49 *947*	3.16 *452*	3.88 *462*	4.26 *435*	2.98 *2626*

2 VEHICLES PER DWELLING UNIT

DISTANCE TO CBD, miles	FROM-HOME TRIPS PER DWELLING UNIT					
	PERSONS PER DWELLING UNIT					TOTAL
	1	2	3	4	5 & MORE	
0.0-0.3	—	1.60 *5*	2.00 *3*	2.67 *3*	1.500 *1*	3.08 *12*
0.4-0.6	1.00 *1*	2.75 *28*	3.61 *31*	2.60 *10*	4.78 *9*	3.28 *79*
0.7-0.9	2.50 *2*	2.87 *38*	3.52 *29*	4.71 *17*	4.93 *15*	3.66 *101*
1.0-1.4	2.00 *2*	2.68 *62*	4.10 *60*	4.76 *69*	5.16 *66*	4.18 *259*
1.5-1.9	1.50 *2*	2.83 *74*	3.95 *64*	4.37 *86*	5.46 *82*	4.18 *308*
2.0-2.4	2.00 *3*	2.74 *51*	4.09 *56*	4.58 *60*	5.66 *68*	4.35 *238*
2.5-2.9	1.00 *2*	2.20 *35*	3.50 *32*	5.03 *38*	6.26 *50*	4.42 *157*
3.0-3.9	1.00 *2*	2.11 *35*	3.47 *34*	4.64 *28*	5.92 *38*	4.01 *137*
4.0 & OVER	3.00 *1*	2.87 *24*	3.66 *24*	3.73 *26*	4.63 *41*	3.85 *116*
TOTAL	1.53 *15*	2.64 *352*	3.80 *333*	4.48 *337*	5.49 *370*	4.09 *1407*

3 & MORE VEHICLES PER DWELLING UNIT

DISTANCE TO CBD, miles	FROM-HOME TRIPS PER DWELLING UNIT					
	PERSONS PER DWELLING UNIT					TOTAL
	1	2	3	4	5 & MORE	
0.0-0.3	—	2.00 *1*	—	3.00 *1*	—	2.50 *2*
0.4-0.6	—	4.00 *4*	3.33 *6*	9.00 *1*	4.75 *4*	4.27 *15*
0.7-0.9	2.00 *1*	4.00 *1*	5.17 *6*	6.50 *4*	8.00 *11*	6.56 *23*
1.0-1.4	—	4.50 *4*	4.24 *12*	5.50 *12*	4.69 *16*	4.78 *44*
1.5-1.9	2.00 *3*	1.67 *6*	3.83 *12*	5.94 *19*	7.14 *14*	5.09 *54*
2.0-2.4	1.00 *1*	2.00 *2*	3.94 *18*	4.86 *14*	7.31 *22*	5.35 *57*
2.5-2.9	—	3.00 *4*	3.74 *4*	4.14 *7*	5.10 *10*	4.52 *25*
3.0-3.9	—	2.75 *4*	4.00 *5*	5.63 *8*	8.19 *11*	5.93 *28*
4.0 & OVER	3.00 *1*	3.60 *5*	3.50 *6*	7.14 *7*	6.38 *8*	5.29 *27*
TOTAL	2.50 *6*	3.13 *31*	3.98 *69*	5.61 *73*	6.61 *96*	5.21 *275*

0.21 = FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT
70 = NUMBER OF DWELLING UNITS IN SAMPLE

according to type. Mean trip frequency, family size, and vehicle ownership were then computed for each type. This information is summarized in Table 5, where the five dwelling unit types are arranged in increasing order of permanency. In keeping with the hypothesis, average trip frequencies increase with increasing degree of permanency—but so do family size and vehicle ownership. To account crudely for these concurrent variations, the mean trip frequencies were adjusted for differences in vehicle ownership and family size according to the multiple regression equation developed earlier. Adjustment in this manner greatly reduces the differences in average trip frequency between each type, although the ranking of the various types is unchanged. (The more rigorous approach would have been to compute separate regression equations for ve-

TABLE 5

EFFECT OF FAMILY SIZE AND VEHICLE OWNERSHIP ON FROM-HOME TRIP FREQUENCY BY DWELLING UNIT TYPE

DU Type	Avg No. of Persons per DU (p)	Avg No. of Veh. per DU (v)	Avg. No. of From-Home Trips per DU (T)	Adjusted No. of From-Home Trips per DU (Ta)[1]	No. of DU
Hotel, motel, Rooming house, etc.	1.99	0.67	1.50	2.95	206
House trailer	2.15	0.82	1.91	3.10	112
Apartment	1 74	0 64	1.57	3.19	149
Duplex and flat	2 37	0 94	2.31	3.26	334
Single-family	3.25	1 35	3.32	3.32	4,237

[1] Average trip frequencies for each dwelling unit type were adjusted by moving T up regression line, $T = -0.137 + 0.632p + 0.950v$, to point where levels of family size and vehicle ownership were all equal to those of single-family group. For example, in apartment category:

$$T_a = 1.57 + (3.25 - 1.74)(0\ 632) + (1.35 - 0.64)(0.950)$$
$$= 1.57 + 0.95 + 0\ 67$$
$$= 3.19.$$

