CHAPTER 3

DETERMINANTS OF TRIP GENERATION

This chapter deals with an empirical analysis of trip generation and identification of the partial impacts of various explanatory factors on trip generation. Considered here are the effects of household characteristics--such as family size, vehicle ownership, distance to the CBD and socio-economic of the household--on the frequency of trips made from home.

The Behavioral Unit and the Variable

In this thesis, the unit of analysis was taken as a household: a collection of individuals who choose to reside together. Logic suggests that the household is the major decision-making unit, as opposed to an individual person or an individual trip maker. Alternatively, the entire analysis could have referred to land use; that is, the unit of analysis could have represented a unit of land allocated to some particular use. However, the trips attracted or generated by any parcel of land must have been initiated by the decisions in households. As the aim of this research is to identify the factors affecting trip generation, the household would appear to be the pertinent behavioral unit.

In this research, the dependent variable represents "from home" trips per occupied dwelling unit, irrespective of the trip-purpose at the destination. Another dependent variable also denotes total reported trips per occupied dwelling unit (all trips reported by the residents of a dwelling unit, regardless of origin or destination). The "from home" definition may be interpreted as home-based travel. As such, it more closely approximates the trip generation rate of a

household. The "total" definition would seem to be more appropriate for an analysis of total travel demands within an urban area.

The selection of independent variables to be used in the analysis represented a significant initial step in the research. The choice was subject to the following criteria.

1. Variables should be highly correlated to trip-making in a statistical sense.

2. Variables should have a strong logical relationship with trip-making in a causal sense.

3. Variables should generally not be difficult to forecast.

4. Variables should have been commonly used in operational studies of trip generation.

5. Variables should be limited in number so the analysis is not distorted with a multitude of interrelated factors.

6. Variables must be compatible with all of the techniques to be tested.

The sixth criterion eliminates from consideration a number of variables that have been used frequently in trip-generation analysis. A preliminary list of variables was compiled and a simple correlation analysis was performed to evaluate the variables in terms of the first criterion. The varibles most highly correlated with trip-making were total persons, automobiles, and total income. Of these, income was eliminated because it is a difficult variable to get and forecast, particularly on a small-area basis. Persons and automobiles were judged to be the best in terms of the established criteria outlined previously, and were adopted for use in this research.

Impact of Household 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 458 dwelling units in the five estates studied were grouped according to the number of persons in each household. Separate mean generation rates were then computed for each family-size category. These data, summarized as subtotals in Table 7, are shown in Fig. 7. Average from-home trip frequency increased uniformly with increasing persons per household; average total trips similarly increased, as shown in Table 8 and Fig. 7.

The ratio of trip-makers to residents is quite an important variable. If the ratio of trip-makers to residents were low, trips per dwelling unit would also be low and the frequency of trips per dwelling unit at various levels of family size would be smaller for households having lower ratios of trip makers to residents. This would be apparent in households containing higher proportions of children. To analyze this hypothesis, household size was alternatively measured by: (1) all residents (Fig. 7), and (2) only persons aged 5 and over and the children who have already gone to school (Fig. 8). The mean number of from-home trips as a function of the latter measure of alternative household size, summarized in Table 7a, as shown in Fig. 8. The slope of curve tends to increase, especially at a family size of seven persons and more. This is likely attributable to larger households typically containing higher proportions of children.

In Fig. 7, the relationship among the data 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:

Table 7: Effect of Family Size and Vehicle Ownership on From-home Trip Frequency

No.of Persons/DU	0 Veh per DU		1 Veh per DU		2 Veh or more/DU		Total	
	Trips/DU	No.of DU	Trips/DU	No.of DU	Trips/DU	No.of DU	Trips/DU	No.of DU
1 & 2	1.21	14	2.00	2	1.00	1	1.29	17
3	2.07	41	2.33	18	-	-	2.15	59
4	3.05	38	3.14	22	3.00	4	3.08	64
5	3.78	45	3.80	30	4.14	7	3.82	82
6	4.16	50	4.88	26	4.43	7	4.41	83
7	5.18	38	5.18	17	4.80	5	5.15	60
8	6.36	28	5.90	10	6.50	2	6.25	40
9	6.67	15	6.50	2	7.00	1	6.67	18
10 or more	7.60	25	7.57	7	8.33	3	7.66	35
Total	4.29	294	4.25	134	4.73	30	4.30	458

Table 7a: Effect of Family Size Excluding Children Who Are Not Yet Going to School on From-home Trip and Total Trip Frequency

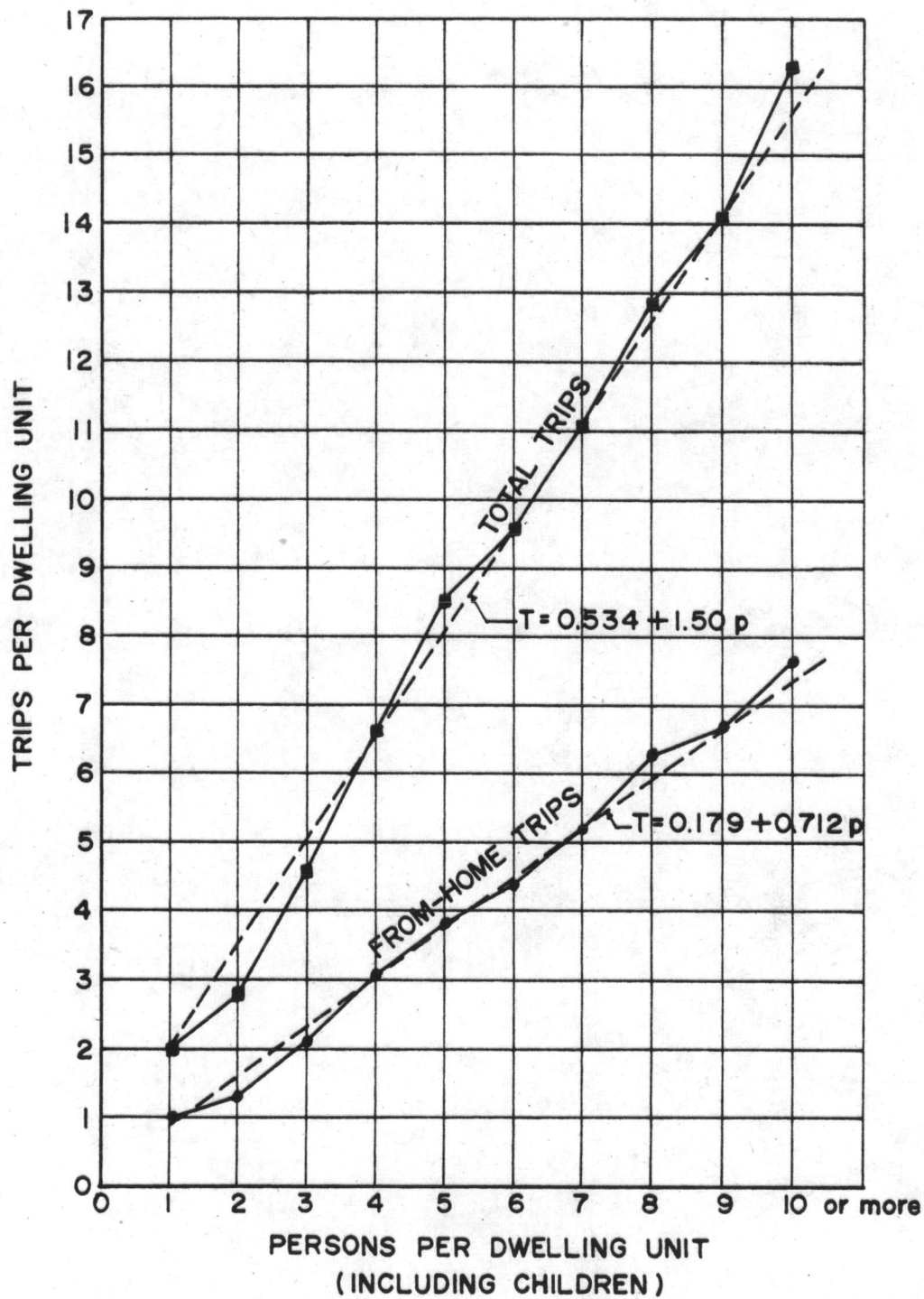| No.of person/DU	No.of DU	From-home trips/DU	Total trips/DU
1	3	1.00	2.00
2	32	1.53	3.17
3	63	2.39	5.12
4	80	3.15	6.97
5	85	4.22	9.42
6	76	4.87	10.44
7	50	5.33	11.76
8	32	7.23	14.40
9	17	7.50	15.75
10 or more	20	8.11	17.16
Av = 5.31	Σ = 458	Av = 4.30	Av = 9.26

FIGURE 7 : FREQUENCY OF FROM—HOME TRIPS AND TOTAL TRIPS PER DWELLING
UNIT AT VARIOUS LEVELS OF FAMILY SIZE

The plot shows TRIPS PER DWELLING UNIT on the vertical axis (0 to 17) and PERSONS PER DWELLING UNIT (INCLUDING CHILDREN) on the horizontal axis (0 to 10 or more).

Total Trips line: $T = 0.534 + 1.50\,p$

From-Home Trips line: $T = 0.179 + 0.712\,p$

Table 8: Mean Total Trip Generation and Percentage of Trip-makers Classified by Household Size and Car Ownership

	No. of persons per dwelling unit									
	1 & 2	3	4	5	6	7	8	9	10 or more	All sizes
Zero-Car Household										
No. of total trips/DU	2.50	4.29	6.21	7.84	8.44	10.63	12.71	13.53	15.32	8.73
Percentage of trip-makers to residents	65.4	69.1	76.3	75.1	69.0	74.1	79.5	73.3	69.5	72.9
No. of trips/person	1.35	1.43	1.55	1.57	1.41	1.52	1.59	1.50	1.41	1.49
No. of trips/trip-maker	2.06	2.07	2.03	2.09	2.04	2.05	2.00	2.05	2.03	2.04
Average household size	1.86	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.88	5.86
No. of dwelling unit	14	41	38	45	50	38	28	15	25	294
One-Car Household										
No. of total trips/DU	5.00	5.33	7.14	9.20	11.42	12.00	13.00	16.50	18.00	9.92
Percentage of trip-makers to residents	100.0	77.8	78.4	76.0	78.8	72.2	73.8	72.2	70.3	75.6
No. of trips/person	2.50	1.78	1.78	1.84	1.90	1.71	1.63	1.83	1.70	1.79
No. of trips/trip-maker	2.50	2.28	2.28	2.42	2.41	2.37	2.20	2.54	2.42	2.36
Average household size	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.57	5.54
No. of dwelling unit	2	18	22	30	26	17	10	2	7	134

Table 8: Mean Total Trip Generation and Percentage of Trip-makers Classified by Household Size and Car Ownership

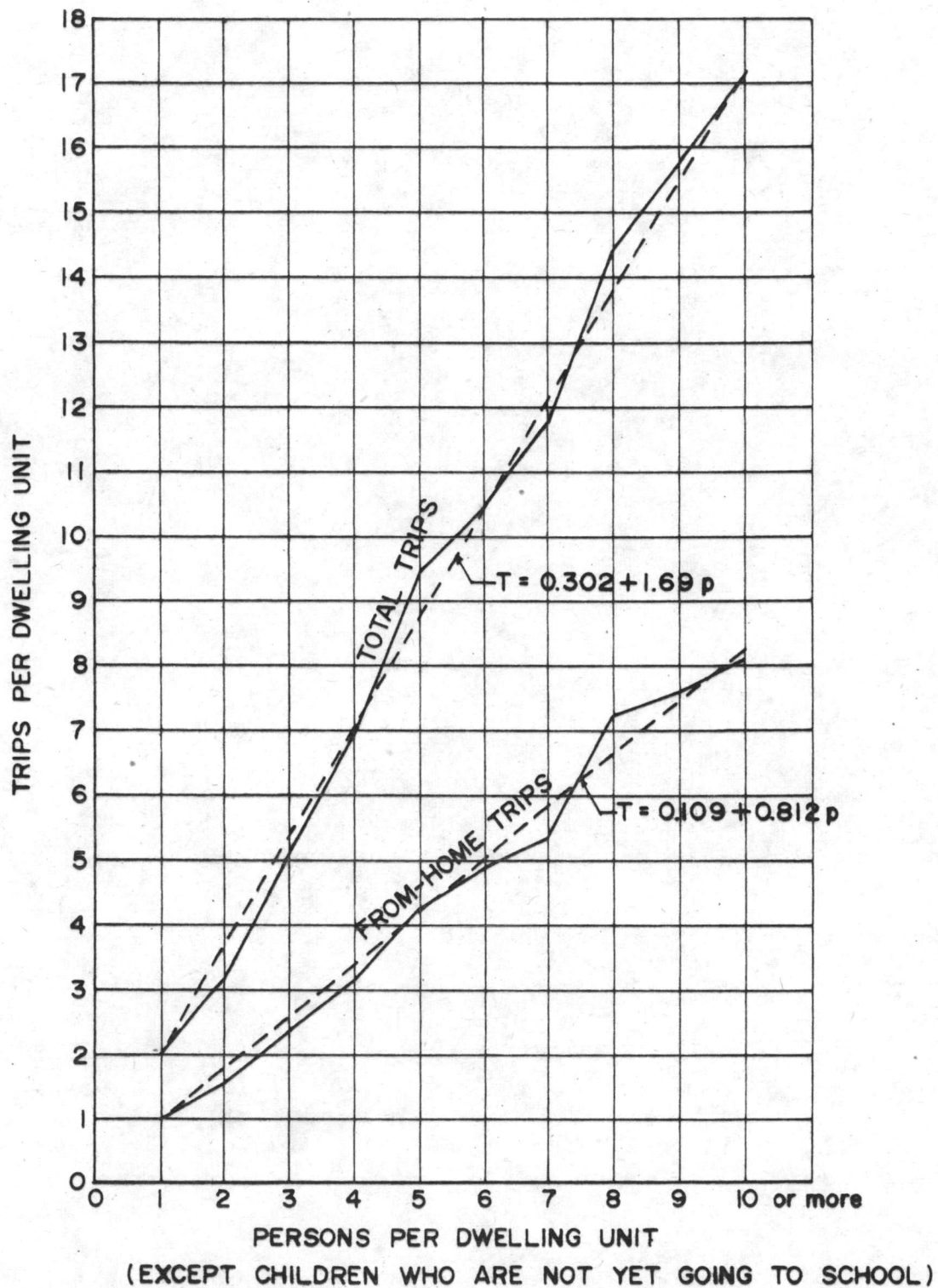| | No.of persons per dwelling unit | | | | | | | | | |
	1 & 2	3	4	5	6	7	8	9	10 or more	All sizes
Muti-Car Household										
No.of total trips/DU	2.00	–	8.25	10.00	10.57	11.60	14.00	18.00	20.70	11.50
Percentage of trip-makers to residents	50.0	–	68.8	80.0	73.8	68.6	81.2	77.8	70.6	73.5
No.of trips/person	1.00	–	2.06	2.00	1.76	1.66	1.75	2.00	1.82	1.82
No.of trips/trip-maker	2.00	–	3.00	2.50	2.39	2.42	2.15	2.57	2.58	2.48
Average household size	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	11.33	6.30
No.of dwelling unit	1	–	4	7	7	5	2	1	3	30
Total Household										
No.of total trip/DU	2.74	4.61	6.67	8.52	9.55	11.10	12.85	14.11	16.31	9.26
Percentage of trip-makers to residents	68.7	71.7	76.6	75.8	72.3	73.1	78.1	73.5	69.7	73.7
No.of trips/person	1.47	1.54	1.66	1.70	1.59	1.59	1.61	1.57	1.50	1.60
No.of trips/trip-maker	2.14	2.14	2.17	2.25	2.20	2.17	2.06	2.13	2.15	2.17
Average household size	1.88	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.86	5.80
No.of dwelling unit	17	59	64	82	83	60	40	18	35	458