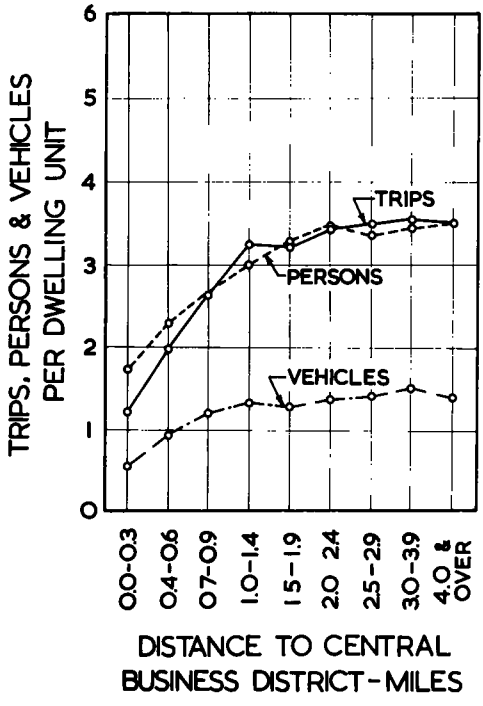

Figure 9. Frequency of from-home trips per dwelling unit, family size and vehicle ownership at different distances from CBD

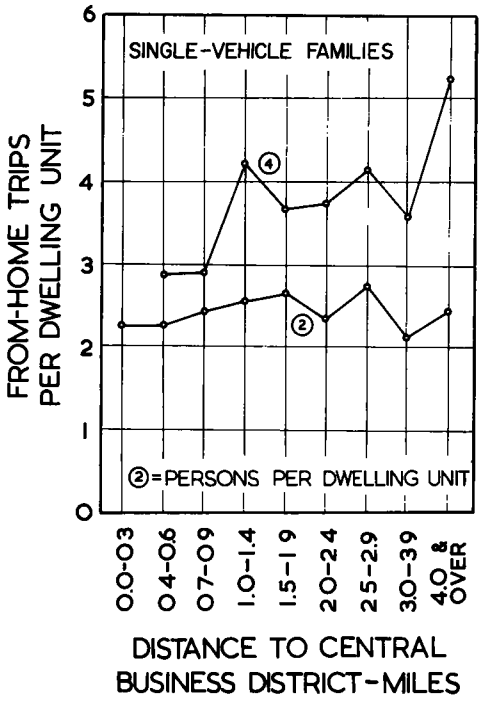

Figure 10. Frequency of from-home trips per dwelling unit for various family sizes at different distances from CBD.

TABLE 6

COMPOSITION OF THE FOUR OCCUPATION STATUS GROUPS

Status Group	Occupation
High	Professional and semi-professional; proprietors; managers, and officials; farmers and farm managers
Medium	Clerks and salesmen (including traveling salesmen), protective services, military personnel
Low	Operators, semiskilled laborers, farm laborers; personal service; truck and taxi drivers; deliverymen
Non-gainful	Retired, housewives, students, looking for work, employment status unknown

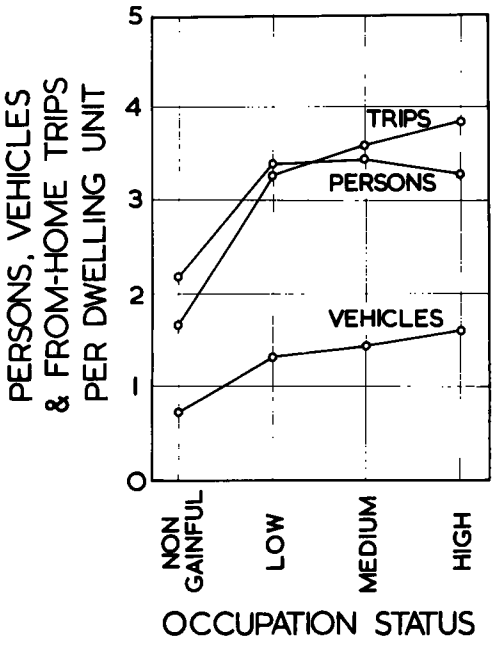

Figure 11. Variations in from-home trips, persons and vehicles per dwelling unit for different occupation status groups.

TABLE 7

EFFECT OF FAMILY SIZE AND VEHICLE OWNERSHIP ON FROM-HOME TRIP FREQUENCIES BY OCCUPATION STATUS

Occupation Status of Head of Household	Avg No. of Persons per DU (p)	Avg No. of Veh per DU (v)	Unadjusted No of From-Home Trips per DU (T)	Adjusted No. of From-Home Trips per DU (Ta)[1]	No. of DU
Non-gainful	2.17	0 74	1.68	2.97	1,202
Low	3.37	1.30	3.24	3.24	1,381
Medium	3 41	1.42	3.58	3 44	1,263
High	3.26	1.58	3.83	3.63	1,192

[1] Trips adjusted to level of low group on basis of regression equation: T = -0.137 + 0.632p + 0 950v.

hicles and persons within each class of dwelling unit. The average number of trips per dwelling unit for each type would then have been adjusted according to the equation for that particular type.)