FIGURE 8 . FREQUENCY OF FROM−HOME TRIPS AND TOTAL TRIPS PER DWELLING
UNIT AT VARIOUS LEVELS OF FAMILY SIZE

$$T = 0.179 + 0.712 P \qquad\qquad \text{Eq.(1)}$$

in which

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

      P = number of persons living in the dwelling unit.

The coefficient, 0.712, indicates that the addition of each additional family member increases from-home trip production by about 0.7 trips per day. Comparison of the slope of the regression line with the curve in Fig. 7 shows that the coefficient, 0.7, approximates the measured increases over the entire range. The predicted curve closely fits the actual observations in the middle range of household size. Over the entire range, the standard error of estimate, σ_e is ± 1.12 trips per day, the proportion of the standard error to the mean is 0.23, and the coefficient of determination $(R^2) = 0.67$.

Impact of Car Ownership

The over-riding importance of car ownership as an explanatory variable stems from its close association with trip generation rates. Earlier studies have reported impressively high correlations between mean trip generation rates and average car ownership. In some cases, these close fits were induced by grouping the data into relatively large aggregations, thereby concealing much of the dispersion among households. Nevertheless, car ownership is the one variable which exhibits the closest association with reported trip-generation rates. These close correlations are usually rationalized by arguing along the following lines. Without an auto, the family's travel activities are sharply circumscribed by the available public transit, or by the high cost of taxi trips. The ownership of a car offers the family an opportunity of satisfy its travel "needs". It enables the family to exercise greater flexibility, both spatially

and temporally, in its travel activities. Thus, the ownership of an auto would be expected to increase the number of trips taken by each household.

By separating the 458 households in the five estates according to the number of vehicles owned, this hypothesis could be tested. These data, summarized along the lower margin in Table 7, are shown in Fig. 9. In contrast to the case of family size, the vehicle-ownership curve is flat. This indicates that from-home trips per household are almost constant irrespective of the number cars per household. The frequency of from-home trips per dwelling unit at each car-ownering household in each housing estate is detailed in Appendix Table A2,B2,C2,D2,E2,F2, and G2 and summarized in Fig.10. There are random dispersions of trips per dwelling unit associated with car ownership because of the small samples of multi-car households and the many zero-car households. Fig. 11 shows the increasing frequency of from-home trips with increasing numbers of persons per household at various levels of car ownership. The curves for various levels of car ownership cluster together denoting the small effect of car ownership on from-home trips per household found in this research.

Considering the total trips per household, the average trip frequency increases with an increasing number of cars per household. This is shown in Table 8 and Fig. 9. On the average, families owning one car generated 1.2 more total trips than zero-car households. Multi-car households generated approximately 1.6 more total trips than one-car households.