OCCUPATION OF HEAD OF HOUSEHOLD

The occupation of the head of the household is one of the major determinants of the level of living a family enjoys. As such, occupation should be associated with trip frequency, as well as with other household characteristics (such as family size and vehicle ownership) which have been shown to affect trip production.

To test the relation between occupation and trip generation, the 14 occupation groups reported in the Modesto study were combined into four categories roughly indicative of the status of the several occupations included within each category. The composition of each category is shown in Table 6. The dwelling units in the Modesto area were then identified with one of the four status groups according to the reported occupation of the head of the household. Average trip frequency, vehicle ownership, and family size were computed for each of these four groups and are reported in Table 7. Figure 11 shows all three variables exhibit approximately parallel changes in moving between the four occupation groups. Adjusting trip frequencies for differences in the other two variables according to the approximate technique previously discussed decreases the differences between the mean trip frequencies considerably. A very crude analysis of the resulting variances indicates that this adjustment reduces the variance ratio from approximately 40 to 4.5, a value that is significant at the 0.005 level.

To study further the effects of occupation status on trip generation, each of the four occupation groups was subdivided into 16 classes depending on level of family size and vehicle ownership. Mean trip generation rates for each of the 64 resulting categories are given in Table 8. These data are summarized in Figure 12, which shows the manner in which trip generation varies with changing occupation for each combination of vehicle ownership and family size. A slight increase in trip frequency is noticeable with changing occupation, but most of the variation apparent in Figure 11 is seen to be a result of associated variations in household size and vehicle ownership.

Table 9 and Figure 13 show the distribution of from-home trips by purpose for the different status groups. With the exceptions of an understandably small proportion of

TABLE 8

FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT AT VARIOUS LEVELS OF FAMILY SIZE AND VEHICLE OWNERSHIP WITHIN FOUR OCCUPATION STATUS GROUPS

NON GAINFUL

PERSONS PER DWELLING UNIT	FROM-HOME TRIPS PER DWELLING UNIT				
	NUMBER OF VEHICLES OWNED				TOTAL
	0	1	2	3	
1	0.30 *276*	1.24 *106*	2.00 *2*	0.00 *1*	0.57 *385*
2	0.70 *138*	2.02 *327*	2.32 *47*	1.33 *3*	1.69 *515*
3	1.30 *30*	2.33 *70*	3.13 *38*	4.75 *4*	2.40 *142*
4	1.64 *11*	3.22 *36*	4.83 *18*	4.60 *5*	3.49 *70*
TOTAL	0.52 *455*	1.99 *539*	3.04 *105*	3.54 *13*	1.51 *1112*

LOW STATUS

PERSONS PER DWELLING UNIT	FROM-HOME TRIPS PER DWELLING UNIT				
	NUMBER OF VEHICLES OWNED				TOTAL
	0	1	2	3	
1	0.47 *78*	0.99 *84*	1.50 *4*	1.67 *3*	0.78 *169*
2	0.92 *38*	2.70 *221*	2.46 *79*	3.33 *6*	2.46 *344*
3	2.06 *17*	3.28 *144*	3.53 *96*	4.16 *13*	3.33 *270*
4	1.50 *8*	3.94 *138*	4.33 *86*	4.50 *16*	4.03 *248*
TOTAL	0.84 *141*	2.89 *587*	3.43 *265*	3.97 *38*	2.79 *1031*

MEDIUM STATUS

PERSONS PER DWELLING UNIT	FROM-HOME TRIPS PER DWELLING UNIT				
	NUMBER OF VEHICLES OWNED				TOTAL
	0	1	2	3	
1	0.67 *27*	1.20 *64*	1.50 *4*	2.00 *2*	1.08 *97*
2	0.86 *7*	2.72 *212*	2.66 *97*	3.33 *3*	2.67 *319*
3	—	2.98 *132*	3.92 *102*	3.61 *18*	3.40 *252*
4	—	3.81 *167*	4.54 *122*	5.33 *15*	4.21 *304*
TOTAL	0.71 *34*	2.93 *575*	3.75 *325*	4.39 *38*	3.18 *972*

HIGH STATUS

PERSONS PER DWELLING UNIT	FROM-HOME TRIPS PER DWELLING UNIT				
	NUMBER OF VEHICLES OWNED				TOTAL
	0	1	2	3	
1	0.50 *22*	1.41 *76*	2.00 *5*	3.00 *1*	1.26 *104*
2	1.50 *10*	2.79 *187*	2.85 *129*	3.55 *11*	2.80 *337*
3	1.25 *4*	3.74 *111*	4.21 *97*	4.00 *22*	3.91 *234*
4	6.33 *3*	4.05 *124*	4.48 *111*	6.04 *24*	4.44 *262*
TOTAL	1.28 *39*	3.10 *498*	3.76 *342*	4.74 *58*	3.37 *937*

0.30 = FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT

276 = NUMBER OF DWELLING UNITS IN SAMPLE

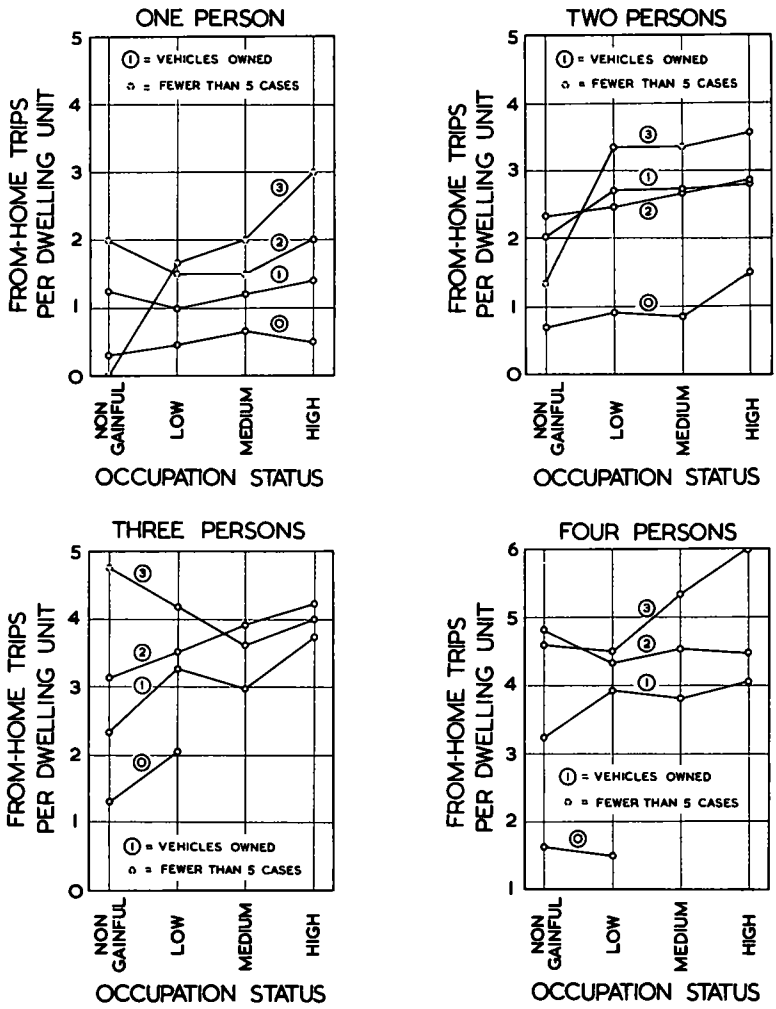

Figure 12. Frequency of from-home trips per dwelling unit for different occupation status groups at various levels of family size and vehicle ownership.

work trips in the non-gainfully employed group and a relatively large percentage of related business trips in the high group, a remarkable similarity in travel habits is evidenced. But for these two exceptions, occupation status apparently has little effect on the relative proportions of trips that families make for various purposes.

To facilitate comparison of the non-work trips, Table 10 gives the percent distribution of the five non-work categories alone. In this way, the effect of the very low proportion of work trips in the non-gainful group is eliminated, permitting a more realistic comparison to be made between the remaining non-work portions. As a result, the percentages for the non-gainful group fall more clearly into line with the other three classes and the similarities in the distributions becomes even more marked.

The lack of appreciable variations between the travel habits of families in the four status groups may be examined from diverse points of view. On one hand, the observed similarities may reflect a real lack of social differentiation between the various groups, at least insofar as travel habits are concerned. It may be that society is less rigid in western cities than in the older settled areas of the country. Perhaps the activities of lawyers and bricklayers in Modesto do not vary nearly so much as they do in Phila-

TABLE 9

DISTRIBUTION OF FROM-HOME TRIPS BY PURPOSE FOR VARIOUS OCCUPATION STATUS GROUPS

Occupation Status of Head of Household	Work (%)	Related Business (%)	Shopping (%)	Social Recreational (%)	Medical Dental (%)	Education Religion Civic (%)	Other[1] (%)	Total (%)
Non-gainful	11.0	0.5	22.9	29.3	2.2	7.5	26.6	100.0
Low	31.8	1.5	14.3	23.2	1.4	6.8	21.1	100.0
Medium	26.4	3.1	13.2	25.4	1.8	6.7	23.4	100.0
High	22.3	6.0	13.8	22.9	1.7	7.6	25.7	100.0
All groups	24.7	3.2	15.0	24.6	1.7	7.0	23.8	100.0

[1] Includes eat meal, serve passenger, change mode, and others.

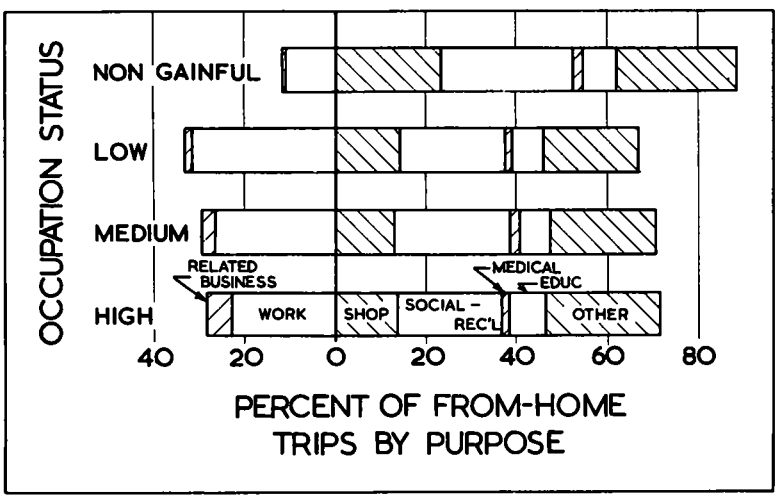

Figure 13. Percent distribution of from-home trips for four occupation status groups.

delphia or Boston, or even in smaller eastern communities. Studies of possible variations in relationships between status and trip characteristics in cities of differing types and in different parts of the country might provide a test of this premise.