From Fig. 9, the relationship among the data may be described by a linear regression equation. The least squares regression equation relating car ownership and from-home trip frequency was determined to be:
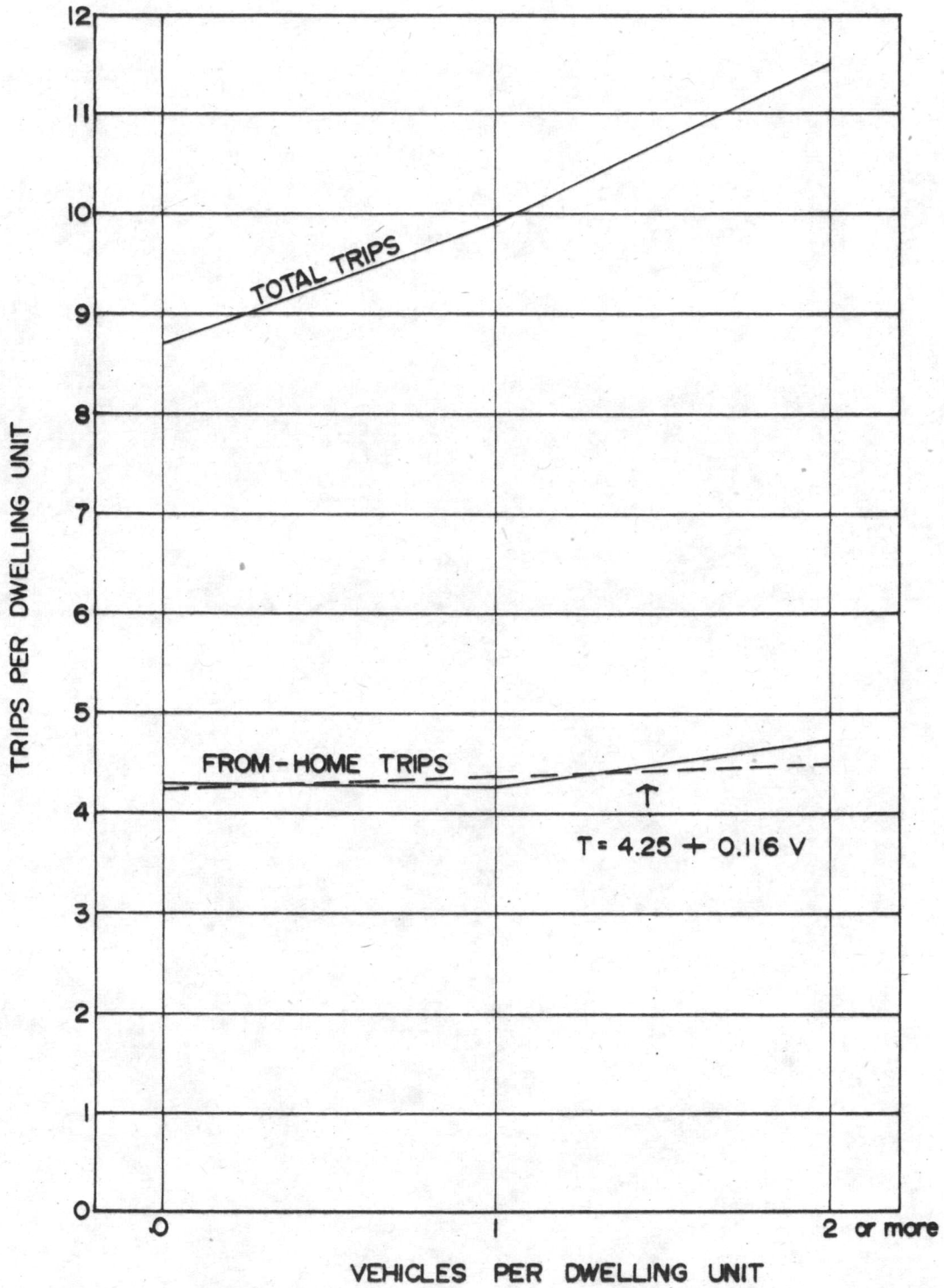
FIGURE 9 : FREQUENCY OF FROM-HOME TRIPS AND TOTAL TRIPS PER DWELLING UNIT AT VARIOUS LEVELS OF CAR OWNERSHIP
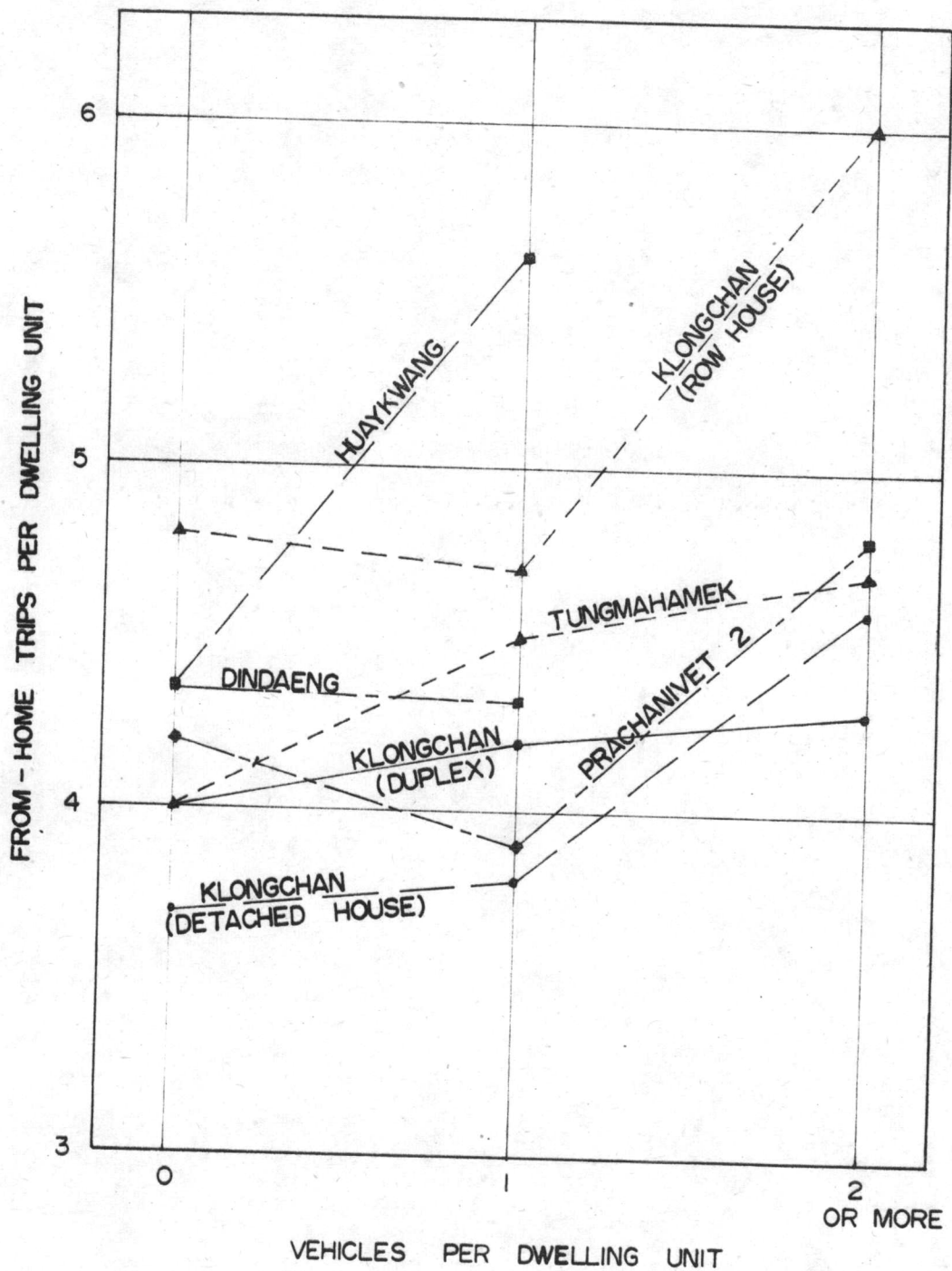
FIGURE 10: FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT
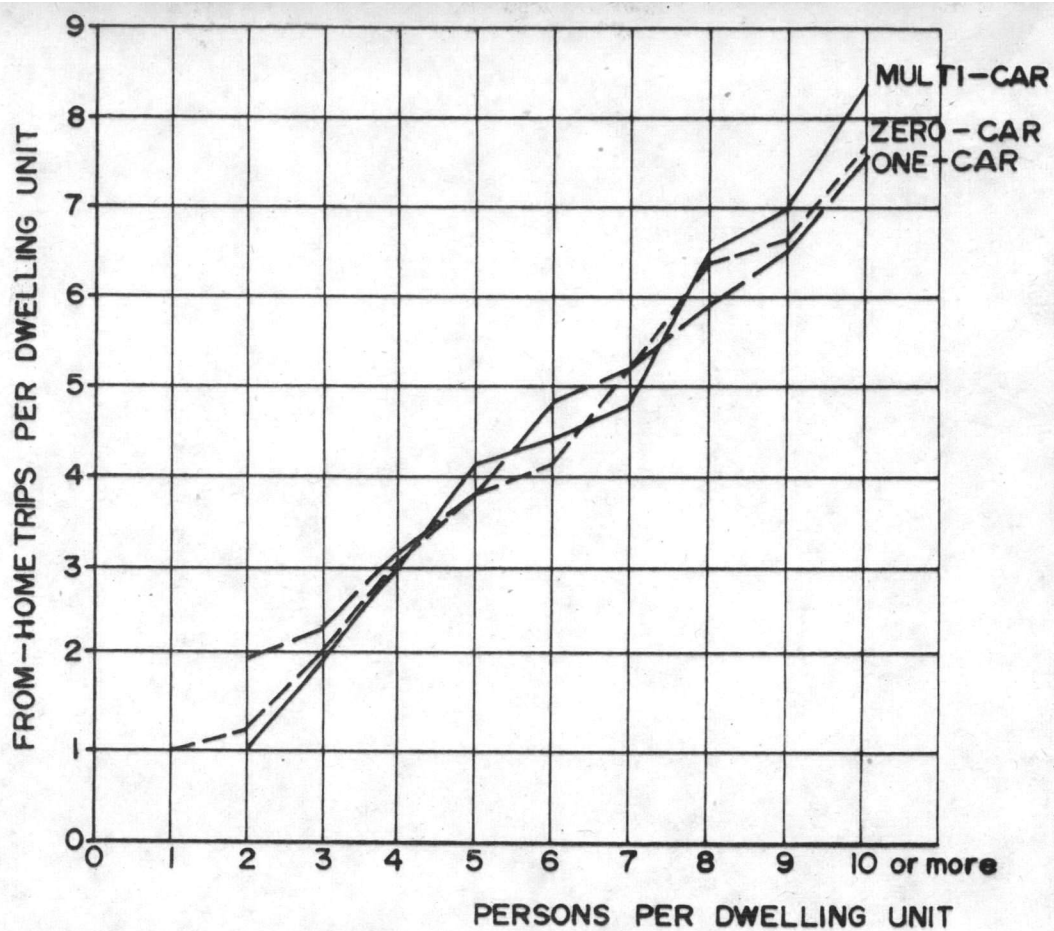AT VARIOUS LEVELS OF CAR OWNER SHIP FOR VARIOUS HOUSING ESTATES

FIGURE 11:   FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT
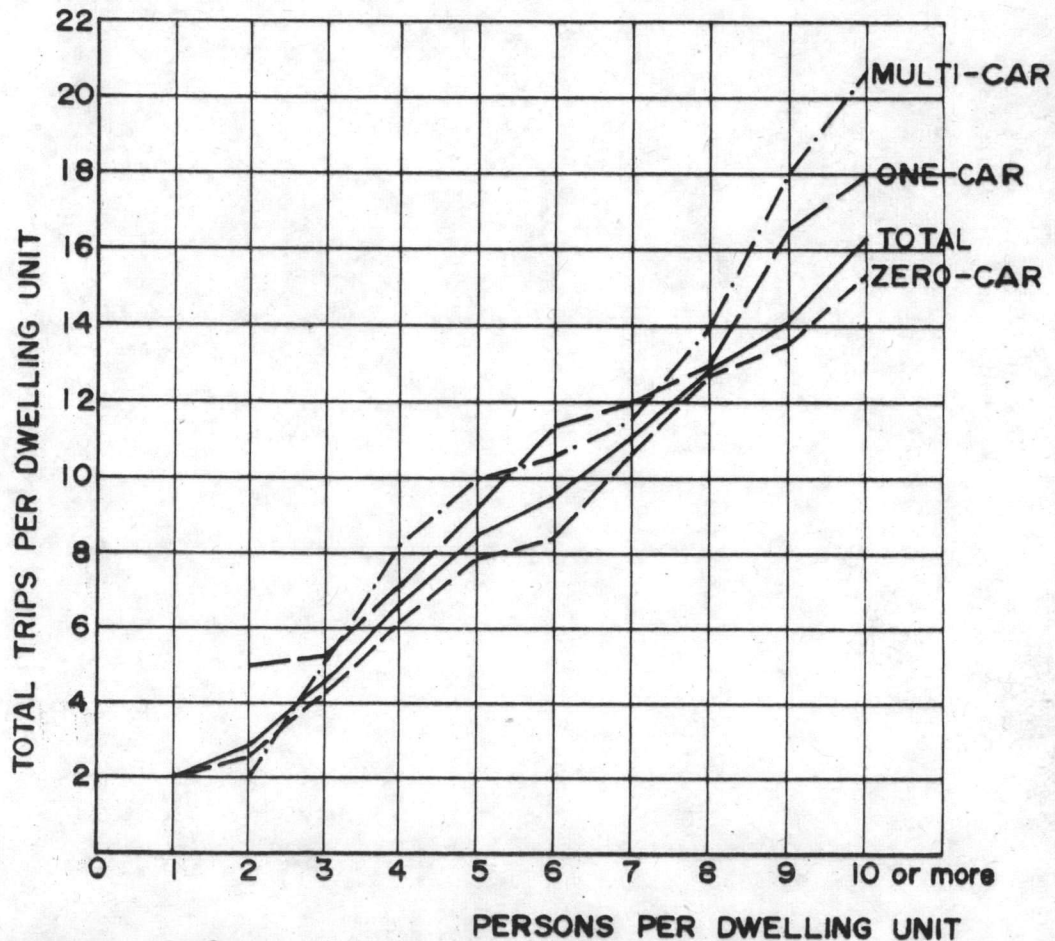AT VARIOUS LEVELS OF FAMILY SIZE AND CAR OWNERSHIP

FIGURE 12:   FREQUENCY OF TOTAL TRIPS PER DWELLING UNIT

$$T = 4.25 + 0.116V \qquad\qquad \text{Eq.(2)}$$

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 observed data shown in Fig. 9. It may be seen that the coefficient, 0.116, slightly overstates the effect of vehicle ownership in the lower range of the independent variable, and understates it in the upper range of the curve. The coefficient, 0.116, indicates that the addition of each car in a household does not greatly increase trip production. The standard error of estimate, σ_e is $\pm$ 1.94 trips per day, the proportion of the standard error to the mean is 0.45.