On the other hand, failure to observe appreciable variations in travel habits may result from lack of a valid operational classification of occupational status and from the aggregation of dissimilar status classes into the same group. The status level of each occupation, as used in Table 6, is based on the classification scheme developed by Alba M. Edwards for use with the United States Census of 1930 (3). Changes in the status of certain occupations since that time, principally the economic and social gains made by semi-skilled laborers during and since World War II, tend to reduce the usefulness of this system of occupational ranking. The applicability of the Edwards ranking was further reduced by the combination in this study of such diverse classes as farmers and farm managers within the same status group.

TABLE 10

DISTRIBUTION OF NON-WORK FROM-HOME TRIPS BY PURPOSE FOR VARIOUS OCCUPATION STATUS GROUPS

Occupation Status of Head of Household	Shopping (%)	Social Recreational (%)	Medical Dental (%)	Education Religion Civic (%)	Other[1] (%)	Total (%)
Non-gainful	25.9	33.1	2.5	8.5	30.0	100.0
Low	21.4	34.8	2 1	10.1	31.6	100.0
Medium	18.7	36.0	2.6	9 5	33.2	100.0
High	14.3	31.9	2.4	10.6	35.8	100.0
All groups	20.8	34.1	2.4	9 7	33.0	100.0

[1] Includes eat meal, serve passenger, change mode, and others.

It is most important that future studies of this kind be based on a system of occupational ranking that is more in keeping with the current status of the various occupations. Also, every effort should be made to maintain the identity of each occupation throughout the analysis, rather than to combine occupations prematurely into larger status groups.

To test the generality of the relationships between occupation and trip generation developed for Modesto, data from another, quite different, community were examined.

TABLE 11

DISTRIBUTION OF TRIPS BY PURPOSE OF TRAVEL FOR VARIOUS OCCUPATION GROUPS (Chicago)

Status Group and Occupation		All Trips Other Than To-Home						No. of DU
		Avg. No. per DU	Percent by Purpose					
			Work	Shop	Social-Recreation	Other	Total	
High:	Managers and proprietors	4 36	43.6	12.2	15.8	28.4	100.0	643
	Professional	4 05	38.0	13.8	17.3	30.9	100.0	526
	Total	4 22	41.1	12.9	16.5	29.5	100.0	1,169
Medium:	Sales workers	4 74	54.9	9.3	11.4	24.4	100.0	324
	Craftsmen and foremen	3.10	46.2	14.2	14.8	24 8	100.0	896
	Clerical	2 64	51.1	11.4	13.6	23.9	100.0	469
	Total	3 29	49.2	12.5	13.8	24.5	100.0	1,689
Low:	Operatives	2 66	53.7	12.4	13.2	20.7	100.0	663
	Service Workers	2 71	50.9	10.0	15.1	24.0	100.0	340
	Laborers	2.43	57.6	7.0	13.6	21.8	100.0	270
	Total	2 62	53.8	10.6	13.8	21.8	100.0	1,273
Unemployed		2 45	13.5	24.9	25.7	35.9	100 0	293
Total		3 29	46.0	12.9	15.3	25.8	100.0	4,424

A sample of 4,455 dwelling units in the Chicago area were obtained from the Chicago Area Transportation Study and subdivided into twelve occupation categories. For each category, mean trip generation rates by trip purpose were computed. Table 11 summarizes these data for the major occupation categories, grouped into four classes roughly comparable to the four occupation status groups used in the Modesto study. Because Table 11 is based on all trips (except trips to home), it is not strictly comparable to Tables 9 and 10 for which only those trips originating at the home were used. There is enough in common, however, between the two studies to permit the following observations to be made.

Average daily trip frequencies vary with occupation, being greatest for the high group and lowest for the non-gainfully employed. The one occupation that is markedly different from the other occupations in its group is sales workers. The trip frequency for the sales group reflects the disproportionate number of job trip characteristic of this occupation. Because the Modesto data included only from-home trips, work trips made as part of the day's activities were not considered. With this one exception, the ranking of occupation groups according to average trip frequency agrees very well between the two studies. Further agreement is noted for the ranking of trips to work. As before, the proportion of work trips for the gainfully employed groups decreases as occupation status increases; the major exception once again being the sales group. Because trips to work represent the largest percentage of trips in Table 11, the relative proportions of trips for other purposes more or less reflect the variations previously discussed. The percentage for non-work purposes varies little between the several occupations (with the exception of the unemployed category).

Variations in family size and vehicle ownership between the different occupations are currently being analyzed. Pending completion of this analysis, further discussion of these data do not appear to be warranted at this time.

SOCIAL AREA INDEXES

The discussion heretofore has dealt with characteristics that were applicable to individual dwelling units. Differentiations between households in terms of family size, vehicle ownership, or some other attributes of a single dwelling unit, have been attempted which would help to explain why one household differs from other households in terms of the number of trips it produces. Yet, a family does not live in isolation; it affects and is affected by its environment. Indeed, the very nature of a trip demands that this be so.

Distance to the CBD is one way of summarizing a large number of environmental features that in some way may affect trip generation rates. However, at least for Modesto, the effect of distance is minimal once related variations in family size and vehicle ownership have been accounted for. Residential density is another environmental variable that, primarily through its effect on the rate at which walking trips are substituted for vehicular trips, is related to reported generation rates.

This section borrows from recent work in sociology in an attempt to describe the social environment in which a family lives, more fully and with a greater degree of precision than is possible through geographic measures such as location or residential density. The device used consists of three mutually independent indexes derived from census data to form a social area typology (4). This set of indexes, known as the Shevky-Bell typology, has been shown to exhibit a strong association with certain aspects of social behavior, such as neighborhood participation and political preference (5). To the extent that urban travel is a manifestation of urban social behavior, it is reasonable to expect that these indexes will help explain variations in urban trip making as well.

Three basic forms of social differentiation are proposed in the Shevky-Bell typology. Each local area (census tract, block, or enumeration district) is described in terms of social rank (economic status), urbanization (family status) and segregation (ethnic status). Using census statistics, these indexes are developed in the following manner:

1. Social Rank.—This index contains two elements: (a) the proportion of blue-collar workers, defined as the ratio of (1) craftsmen, operatives, and laborers to (2) all employees; and (b) education level as measured by the proportion of persons 25 years old and older who have completed eight or fewer years of schooling. The social rank index is inversely related to both ratios; hence, it attains a maximum value where no residents fall into the blue-collar jobs, and all residents 25 years and older have more than eight years of education.

2. Degree of Urbanization.—This index contains three elements: (a) fertility rate, defined as the ratio of children under five years of age to the female population of child-bearing age, "14 to 45" years of age; (b) female labor-force participation rate, meaning the percentage of women over 14 years of age who are in the labor force, and (c) incidence of single family dwelling units, or simply the percentage of single units to total dwelling units. The degree of urbanization index would be increased by (a) lower fertility rate, (b) higher female labor force participation rate, and (c) lower proportion of single dwelling units. In a sense, this index meters, in a rather negative way, the degree of attachment to the home. High values for this index imply less attachment to the home because of fewer children, higher likelihood of being employed, and less permanency of dwelling unit type in terms of average tenure.

3. Extent of Segregation.—This index is defined as the proportion of an area's residents who belong to certain minority groups, such as non-whites, foreign born Eastern Europeans, etc. It measures the extent to which these minority groups live in relative isolation.

From census tract data for Los Angeles and San Francisco, Shevky and Bell have shown that these three indexes are mutually orthogonal; that is, the frequency distribution of any one index is independent of the values assumed by the other two indexes. This is a highly desirable feature insofar as the indexes are used in multiple correlation analysis.

The impact of these social area indexes on trip generation rates was investigated with the aid of data for 57 traffic analysis zones in the Chicago area. From the CATS O-D survey, the following information was obtained for each of the 57 zones: average trips per occupied dwelling unit, Y; average car ownership, A; and average household size, H. The social area indexes for each census tract were computed from the 1950 population census data. Because each traffic analysis zone typically contains more than one census tract, some form of averaging proved essential. The three social area indexes for each traffic analysis zone represent weighted averages of the corresponding indexes for its constituent census tracts, where weights were proportional to land areas. Complete data for all 57 zones are given in Table 12.

The degree of association between pairs of variables is summarized by the matrix of correlation coefficients given in Table 13. Each coefficient indicates the direction (positive or negative), and closeness of the linear association between two variables; a value of zero corresponds to no association.

Inspection of the correlation matrix reveals several interesting results. As expected, the trip generation rate, Y, is most closely correlated with average car ownership A. The urbanization index, X_2, exhibits almost as high a negative correlation with trip frequency. This latter correlation may be interpreted as follows. A low urbanization index reflects greater attachment to the home as measured by larger proportions of children, fewer women in the labor force, and larger fractions of single-family dwelling units. Families who choose to reside in such low urbanization zones presumably have exhibited a preference for a way of life centering around the home. This preference must, in general, be accompanied by a commitment to greater travel demands. Indeed, the negative correlation of -0.883 between Y and X_2 would seem to support this line of argument.

The remaining two indexes, social rank, X_1, and segregation, X_3, show only modest correlations with trip generation rates. Furthermore, the three indexes were found to be approximately orthogonal to one another as advertised by Shevky and Bell.