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 dispersed by the contributory effects of the other. Interference of this type can be eliminated by cross tabulating the two independent variables. Table 7 shows such a cross-tabulation which permits analysis of the relationship between family size, for example, and trip frequency at any level of vehicle ownership. Conversely, it enables study of the effects of variations in vehicle ownership at any level of family size.

The data of Table 7 are shown graphically in Fig. 11 which illustrates the effect of family size on from-home trip production at three different levels of vehicle ownership. This set of curves shows that from-home trips per household increase primarily with increasing family size. The increase is not obviously
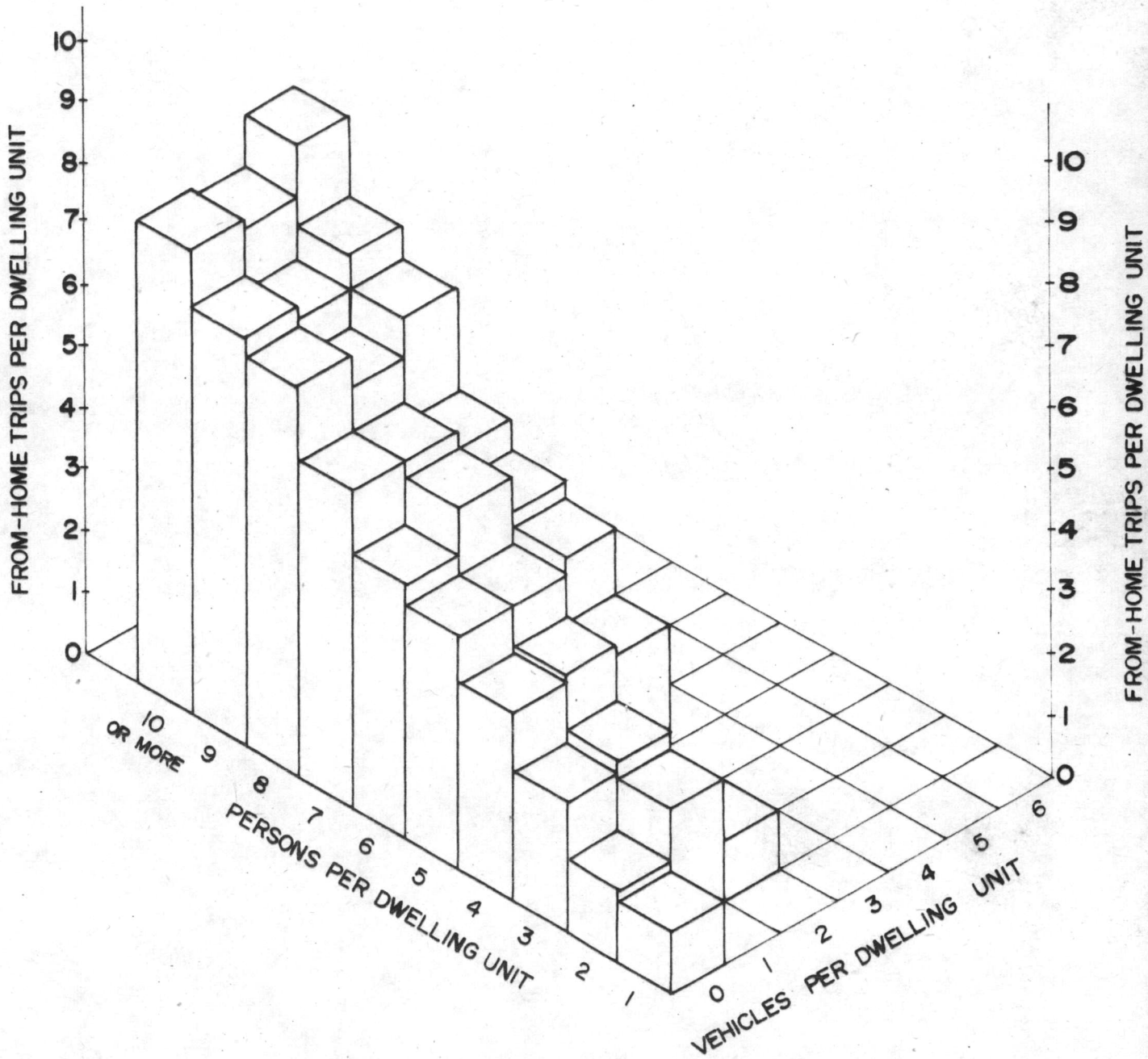
FIGURE 13: FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT AT VARIOUS LEVELS OF FAMILY SIZE AND VEHICLE OWNERSHIP (AN ISOMETRIC BLOCK DIAGRAM)

related to increasing car ownership. An isometric block diagram, as shown in Fig. 11, illustrates the joint relationship between family size, vehicle ownership, and frequency of from-home trips. The surface describing the relationship shown in Fig. 11 may be described by: $T = 0.193 + 0.713P - 0.046V$, in which T, P and V are defined as before. The standard error of estimate is 1.12 trips per day, the proportion of the standard error to the mean is 0.23, and the coefficient of determination is 0.67.

Impact of Other Variables on Trip Generation

After analysis of the two main explanatory variables-household size and car ownership-the other variables which are thought to affect a family's travel activities were examined as far as the data permit.

CBD Distance

The 458 household data in five estates were grouped according to the distance from each estate to the CBD. Two groups seemed adequate: (1) estates inside the core area, and, (2) those outside the core area. The inside core area estates are located in the part of the metropolitan area having a high population density and are not far from the CBD (about 5 km.). The estates that are located in the core area of Greater Bangkok were: Tungmahamek, Dindaeng Flats and Huaykwang Flats. The estates classified as outside the core area are located in areas of medium population density and are a considerable distance from the CBD (about 15 km.). The estates that are located outside the core area of Greater Bangkok were Klongchan and Prachanivet 2. Separate mean trip generation rates were then computed for each family size category in each of the two groups. These data, summarized in Table 9, are shown in Fig. 14.