The first model which was attempted related the trip generation rate, Y, to the three social area indexes, ignoring both car ownership and household size. The multiple

TABLE 12

SOCIAL AREA INDEXES AND RELATED VARIABLES FOR SELECTED TRAFFIC ANALYSIS ZONES (Chicago)

Traffic Analysis Zone	Trips per Occupied DU, Y	Average Car Ownership, A	Average Household Size, H	Social Rank Index X_1	Urbanization Index X_2	Segregation Index X_3
6	3 18	0.59	3 26	28 32	60.10	21 01
10	3 89	0 57	3.13	20.89	65 71	21.61
25	3 98	0 61	3.02	25 99	63 19	12 57
28	4.16	0 61	3 14	28 52	66 24	17 61
34	3 60	0 63	3 75	27.18	58.36	35 32
41	4 10	0 66	3 24	27 95	59 58	14 73
57	4 36	0 71	2 77	39 91	64 64	11 61
58	4 87	0.77	2 74	48 36	67 88	10 71
60	5 85	0 84	3 02	42 15	56 86	8 20
61	4 97	0.74	2 84	38 14	62 44	7.94
65	3 54	0 67	2.93	51 30	68 67	12.72
67	4 31	0 64	3 87	43 90	59 49	27 33
73	4 54	0 73	3 16	30 27	57 76	18 70
74	4 82	0 86	3 42	32.18	63 06	14 52
79	4 04	0 66	3 54	34 45	47.73	3 82
81	4 60	0 64	3.49	43.32	59.36	8 73
84	3 40	0 50	2.76	75 32	75 81	11 40
88	4 65	0 58	2.91	62 20	75 26	58 43
97	3 02	0 53	1 83	82 53	83 66	8.32
102	9 14	1 11	3 00	67 31	38 21	11 49
104	4 30	0 70	2 94	64 01	55 51	17.95
106	4 24	0.80	3 19	51 16	52 44	8 10
108	5 00	0.77	2 61	59.15	59.38	4 67
110	5 93	0 96	3 24	48 51	46 51	6 82
113	5 11	0 86	2 95	47 44	51.17	10 43
119	5 84	0.92	2 95	57.34	58.60	6 53
122	4 70	0 80	3 00	62 60	62 40	3.37
125	4 54	0 79	2 71	73 00	67 23	10 10
146	5 51	0 91	3 46	33.96	41.29	14 36
153	5 10	0 75	3 38	43 67	56 64	17 94
155	4 70	0 83	3 11	52 74	54.02	9 38
156	5 17	0 76	3.20	52 29	58 35	3 02
158	5 41	0 87	3 24	43 42	47.78	12 75
159	6 46	1.16	3 60	45 94	51.21	16.49
161	6 03	0 90	3 02	61.53	54.92	2.80
166	4 79	0.53	3 09	49 37	58 63	62.53
167	4 83	0.75	2.46	87.38	65.67	6 92
169	6 30	0 78	3 36	55.85	59.00	16 34
171	4 94	0 69	2 94	50.15	61.09	9 51
173	6 01	0 96	3 27	67 01	48 39	4 25
175	6 39	0 86	3 32	62.18	50.04	3 85
203	5 82	1 09	3 29	45 58	46.47	7.54
205	6 25	1 15	3 58	60.85	26 36	3 41
249	6 13	0 90	3 09	55 59	43 58	3 62
255	6 70	1 02	3 02	75 73	35 89	2.17
260	7 10	1 00	3 33	57 84	28.28	3 78
262	7 89	1 32	3 58	79 69	25 37	2 42
275	7 80	1 06	3 17	57 01	31 97	7 20
282	8 02	1 02	3 35	50 93	38 17	9 17
280	7 20	0 98	3 43	49.75	34 69	9 86
278	5 14	0 82	3 31	36.36	46 98	7 61
352	5.56	0 94	3 21	62 27	36 27	47 73
380	5 74	0 90	3 52	42 64	26 15	4 17
382	6.77	0 62	3 92	21.66	24 08	11 36
385	4 94	0 77	3 02	49 18	51 39	8.73
391	7 64	0 93	3 37	34 74	44 54	15 08
393	7 25	0 75	4.50	26 21	44 80	16 44

linear regression equation, estimated by least squares, is given by

$$Y = 8.47 + 0.0172X_1 - 0.0744X_2 - 0.0023X_3 \quad (4a)$$

$$(R^2 = 0.8381) \quad (4b)$$

R^2 denotes the multiple coefficient of determination, uncorrected for degrees of freedom. The three indexes together account for 84 percent of the variance among zones in trip generation rates. The segregation index, X_3, exercises so slight an impact on trip generation rates, that it was omitted in the second model.

In the second model, average trips per occupied dwelling unit, Y, was expressed as a linear function of four explanatory variables: car ownership, A; household size, H; social rank index, X_1, and urbanization index, X_2. The least squares estimates for the parameters of this equation are given by

$$Y = 2.18 + 3.404A + 0.516H + 0.0119X_1 - 0.0343X_2 \quad (5a)$$

$$(R^2 = 0.9597) \quad (5b)$$

The four explanatory variables account for 96 percent of the variance in Y, and when corrected for degrees of freedom, 95.7 percent. Car ownership taken alone accounts for 83.6 percent of the variance. The regression coefficient for X_2 shows the expected change in trips per DU as the result of a unit increase in the urbanization index, X_2. When car ownership is ignored, as in Eq. 4, this coefficient is -0.0744, but the inclusion of car ownership in Eq. 5, reduces the coefficient to -0.0344. The partial regression coefficient for car ownership of +3.4 is substantially lower than that reported in the published CATS report, reflecting, as it does, the effect of the other variables included in Eq. 5.