Table 9: Frequency of From-home Trips per Dwelling Unit at Various
Levels of Family Size and Locations of Housing Estates

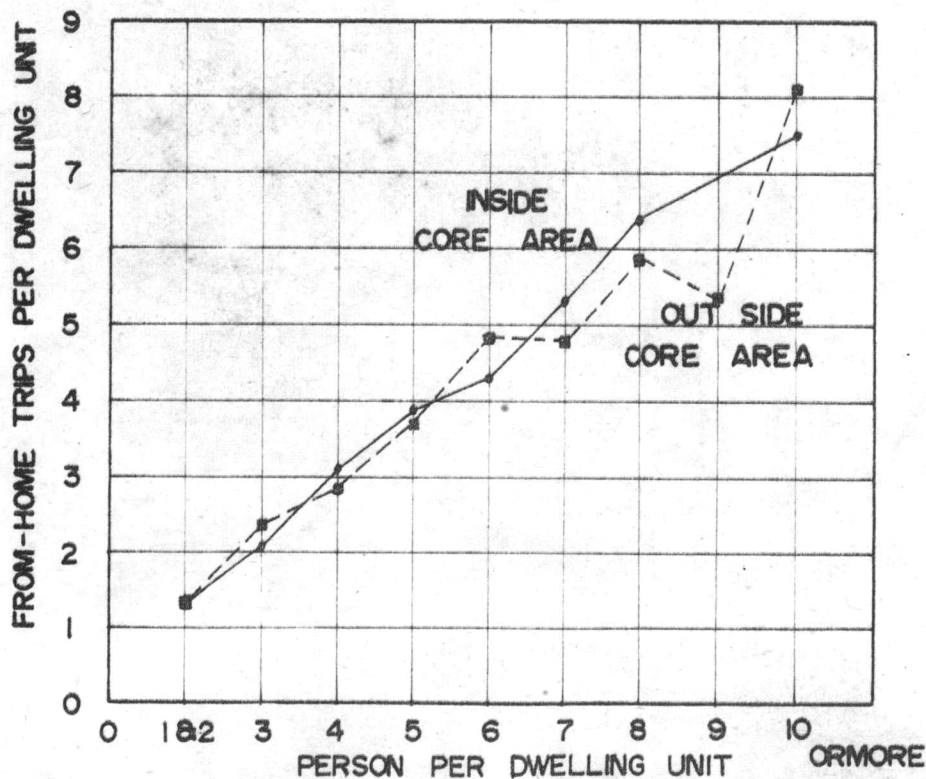| Persons per DU	Inside core area estates		Outside core area estates	
	DU	From-home trips/DU	DU	From-home trips/DU
1 & 2	14	1.29	3	1.33
3	43	2.07	16	2.37
4	38	3.11	26	2.88
5	45	3.87	37	3.76
6	57	4.28	26	4.84
7	45	5.27	15	4.80
8	29	6.38	11	5.91
9	15	6.93	3	5.33
10 or more	26	7.50	9	8.11
	$\Sigma = 312$	Av. = 4.37	$\Sigma = 146$	Av. = 4.16

FIGURE 14: FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT AT
VARIOUS LEVELS OF FAMILY SIZE AND LOCATIONS OF HOUSING
ESTATE

In the lower range, average trip frequency of two curves are not significantly different, but the curves separate in the upper range. There was a higher frequency of tripmaking by the inside-core-area group than by the other in the upper range of family size, except by the ten-person households

The average number of from-home trips per dwelling of the inside-core-area group is 4.37, and that for the other group is 4.16. The housing estate which is the nearest the CBD is Tungmahamek; ranking outwards are: Dindaeng Flats, Huaykwang Flats, Klongchan, and Prachanivet, respectively. As shown in Table 10, the average numbers of from-home trips per dwelling unit of these housing estates are: 4.58, 4.30, 4.50, 4.14 and 4.10, respectively[1]. It may be stated that an increasing distance from the CBD leads to a tendency of decreasing frequency of from-home trips per dwelling unit. Residents of inside-core-area group can travel more readily than can those residing outside the core area. Many buses, minibuses, many bus routes and many roads are available to serve residents inside the core area, while the outside group has less flexibility. Nevertheless, from the data shown in Table 9 and Fig. 14, it cannot be stated with assurance that an increasing distance from CBD results in a decrease in from-home trips per dwelling unit.

Socio-economic Level

Socio- economic status is a measure of the standard of living that is based upon family income, occupational status of the members of the household, and

[1] For the detailed tabulations, refer to Appendix.

Table 10: Household Characteristics and Trip Generation

Housing estates	Dindaeng	Huaykwang	Klongchan	Klongchan	Klongchan	Prachanivet 2	Tungmahamek
Type of dwelling unit	Flats	Flats	Row-house	Duplex	Detached house	Detached house	Detached house
Total dwelling units	4144	1600	190	524	621	600	480
No.of samples	208	80	19	31	36	60	24
No.of persons per DU	5.70	6.34	6.21	5.39	5.25	5.80	6.00
No.of cars per DU	0.10	0.18	0.32	0.77	1.08	1.05	1.33
No.of from-home trips– per DU	4.30	4.50	4.84	4.13	3.94	4.10	4.58
No. of total trips per DU	8.67	9.43	10.21	8.87	9.50	9.97	11.46
Percentage of trip-makers– residents	75.4	69.8	77.1	76.6	75.1	70.0	75.8
No.of total trips per person	1.52	1.49	1.64	1.65	1.81	1.72	1.95
No.of total trips per trip- maker	2.02	2.13	2.13	2.15	2.41	2.46	2.57
No.of wage earners per DU	2.04	2.46	2.11	2.03	2.22	2.07	1.75
Family income level	low	low	low	medium to high	medium to high	medium to high	high

their ownership of material goods. This scale appears to be a more stable indicator of a family's social and economic position in the community than family income, which may fluctuate for many reasons. The items included in this scale in the present research were: family income, type of dwelling unit, rooms per person, occupations of the members of the household, and the ownership of material goods such as radio, television, telephone, electric refrigerator, and automobile.

Table 11: Trip Generation Rates at Various Levels of Family Size and Socio-economic Level

Persons per DU	Low-level			Medium and High Level		
	DU	From-home trips per DU	Total trips per DU	DU	From-home trips per DU	Total trips per DU
1 & 2	14	1.29	2.57	3	1.33	3.67
3	44	2.11	4.36	15	2.27	5.33
4	38	3.11	6.26	26	3.04	7.23
5	43	3.86	7.63	39	3.77	9.51
6	53	4.25	8.87	30	4.70	10.77
7	42	5.29	11.00	18	4.83	11.33
8	32	6.44	13.03	8	5.50	12.12
9	14	6.79	13.71	4	6.25	15.50
10 or more	27	7.52	15.44	8	8.12	19.25
	$\Sigma = 307$	Av = 4.38	Av = 8.96	$\Sigma = 151$	Av = 4.15	Av = 9.87

All data of the five estates were grouped into two levels: (1) low level, and (2) medium to high level. Low level represents the low income families which live in Dindaeng Flats, Huaykwang Flats, and row houses in Klongchan. Average family income for this group is about 1,500 baht per month, the average number of persons per room is about 5, the average of cars per household is 0.13, and the household's members are generally occupied as survice workers or laborers. The other category is medium and high level. It was found to be difficult to separate this category into two sub-groups due to the up grading of the medium level households. Now the status of the medium level families and the high level families are not greatly different nor, in many cases, readily distinguishable. The medium and high level estates are Tungmahamek, Prachanivet 2 and Klongchan. These housing estates were earilier constructed for a family income of 3,000 baht per month or more, but now it may be stated that the family income of these households is about 5,000 baht per month or more because of the ownership of material goods that were seen during the survey. The average number of persons per room is about 2, the average of cars per household is 1.05, and the household's members are mostly government and private officials. Data of household characteristic and trip generation of each estate are shown in Table 10 and in Table 4 in Chapter 1.