In summary, the results of this preliminary analysis appear promising. The urbanization index does exert a significant effect on trip generation rates, even when the car ownership effect is controlled by multiple regression techniques. The remaining indexes for social rank and segregation have only slight impacts on trip frequencies. A qualification concerning the use of zonal averages is, however, in order. All the correlations and regression equations are based on data that refer to arithmetic averages, applicable to the reporting households in each traffic analysis zone. As shown in the following section, such regression techniques often prove misleading because of the heterogeneity of households within each traffic analysis zone. Yet, the results are sufficiently striking to warrant further investigation.

In addition to helping to provide a fuller explanation of variations in trip generation, social area analysis may yield a much needed clue to urban travel patterns on the whole.

TABLE 13

CORRELATION COEFFICIENTS FOR SOCIAL AREA INDEXES AND RELATED VARIABLES

Variable	Y	A	H	X_1	X_2	X_3
Trips per occupied DU, Y	1	+0.916	+0.437	+0.211	-0.883	-0.287
Average car ownership, A		1	+0.286	+0.322	-0.713	-0.397
Average household size, H			1	-0.595	-0.572	+0.085
Social rank index, X_1				1	+0.021	-0.183
Urbanization index, X_2					1	+0.249
Segregation index, X_3						1

Trip interchange and trip length, particularly relating to work and social trips, may be better understood through greater knowledge of the social characteristics of households. For example, work trips from an area of known social rank would tend to be attracted to certain kinds of jobs. Information of this nature would be of considerable value in improving the accuracy of the various traffic models used to compute future interzonal movements. Again, knowledge of the social rank of a household as compared with the rank of the area in which that household is situated would aid in predicting the distribution of social and recreational trips. In this instance, the greater the disparity between the social rank of an individual family and the mean rank for the neighborhood, the greater should be the number and average length of social trips made by the family. Analyses of these sorts require that the relationships between trip making and social indexes developed in this study on an area basis be refined to consider individual households. Such research is now being carried on at Northwestern University and will be reported on when the results are available.

IMPROVEMENT GAINED THROUGH GROUPING OF DATA

Most of the conclusions presented in the previous sections have been based on data from either individual dwelling units or from groups of dwelling unit so arranged that the independent variable was identical for all units within each group. It is both interesting and instructive to compare results so obtained with those that would be achieved through the customary procedure of working with average values for traffic zones or other areal groups.

To facilitate comparison, Eqs. 1, 2, and 3 have been repeated in Table 14, along with similar equations based on average values for 58 traffic census zones composed of a sample of 630 individual dwelling units in Modesto used in the original computations. As may be seen from Eq. 3 and 3a, for example, the coefficient of variation may be reduced by averaging from a value of about 24 percent to just a little below 16 percent, whereas the multiple correlation coefficient goes from 0.55 to 0.83.

Although the grouping of data, by averaging out random variations, does produce a seemingly more precise estimate of average trip generation in the least-squares sense, it also results in a less accurate estimate. The bias resulting from aggrega-

TABLE 14

LEAST SQUARES RELATIONSHIP BETWEEN FAMILY SIZE VEHICLE OWNERSHIP AND TRIP FREQUENCY FOR INDIVIDUAL DWELLING UNITS AND FOR AGGREGATES OF DWELLING UNITS

Basis of Values	Equation No.	Multiple Regression Equation[1]	Variable[2] σ_e	C%	R	R^2
630 individual DU	1	T = 0.467 + 0.831p	0.76	25.4	0.47	0.22
	2	T = 1.229 + 1.379v	0.78	26.0	0.44	0.19
	3	T = -0.137 + 0.632p + 0.950v	0.72	24.0	0.55	0 30
58 traffic census zones	1a	T = -0.627 + 1.216p	0.51	17.0	0.82	0.67
	2a	T = 0.653 + 1.850v	0.62	20.7	0.70	0.49
	3a	T = 0.648 + 0.964p + 0.608v	0.49	16.3	0.83	0.69

[1] T = average daily number of person trips from home; p = number of persons per dwelling unit; and v = number of vehicles per dwelling unit.

[2] σ_e = standard error of estimate; C% = coefficient of variation ($\sigma_e/\overline{T}$); R = coefficient of multiple correlation; and R^2 = square of coefficient of multiple correlation. R^2 (100 percent) is a measure of percent of variation in T which is "explained" by variation in independent variables.

tion of data may be seen by comparing the regression coefficients developed in the two sets of equations. The coefficients associate with family size, p, and vehicle ownership, v, are seen to be higher in every case where aggregative values are used. In other words, aggregating data in this fashion results in estimates of the effects of the independent variables on trip generation which are invariably higher than those obtained by single-unit analysis. Uncritical use of grouped data may lead not only to a reliance on faulty relationships, but, also, because of the false degree of precision introduced, to potentially rewarding areas of investigation being ignored or rejected.

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