The frequencies of from-home trips and total trips per dwelling unit--at various levels of family size and socio-economic status--are summarized in Table 11 and shown in Figs. 15 and 16. The average number of from-home trips per dwelling unit from the low socio-economic level estates was 0.23 greater than that from the medium and high level estates, but the frequency distribution curves did not show this as a significant difference. Because of the small number of samples from the upper range (larger family size) of the medium and high socio-
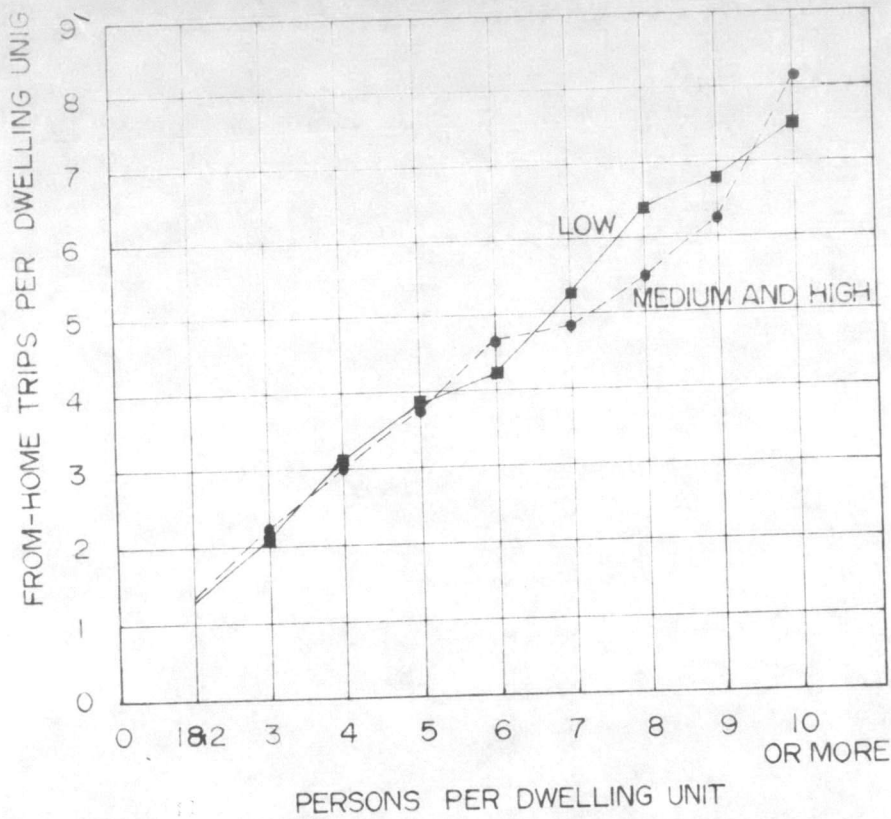
FIGURE 15: FREQUENCY OF FROM-HOME TRIPS PER DWELLING UNIT AT VARIOUS LEVELS OF FAMILY SIZE AND SOCIO-ECONOMIC LEVEL
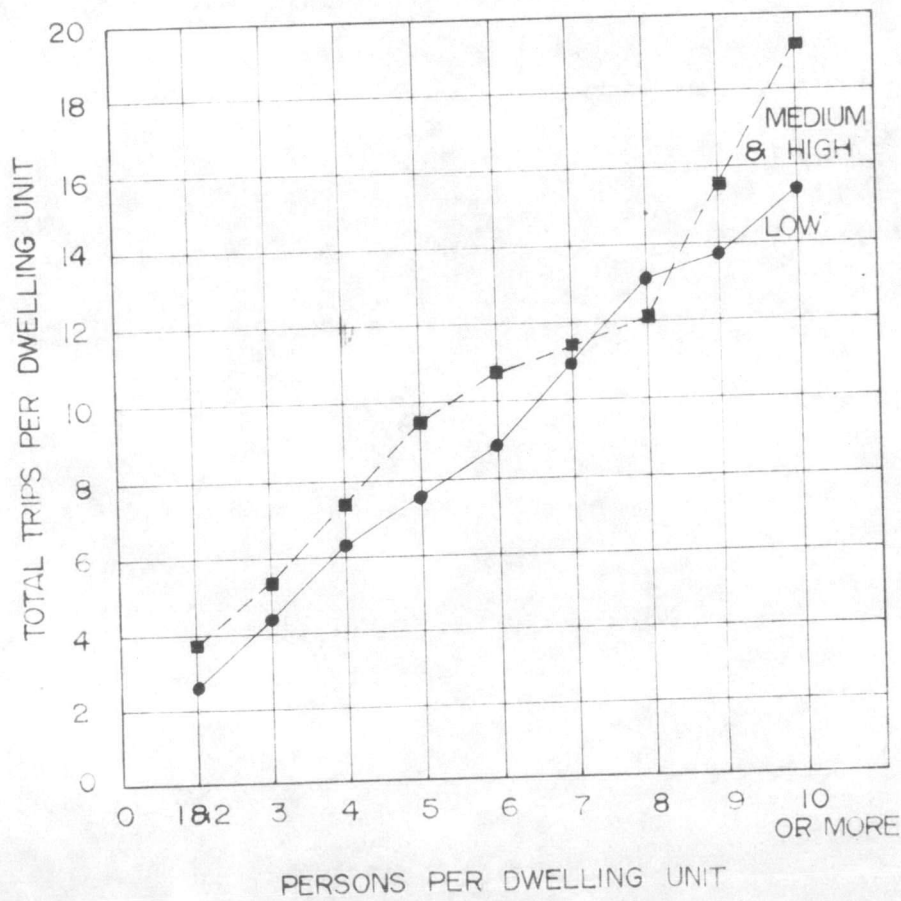

FIGURE 16: FREQUENCY OF TOTAL TRIPS PER DWELLING UNIT AT VARIOUS

economic level, larger variations appear in the upper range of the curves. The frequency of making from-home trips per dwelling unit seems not to be affected significantly by socio-economic level. On the contrary, the frequency of total trips per dwelling unit of the medium and high socio-economic level are substantially greater than from the low level, as shown in Fig. 16. Data from eight-person households was sparse and the cross-over between the curves at this family size is imputed to an inadequate sample. The average number of total trips per dwelling unit of the medium and high level is 0.91 greater than that of the low level. It is concluded that the average number of total trips per dwelling unit increases with an increasing socio-economic level.